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Application of machine learning algorithms to the safeguards verification of spent nuclear fuel

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List of acronyms

AP	Additional Protocol
BTCs	Basic Technical Characteristics
CA	Complementary Access
CEN	Central position
C/S	Containment and Surveillance
DCVD	Digital Cherenkov Viewing Device
DIV	Design Information Verification
EU	European Union
EXT	External position
EURATOM	European Atomic energy community
FA	Fast neutrons: response of bare ^{238}U fission chamber
GWd	GigaWatt-day
IAEA	International Atomic Energy Agency
K-NN	K-Nearest Neighbors
MATLAB	Matrix Laboratory
NDA	Non-Destructive Assay
NMA	Nuclear Material Accountancy
NMB	Nuclear Materials Balance
NPT	Non-Proliferation Treaty
NNWS	Non-Nuclear Weapon State
NwithCd	Fast neutrons: response of fission chamber with Cd
NwithoutCd	Total neutrons: response of fission chamber without Cd
NWS	Nuclear Weapon State
ORIGEN	Oak Ridge Isotope Generator
P	Gamma-rays: response of ionization chamber.
PDET	Partial Defect Tester
PER	Peripheral position
PGET	Passive Gamma-ray Emission Tomography

PWR	Pressurized Water Reactor
RES	0.3 eV resonance neutrons: response of ^{239}Pu fission chambers using Gd and Cd filters
SER	Safeguards Evaluation Report
SCK•CEN	StudieCentrum voor Kernenergie – Centre d'Étude de l'énergie Nucléaire (Belgian nuclear research centre)
SFAT	Spent Fuel Attribute Tester
SINRD	Self-Indication Neutron Resonance Densitometry
TH	Thermal neutrons: response of bare ^{235}U fission chamber

Summary

Several types of machine learning algorithms have been analyzed in this thesis in the framework of safeguards verifications, with the purpose of detecting the diversion of fuel pins from spent fuel assemblies. The goal of the thesis is to classify spent fuel assemblies according to the percentage of diverted pins.

The term spent fuel corresponds to the assemblies that after a long period of irradiation are no longer able to sustain the chain reaction and for this reason are unloaded from the reactor core and transferred to the spent fuel pool. Spent fuel is a large radiation source, both in terms of neutrons and gamma-rays, as well as residual heat due to the presence of fission products and minor actinides. The presence of fissile material ($_{235}$U, $_{239}$Pu) in amounts around 2% make spent fuel a very important material for safeguards, in order to verify that this material is used only for peaceful purpose.

The safeguards department of International Atomic Energy Agency (IAEA) makes regular check and verifications inside nuclear facilities to control that the material has not been diverted from the quantity declared. To make this verification several non-destructive analysis (NDA) detectors have been developed: the Fork detector, the Digital Cherenkov Viewing Device (DCVD), the Spent Fuel Attribute Tester (SFAT), the Passive Gamma-ray Emission Tomography (PGET), Self-interrogation neutron resonance densitometry (SINRD) and Partial defect tester (PDET).

The detector responses obtained from Monte Carlo simulations for three type of detectors, namely the Fork detector, Self-interrogation neutron resonance densitometry (SINRD) and Partial defect tester (PDET), were organized in databases to be used in this thesis.

The detector responses are used as input features inside 3 different type of machine learning algorithms to generate models that are able to classify the fuel assembly according to the percentage of diverted fuel pins. A machine learning algorithm is an algorithm that receives as input a database containing both input predictors and the associated output responses; in this case study the detectors responses represented the input predictors, and the class of the assembly based on the percentage of the missing pins indicated the output response. Once a machine learning model has been trained, it is able to predict the class of a new observation starting from the values of the detector responses. The machine learning models considered in this study were discriminant analysis, the decision tree, and the K-nearest neighbors (KNN).

For each type of algorithm the input features (detector responses) are used singularly or in combination considering also, in case of PDET and SINRD, the three different position of the detectors: central, peripheral and external. Using all these combinations of features and positions different models are generated with a correspondent accuracy that give information about the reliability of the method used.

Through these different models is possible to assess which combination of features, detector position, type of detector, and type of algorithm, gives the lowest classification error. The results showed that the gamma-ray detector response is generally the most sensitive to the diversion of fuel pins, and that higher classification accuracy was obtained for PDET and SINRD compared to the Fork detector. Comparing the different machine learning models, the KNN approach usually led to larger classification accuracies, followed by decision trees and by discriminant analysis.

The first chapter of this thesis gives an introduction to the topics of nuclear safeguards, spent nuclear fuel, and machine learning. The second chapter deals with the NDA techniques that were used in this study,

whereas chapter three describes the several machine learning models that were considered. The results of the study are included in chapter four, which is followed by the conclusions.

Sommario

In questa tesi sono stati analizzati diversi tipi di algoritmi di Machine Learning nel campo delle verifiche per la salvaguardia nucleare, allo scopo di rilevare la mancanza di barrette di combustibile dagli elementi di combustibile esauriti. L'obiettivo della tesi è classificare gli elementi di combustibile esaurito in base alla percentuale di barrette mancanti.

Con il termine combustibile esaurito vengono indicati gli elementi di combustibile, che dopo un lungo periodo di irradiazione non sono più in grado di sostenere la reazione a catena e per questo motivo vengono scaricati dal nocciolo del reattore e trasferiti alla piscina del combustibile esaurito. Il combustibile esaurito è una grande fonte di radiazioni, sia in termini di neutroni e raggi gamma, sia di calore residuo dovuto alla presenza di prodotti di fissione e attinidi minori. La presenza di materiale fissile ($_{235}$U, $_{239}$Pu) in quantità pari a circa il 2% rende il combustibile esaurito un materiale molto importante per la salvaguardia, al fine di verificare che questo materiale sia utilizzato solo a scopo pacifico.

Il dipartimento di sicurezza dell'Agenzia internazionale per l'energia atomica (IAEA) effettua controlli e verifiche periodici all'interno degli impianti nucleari per controllare che il materiale non sia differente dalla quantità dichiarata. Per effettuare queste verifiche sono state sviluppate diverse tipologie di detector che sfruttano l'analisi non distruttiva (NDA): il Fork detector, il Digital Cherenkov Viewing Device (DCVD), il Spent Fuel Attribute Tester (SFAT), Passive Gamma-ray Emission Tomography (PGET), Self-interrogation neutron resonance densitometry (SINRD) and Partial defect tester (PDET).

Le risposte dei detector sono ottenute per mezzo di simulazioni Monte Carlo per tre tipi di rivelatori, vale a dire il Fork detector, Self-interrogation neutron resonance densitometry (SINRD), Partial defect tester (PDET) e sono state organizzate nei database utilizzati in questa tesi.

Le risposte del rivelatore vengono utilizzate come variabili di input all'interno di 3 diversi tipi di algoritmi di Machine Learning per generare modelli in grado di classificare gli elementi di combustibile in base alla percentuale di barrette mancanti. Un algoritmo di Machine Learning è un algoritmo che riceve come input un database contenente sia i predittori di input che le risposte associate; in questo caso le risposte dei detector rappresentano i predittori di input e la classe dell'elemento di combustibile, dipendente dalla percentuale delle barrette mancanti, indica la risposta in output. Una volta che un modello di Machine Learning ha effettuato la fase di training, è in grado di prevedere la classe di una nuova osservazione a partire dai valori delle risposte del rivelatore. I modelli di Machine Learning considerati in questo studio sono l'analisi discriminante, l'albero decisionale e la KNN.

Per ogni tipo di algoritmo le caratteristiche in input (risposte del rivelatore) vengono utilizzate singolarmente o in combinazione considerando anche, nel caso di PDET e SINRD, le tre diverse posizioni dei rivelatori: centrale, periferica ed esterna. Utilizzando tutte queste combinazioni di caratteristiche e posizioni, vengono generati diversi modelli ai quali corrisponde una precisione che fornisce informazioni sull'affidabilità del metodo utilizzato.

Attraverso questi diversi modelli è possibile valutare quale combinazione di caratteristiche, posizione dei detector, tipo di detector e tipo di algoritmo, fornisce l'errore di classificazione più basso. I risultati hanno mostrato che la risposta del detector per i raggi gamma è generalmente la più sensibile alla mancanza delle barrette di combustibile ed è stata ottenuta una maggiore precisione di classificazione per PDET e SINRD rispetto al Fork detector. Confrontando i diversi modelli di Machine Learning, l'approccio KNN di

solito portava a maggiori precisioni di classificazione, seguito dagli alberi decisionali e l’analisi dei discriminanti.

Il primo capitolo di questa tesi fornisce un'introduzione al tema della salvaguardia nucleare, del combustibile nucleare esaurito e del Machine Learning. Il secondo capitolo tratta le tecniche NDA utilizzate in questo studio, mentre il capitolo tre descrive i vari modelli di Machine Learning che sono stati considerati. I risultati dello studio sono stati inseriti nel capitolo quattro, che è seguito dalle conclusioni.

1 Introduction

1.1 Nuclear safeguards

Since its first applications in the 1940's, nuclear energy has been used both for peaceful and military purposes. Among the peaceful applications we can list the production of electricity with nuclear power reactors, medical applications, and testing of several materials. Military applications include nuclear weapons, radiological dispersal devices, or naval reactors used for military ships.

Given the duality of nuclear energy, nuclear safeguards have been conceived to verify that countries observe the International Agreements about the peaceful uses of nuclear energy.

This function is carried out by the Department of Safeguards of the International Atomic Energy Agency (IAEA) through regular inspections that aim to verify that the nuclear material is present as declared and make checks on the materials itself using several techniques.

The goal of the IAEA Department of Safeguards is: "*to administer and implement IAEA safeguards. It also contributes to nuclear arms control and disarmament, by responding to requests for verification and technical assistance associated with related agreements and arrangements.*"(IAEA, 2018).

The need to establish a safeguards department was born after the second World War, due to the dispute about the disposal of leftover fissile material and the risk of proliferation of nuclear weapons. The first step for the foundation of an international agency that regulates nuclear activities was Dwight Eisenhower's Atoms for Peace speech in 1953, in which he promulgated the use and the development of nuclear energy only for peaceful purpose and he also proposed an international fuel bank for the states with leftover fissile material.

In 1954 the foundation of the IAEA was proposed and in 1957 became effective with the aim of contributing to the use of nuclear energy for world-wide peace, health and prosperity and also to control that technology and knowledge are not used to develop weapons.

The Article III.5 of the IAEA statute authorizes the Agency *"to establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information ... are not used in such a way to further any military purpose"* (IAEA, 1989).

The verifications inside the countries are performed by international inspectorates. The requirement to do this verification on global scale led to the treaty on the non-proliferation of nuclear weapons (NPT) (IAEA, 1970), signed currently by 190 countries, in which was declared that:

- the nuclear weapons states (NWS) are China, France, Russia, United Kingdom, United States of America;
- NWS cannot support the production or acquisition of nuclear weapons by non-nuclear weapons states (NNWS) and also transfers of any type of such devices to these countries;
- the nuclear weapons states must provide for the nuclear disarmament;
- obliges non-nuclear weapons states to submit to safeguards rules of the IAEA;

In the INFCIRC/153 (IAEA, 1972) is reported the purpose of the safeguards as *"the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture* *of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection."*

Some issues emerged after the signing of these agreements, in 1992 some irregularities were found in the material declared in North Korea, which denied the possibility of inspections by the authorities. As result of these obstructions, in 1993 the IAEA communicated that could not confirm the peaceful use of nuclear material in North Korea (IAEA, 2019).

Another issue found with the safeguards system under the INFCIRC/153 regime was evident in Iraq. The country was signatory of the NPT and subject to regular inspections; however, after the end of the First Gulf War in 1991 a clandestine nuclear weapons program was discovered parallel to the civilian program declared to the IAEA (Albright 1991).

All these problems led to an extension of the previous agreements signed by IAEA members. In 1997 the INFCIRC/540 (Additional Protocol (AP)) was available for signing to reinforce the safeguards system, by improving the efficiency to detect unlawful and undeclared nuclear activities.

The safeguards inspectors, designated by the IAEA's Director General, then approved by the Board of Governors, selected by the state carry out the function to verify that the NPT and its extensions and protocols are respected. The member states in which they perform verification guarantee immunities and privileges. The activities carried out by safeguards inspectors are divided in three parts:

- Design Information Verification (DIV), in which inspectors investigate the design features of a determinate facility and establish if the parameters are accurate and valid;
- Inspection, that aims to control that nuclear material is not diverted from the quantity expected and facilities are not able to produce undeclared nuclear material;
- Complementary Access (CA), is executed with the authorization of the Additional Protocol and aims to detect unreported activities, answer questions and resolve discrepancies on a facility and in the case of decommissioning confirm the status.

Safeguards Implementation (IAEA,2018) is based on annual cycle and is divided in four essential processes:

- collect and evaluate all information relevant for safeguards;
- develop specific safeguards approach based on the State;
- plan, conduct and evaluate safeguards activities;
- draw the safeguards conclusion.

After the collection of all information obtained from the inspections and through remote monitoring, the IAEA writes a Safeguards Evaluation Report (SER) for each country and outlines safeguards conclusions, which guarantee the international community that states are observing the safeguard regulation. Annually all safeguards conclusions are collected in the Safeguard Implementation Report which is showed to the Board of Governors at its June conference.

In addition to the IAEA on European scale the Euratom Treaty provides regulation to ensure that *"ores, source materials and special fissile materials are not diverted from their intended uses as declared by the users"* (Euratom, 302/2005). With this purpose the Euratom's regulation provides the requirements about the Basic Technical Characteristics (BTCs), nuclear material accountancy reports and programs control activities for structure subjected to safeguards.

The European Commission is responsible for implementing Euratom safeguards, and therefore collects and verifies all these reports.

The Euratom regulation 302/2005 became effective in March 2005 and updates the previous regulation (No. 3227/76) about the requirements of the safeguards reports on Euratom Treaty.

It is worth mentioning that the Euratom safeguards department communicates directly with the operators of nuclear facilities, while the IAEA safeguards is carried out at state level.

One of the main features used to control the quantity of nuclear material is the Nuclear Materials Balance (NMB), that provides discrepancy between the inventory of nuclear material recorded for an infrastructure and the one actually measured.

This procedure cannot be completely precise due to the uncertainties of measurement systems and the dependencies on the state of the plant during the period of accounting. If the measure gives a negative difference in the inventory does not mean a real loss of the material and vice versa. These differences are a fundamental indicator to control the quantities of nuclear material and are combined with a set of security measures (e.g. restricting access to plant areas and personnel monitors to detect nuclear material at the exit to plants) to improve detection of unauthorized subtraction of nuclear material.

The uncertainties on these indicators are also influenced by bulk processes, like reprocessing, due to the huge quantity of material involved. Other uncertainties are generated by the physical state of the fuel, because it is more difficult to investigate and model fuel at the end of the life of the reactor, and these characteristics can lead to an increase of the NMB.

The nuclear material accountancy is only one of the many ways used by safeguards authorities to control that material is not diverted from nuclear sites. Other techniques are the use of devices that control containment, surveillance systems and regular re-verification of the design information.

1.2 Spent nuclear fuel

1.2.1 Characteristics of the spent fuel

Spent nuclear fuel indicates fuel that has been irradiated inside a nuclear reactor for a sufficient time which made it unable to sustain fission reaction inside the reactor. Under irradiation the fresh fuel generates fission products due to the fission reaction of the $_{235}U$ and the $_{239}Pu$ generated inside the reactor, and actinides that in some cases are strong neutron absorbers. As the irradiation continues the quantity of fissile material is consumed according to the fuel burnup, reaching the conditions in which is no longer possible to sustain the chain reaction.

In this condition the fuel contains a lot of radioactive elements able to emit strong neutron and gamma ray fluxes. The radioactive decay is also a source of significant heat production, so the spent fuel is removed from the core of the reactor and transferred to the spent fuel pools in which sufficient cooling and radiation shielding are provided.

In table 1-1 is shown the composition of the spent fuel removed from an irradiated PWR core in standard operating conditions with a burn-up of 33 GWd/t, considering in the first case one Tonne of fuel and in the second case 23 Tonnes, approximately the quantity needed by the reactor to operate for one year. A great amount of the 31.1 kg of short-lived and intermediate-lived fission products stabilizes in almost ten years (IN2P3 Source CEA).

Table 1-1: Distribution of isotopes inside spent fuel. (IN2P3 Source CEA).

RADIOELEMENT	1 Tonne U	23 Tonnes/year
Total uranium	988,4 kg	22300 kg
U-238	940,6	21960
U-235	10,3	238
U-236	4,4	102
U-234	0,2	4
Total plutonium	9,74 kg	223 kg
Pu-238	0,18	4,1
Pu-239	5,67	132
Pu-240	2,21	52
Pu-241	1,19	28
Pu-242	0,49	11
Total minor actinides	0,776 kg	17,5 kg
Neptunium-237	0,43	10,1
Americium-241	0,22	5
Americium-242	0,0007	0,02
Americium-243	0,10	2,4
Curium-242	0,00013	0,003
Curium-243	0,00032	0,007
Curium-244	0.024	0,56
Total Fission products	34,1 kg	760 kg
Short & intermediate-lived FPs	31,1	691
Long-lived FPs of which	3,0 including	69 including
Technetium-99	0,81	19
Iodine-129	0,17	4
Caesium-135	1,31	30
Zirconium-93	0,71	16

The more concerning elements inside the spent fuel are the residual fissile elements, that are investigated by safeguards authorities, in particular the plutonium.

Every year 11000 t_{HM} are unloaded from core's reactors around the world and is estimated that the total amount of spent fuel will reach 450000 t_{HM} by 2020. The figure 1-1 shows the consumption of nuclear fuel during the last 30 years considering also reprocessing and storage (IAEA, 2012b).

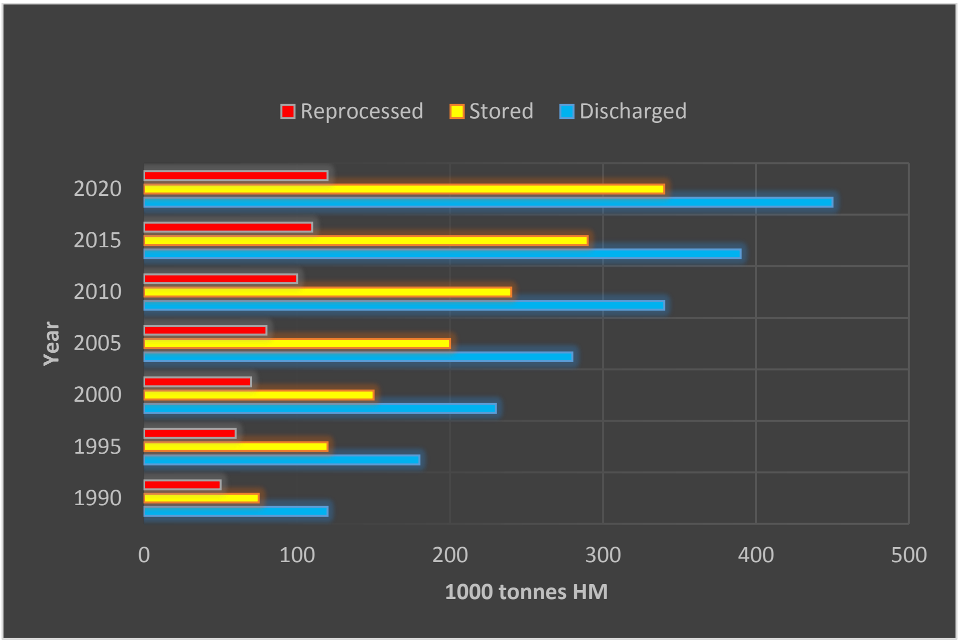

Figure 1-1: Trend of spent fuel in the word. (IAEA, 2012b).

During the last years IAEA has paid particular attention to the safeguards of spent fuel and has developed new methods of monitoring and investigation, due to the many alternative of treatment of the spent fuel (IAEA, 2013).

The accountancy of nuclear spent fuel inside the plant is made through direct measurements or estimations. The quantity of nuclear materials is assumed to be constant or with known variations due to radioactive decay as long as the integrity of the items is conserved.

In addition to accounting procedures monitoring devices and non-destructive analysis are used to control the integrity. To provide continuous knowledge of the nuclear material containment and surveillance measures (C/S) are adopted to restrict or control the movements of the spent fuel or in case of need, the possibility to access to it.

All these procedures must take into account also the possibility to transfer the nuclear materials to other facilities due to the reprocessing process of the spent fuel or the geological disposal.

The results of all measurements are then compared to the declared quantity to control if there is missing material.

1.2.2 NDA techniques for spent fuel in safeguards

As seen in the first chapter, nuclear safeguards verifications are based on nuclear material accountancy, containment and surveillance and measurements or checks on the nuclear material.

In this chapter the measurements systems will be analyzed, considering the NDA (non-destructive analysis) techniques used by the IAEA to analyze the spent fuel. NDA is defined as "*the quantitative or qualitative determination of the kind and/or amount of nuclear material in an item without alteration or invasion of the item.*" (Gavron, 1998). This analysis is the opposite of the destructive analysis in which a sample of the items is removed compromising the initial integrity, is analyzed and the results are applied to the whole original item.

Exploiting the characteristics of the actinides, during the last 30 years many NDA techniques were developed to obtain accurate data in sufficiently short time.

There are two kind of NDA measurements:

- the first is based on the detection of the spontaneous radiation emitted due to radioactive decay,
- the second is based on the detection of the radiation induced irradiating the sample with an external source.

The main NDA techniques used for the safeguards verification of spent fuel are: the Fork detector, the Digital Cherenkov Viewing Device (DCVD), the Spent Fuel Attribute Tester (SFAT), and the Passive Gamma-ray Emission Tomography (PGET).

The burnup of the nuclear fuel can be determined using a Fork detector, that detects the intensity of the gamma rays and the neutron flux from the spent fuel. The burnup is a consequence of the neutron rate and combining the burnup with the rate of emission of gamma the cooling time can be inferred. Through the burnup it is possible to infer the quantity of fissile material inside the fuel. The description of the Fork detector will be deepened in chapter 2 with the self-interrogation neutron resonance densitometry (SINRD) and the partial defect tester (PDET), since these are the techniques used in this study.

The Digital Cherenkov Viewing Device (DCVD) (Branger, 2014) exploits the Cherenkov radiation, that is electromagnetic radiation generated after the passage of a charged particle through a medium. The velocity of this particle must be higher than the speed of light in that medium to have the emission of this kind of radiation. This radiation is the reason of the blue glow of the core of the reactor under water. In nuclear reactors the Cherenkov radiation is emitted due to the charged particles generated during the nuclear decaying of the fission products inside the fuel.

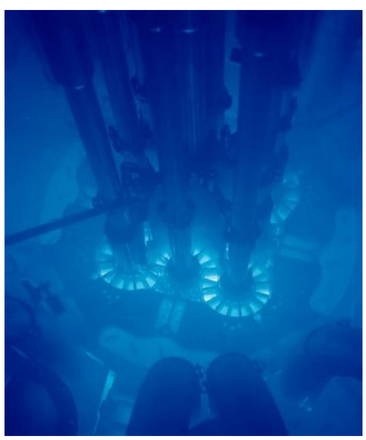

Figure 1-2: Effect of Cherenkov radiation from a nuclear reactor. (Argonne National Laboratory)

This radiation is useful for safeguards purposes, because it is an indicator of the presence of spent fuel inside the spent fuel pools and can be used for defect testing. The Digital Cherenkov Viewing Device detects the intensity of the ultraviolet light associated to Cherenkov radiation and generate images.

For gross defect testing the Spent Fuel Attribute Tester (SFAT) (Arit, 1995) is used. This equipment has a small medium resolution gamma-ray detector surrounded by a lead collimator. This detector analyzes the spectra of the gamma rays emitted by the spent fuel; however, it is able to provide information only from the upper part of the fuel assembly because the bottom part is self-shielded by the fuel assembly.

The PGET detector (Honkamaa, 2014) is a field-portable instrument to make verifications on spent nuclear fuel used to evaluate possible defect. This system allows to:

- detect the locations of the fuel pins through a gamma-ray tomography;
- evaluate the burnup through the neutron counting;
- detect fission products using a medium resolution gamma-ray spectroscopy.

This system has the possibility to rotate around the fuel element thanks to a rotatory baseplate provided with worm gear and servomotor. For the verifications it exploits 174 CdZnTe gamma detectors and two $_{10}$B detectors for neutrons. It has a data acquisition system and safety sensors to detect possible water infiltrations. All these components are contained within a toroid sealed to avoid water infiltration.

In figure1-3 the PGET detector is shown with the details of the components.

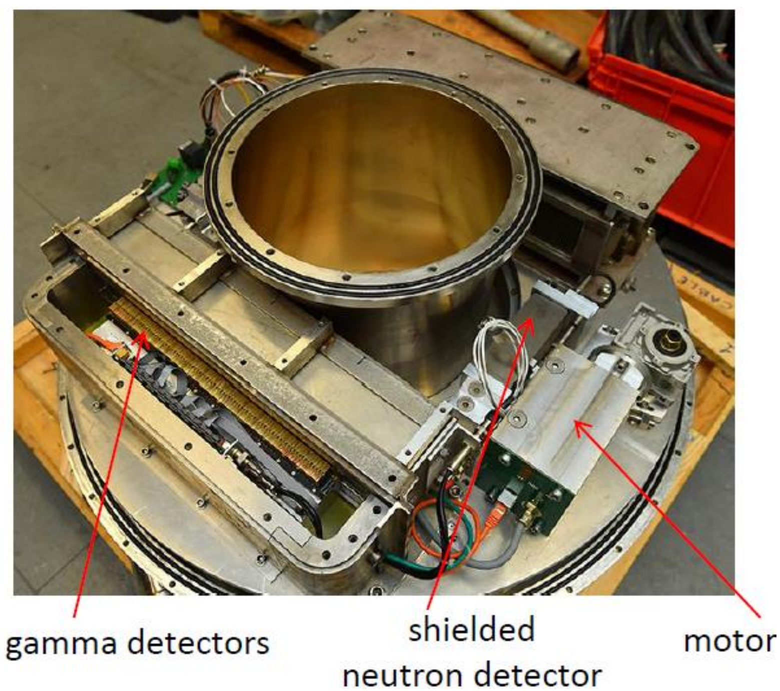

Figure 1-3: PGET system (White, 2017).

All these techniques are utilized by the IAEA around the world to control facilities and to verify that safeguards principles are respected.

The information collected through NDA in addition to remote monitoring like video frames, external radiation monitoring and other signals from sensors guarantee the improvement of safeguards.

Due to the very complex isotopic composition of the spent fuel, with the presence of minor actinides that emit neutrons, and fission products that are gamma emitters and release heat during decay process, the NDA techniques are often used to verify spent fuel.

1.3 Introduction to machine learning

Machine learning is a branch of artificial intelligence that aims to find a way in which computers can learn from experience and adapt or evolve in different and new situations. This is done through machine learning algorithms, mathematical models generated starting from a sample of data called training data and used to make predictions or decisions without being created to achieve that specific task. A fundamental role in this procedure is represented by data mining, that permits the extraction of the key features to insert in the algorithm used to make predictions. The figure 1-4 shows how a machine learning algorithm works, starting from known inputs and outputs through the training phase generate the model, that giving in input new data is able to predict the outputs.

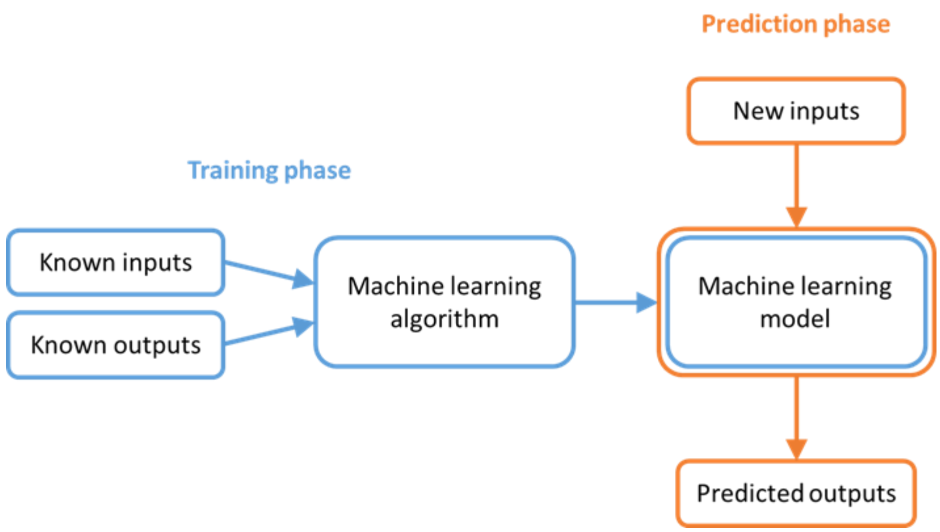

Figure 1-4: Description of the machine learning approach (Rossa, 2019).

The term machine learning started to be used since the 1940's but the most explicative definition is: *"A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P if its performance at tasks in T, as measured by P, improves with experience E."* (Mitchell, 1997). This definition derived from one fundamental question: *"Can machines think?"* then replaced with *"Can machines do what we (as thinking entities) can do?"* (Alan Turing), all investigated in Turing's paper in which he analyzed the characteristics that a *"thinking"* machine must possess:

"Let us suppose we have set up a machine with a certain initial instruction tables, so constructed that these tables might on occasion, if good reason arose, modify those tables. One can imagine that after the machine had been operating for some time, the instructions would have to admit that the machine was still doing very worthwhile calculations. Possibly it might still be getting results of the type desired when the machine was first set up, but in a much more efficient manner. In such a case one would have to admit

that the progress of the machine had not been foreseen when its original instructions were put in. It would be like a pupil who had learnt much from his master, but had much more by his own work. When this happen I feel that one is obliged to regard the machine as showing intelligence" (Turing, 1947).

Machine learning is currently used in several fields:

- finance, to discover possible fraud or to find convenient investment,
- real estate, to make estimation about cost of houses,
- emails, as spam filter of the e-mail to categorize the mail in entrance,
- health care, where thanks to new technologies with sensors that monitoring the patient in real time, can help to make diagnosis and find link between symptoms and diseases,
- government agencies, in economic sector to find ways to save money,
- websites, that give advices about shopping or show correlated sites and images based on previous purchases and researches made on the web,
- transport, to find trends in data to improve infrastructures and public transport efficiency.

Machine learning can be divided in two sub-categories, depending on the type of training data (Mitchell, 1997) (Murphy, 2012) (Smola, 2008):

- supervised learning, if there are both inputs and outputs in the training dataset used to generate the model, so that it can predicts outputs for new available input data,
- unsupervised learning, if there are only inputs in training data. It is used to find structures in the data to group and create categories.

Supervised learning can be divided in other two categories depending on the type of technique used:

- Classification, in which the response is a category or a class. This is the type of machine learning problem discussed in this thesis, in which the response class is based on the percentage of removed pins from a spent fuel assembly,
- Regression, in which the response is continuous and is used for example in the energy field to predict the fluctuation of the power demand.

The most common technique used in unsupervised learning is Clustering and it is used to search hidden trends in data for example in biology for genetic mapping.

There are several types of machine learning algorithms, which can better adapt to the situation in question: Support Vector Machine, Discriminant Analysis, Nearest Neighbors, Neural Networks, Linear Regression, Ensemble Methods, Decision Trees and many others. In this study only supervised learning was considered, using three type of algorithms: Discriminant Analysis, Decision Trees, and Nearest Neighbors.

The scheme below details how to make prediction starting from a set of training data exploiting machine learning. A block was added in this scheme to include the quality metric where the accuracy of machine learning model is analyzed.

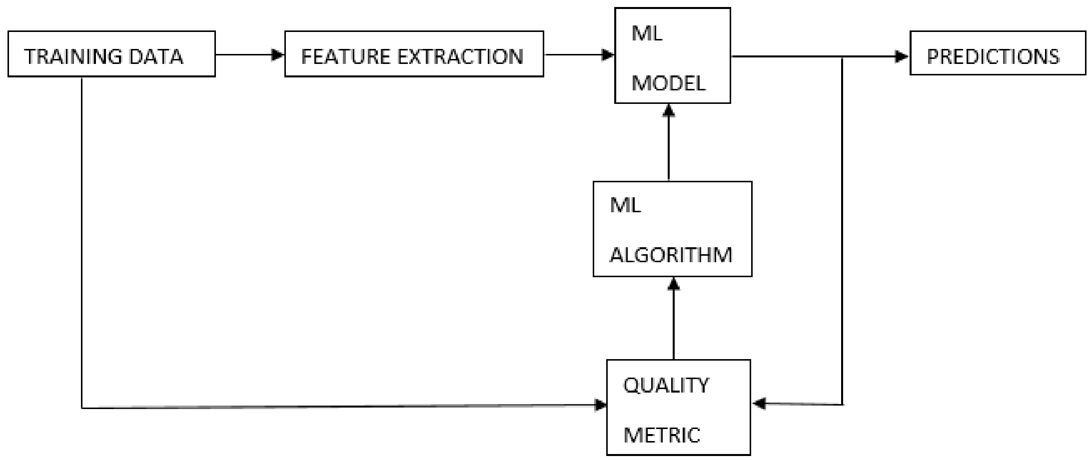

Figure 1-5: Description of the predictions process.

The procedure starts from the training dataset from which the main features to be used inside the machine learning model are extracted. The features selected in the training dataset are then fed to the machine learning model to predict the associated output classes. The predictions from the machine learning model are then compared according to a quality metric with the true values from the observation in the training dataset. The next step based on the calculated error is to refine the parameters of the machine learning algorithm to obtain an optimization of the model with the new weighted input features decreasing the error of the following predictions.

1.4 Purpose of the study

In this study we want to use the machine learning algorithms for the safeguards verification of spent nuclear fuel. Databases of different sizes with a crescent level of details and multiple detector responses resulting from NDA techniques of the spent fuel were used. The NDA techniques considered are: Fork detector, Self-Indication Neutron Resonance Densitometry (SINRD) and Partial Defect Tester (PDET). The responses of the detectors are the input features used inside the machine learning, while the output will be the class of the fuel assembly, depending on the percentage of fuel pins removed from the assembly.

The detector responses were used individually and combined together inside different machine learning algorithms to generate different models that are able to predict with new data the class of the fuel assembly depending on the number of fuel pins replaced.

In this study three types of machine learning algorithms were analyzed: decision tree, nearest neighbors and discriminant analysis that will be described individually in a dedicated chapter. The classification learner of MATLAB is used to generate the function of the machine learning algorithm. This App of MATLAB offers the possibility to change some setting of the algorithm to generate more cases to investigate.

The purpose of the study is to compare the different models generated from the different kind of detectors, different machine learning algorithms and different combinations of detector responses, in order to find the most accurate combination, which is the one with the higher percentage of correct classification.

2 NDA techniques used in this study

2.1 Fork detector

The first NDA technique analyzed in this study is the Fork detector (Vaccaro, 2018), (Van der Meer, 2007), (Borella, 2011). This kind of detector is used by IAEA and Euratom to perform analysis on spent nuclear fuel to verify safeguards requirements.

It is composed by two arms each of which contains three detectors: one ionization chamber that measures the emission of gamma rays and gives as output the current, and two fission chambers that measure neutrons.

These detectors are encapsulated inside a polyethylene block and one of the fission chambers is surrounded by a Cd sheet, which absorbs thermal neutrons allowing to distinguish the complete neutron flux from the flux of fast neutrons. These are the other two outputs of the detector in addition to the current from the ionization chamber. The Fork detector has a typical U-shape and the fuel assembly under investigation is inserted between the two arms as shown in figure 2-1.

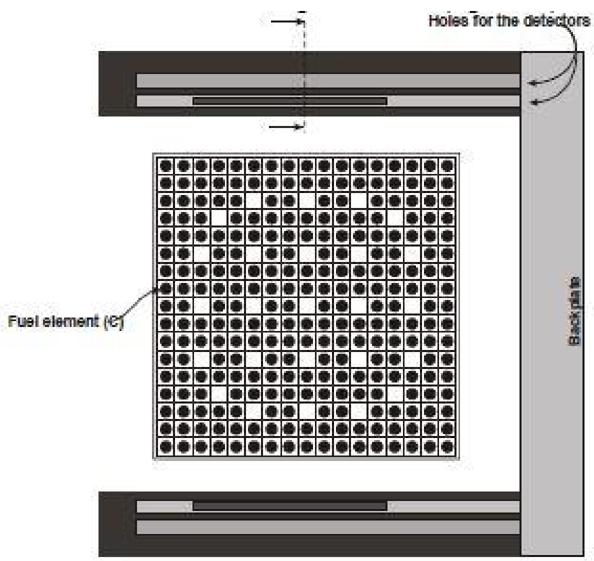

Figure 2-1: Top view of a Fork detector during the analysis of a 17x17 PWR fuel assembly (Van der Meer, 2007).

Combining the signals from the two arms is possible to avoid the radial asymmetry due to the burnup gradient of the fuel assembly.

The next pictures show an example of Fork detector (figure 2-2) and the detailed vertical section of one arm (figure 2-3).

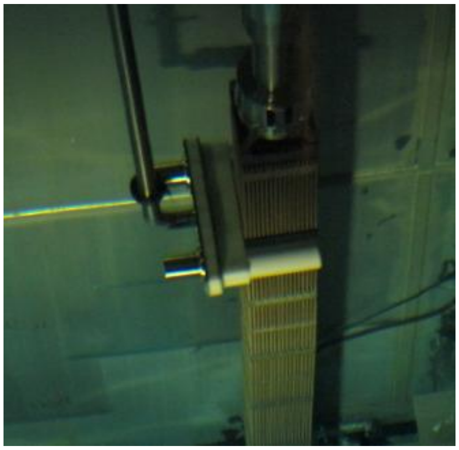

Figure 2-2: Measurements using Fork detector for a 17×17 PWR assembly (Vaccaro, 2018).

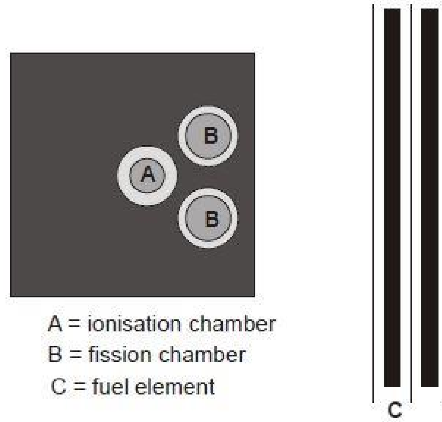

Figure 2-3: Detailed view of an arm of the Fork detector (Van der Meer, 2007).

The two arms are fixed on the head of the detector that contains the cables of transmission to the electronic part of the detector. A stainless-steel pipe further connects the detector head to the data acquisition system placed outside the spent fuel pool.

The IAEA and the Euratom use two different configurations and consequently different model units to process the data:

- IAEA uses portable Gamma-Rays and Neutrons Detector Electronics (GRAND3 or Mini-GRAND) electronics unit, that converts the current from the ionizing chambers into digital signal;
- Euratom uses SMC 2100 as modular unit, that provides low or high voltage to the detector and preamplifiers.

The conversion factor from current to signal is strongly dependent on the electronics, in fact it was observed that with these two different configurations for IAEA the signal was 10 times greater than the one obtained with Euratom configuration for assemblies with similar characteristics (Vaccaro, 2018).

The measurements with this detector are performed under water, inside the spent fuel pool. The neutron and gamma rays are good indicators for gross defect testing, and the neutrons signals are also useful to understand the quantity of boron inside the pool. For a common spent fuel assembly, $_{242}$Cm and $_{244}$Cm are the main neutron emitters due to their spontaneous fissions and $_{137}$Cs is the principal responsible of the emission of gamma rays.

In the last years an analysis module for spent fuel data was developed starting from the ORIGEN burnup code, which it is used to analyze the data from Fork detector in real time (Vaccaro, 2018). It permits to predict neutrons and gamma expected from a measurement performed with a Fork detector, relying on safeguards requirements and operating data of the reactor.

In our case of study, the configuration of the Fork detector is shown in the following picture. The analysis is made on a PWR 17x17 fuel assembly and is performed in water.

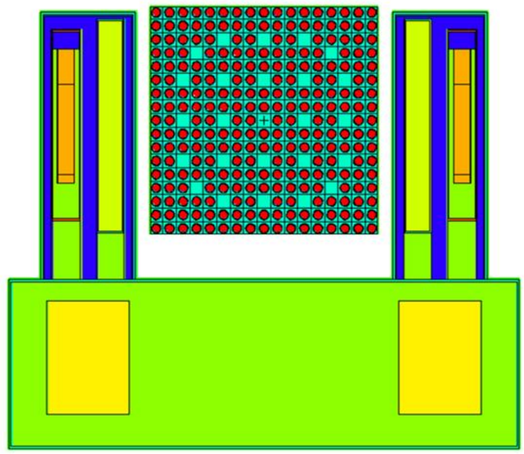

Figure 2-4: Fork detector configuration considered in this study (Borella, 2014).

The responses are the results of the average on the two arms of the detector and are the followings:

- Current: γ detector
- Fast neutrons (NwithCd): fission chamber with Cd
- Total neutrons (NwithoutCd): fission chamber without Cd

These are the features used individually or in combination to generate models with MATLAB using machine learning algorithms for the Fork detector databases.

2.2 Self-interrogation neutron resonance densitometry (SINRD)

The second NDA technique considered in this study to analyze the spent fuel is the self-interrogation neutron resonance densitometry (SINRD).

The first attempts using this technique started in the 1968 when Menlove used a resonance self-indication technique to analyze the isotopic composition of fissile materials. This technique exploited an external neutron source to make active interrogations and was already used to estimate cross section values in the resonance region (Fröhner, 1966), the next step was to apply this technique to spent fuel removing the external source and considering the prompt neutrons emitted by spontaneous fissions of $_{244}$Cm inside the spent fuel. For this reason, LaFleur (2011) proposed the term self-interrogation for this technique. The main purpose of this technique applied to spent fuel was the estimation of the amount of $_{239}$Pu inside the fuel assembly.

In figure 2-5 are shown in detail the microscopic cross section of the $_{239}$Pu in the resonance region and the neutron fluxes transmitted through two samples of $_{238}$U with different percentage of plutonium inside and characteristics comparable to those of a real fuel pin. It can be observed that in correspondence of the peak of the cross section there is a decrease of the neutron fluxes due to absorption of the plutonium in the resonance region and this phenomenon is more evident increasing the percentage of plutonium inside the fuel.

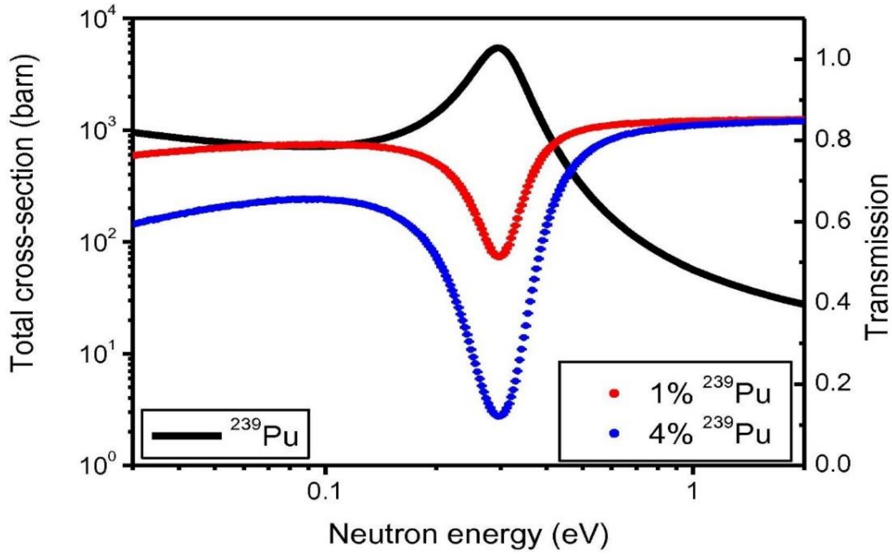

Figure 2-5: Total cross section of ^{239}Pu and transmitted neutron fluxes (Rossa, 2017).

By using this technique, it is possible to estimate the quantity of $_{239}$Pu in the spent fuel analyzing the passive emission of neutrons. To obtain this quantity we need two information:

- The neutron flux in the fast energy region;
- The neutron flux in the resonance region (0.296 eV). It is obtained from two detectors ($_{239}$Pu fission chambers), one surrounded by Gd foil and one surrounded by Cd foil used as filters. From the difference between these two fluxes detected, the neutron flux in the resonance region of $_{239}$Pu can be inferred.

The ratio of the neutron flux in the fast energy region and the neutron flux in the resonance region gives the amount of $_{239}$Pu in the spent fuel.

To develop and elaborate this technique Monte Carlo simulations were used, also to optimize the filters thickness used during detections.

The first approach of this technique with spent fuel was in 2011 when LaFleur used $_{235}$U fission chambers to analyze a spent fuel assembly under water.

This is significantly different from the approach adopted by SCK•CEN (Rossa 2014, Rossa 2015a, Rossa 2015b), in which all the measures are performed in air with dry conditions and the assembly is surrounded by a slab made of polyethylene. To detect the neutron flux in the fast energy region $_{238}$U fission chambers were used, while for the flux in the resonance regions the method explained previously was used, using two different $_{239}$Pu fission chambers. This choice of detectors leads to an increase in sensitivity for neutron energy around the resonance region due to the self-indication principle (Fröhner, 1966). The quantity of plutonium is obtained from the ratio of these two fluxes as explained before.

In figure 2-6 the geometry considered in this study for the SINRD technique is shown.

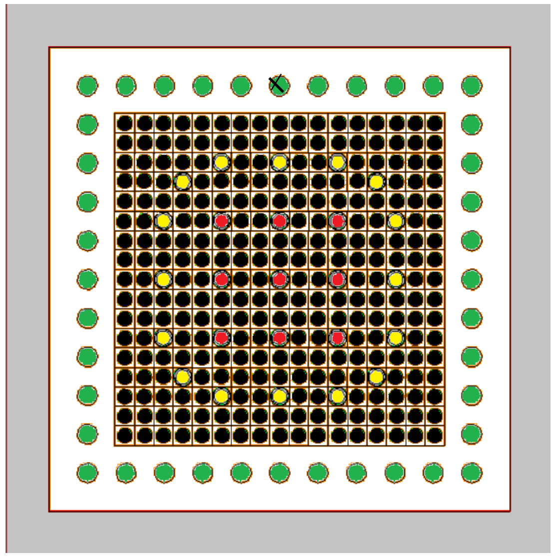

Figure 2-6: Model geometry for SINRD analysis (Rossa, 2019).

The black points of the figure represent the fuel pins of the PWR 17x17 fuel assembly, while the red, yellow and green points represent respectively the central, peripheral and external positions of the detectors and the grey part is the polyethylene that surrounds the fuel assembly. All the responses of the detectors are normalized with the value obtained from the detector marked with the cross in the external position. Then the average is calculated to obtain a single value for each position:

- the average of the 9 detectors in the central positions,
- the average of the 16 detectors in the peripheral positions,
- the average of the 40 detectors in the external positions.

The types of detector responses for each position considered in this study are:

- Thermal neutrons (TH): bare ^{235}U fission chamber;
- 0.3 eV resonance neutrons (RES): ^{239}Pu fission chambers using Gd and Cd filters;
- Fast neutrons (FA): bare ^{238}U fission chamber;
- Gamma-rays (P): ionization chamber.

These are the features considered to generate models according to machine learning algorithms in the case of SINRD analysis.

2.3 Partial defect tester (PDET)

The last NDA technique considered in this study is the partial defect tester (PDET) (Ham, 2009) (Ham, 2013). This technique exploits the presence of the guide tubes for the control rods in the fuel assembly. When the fuel is unloaded from the core and inserted in the spent fuel pool these guide tubes are generally empty and filled with water. By inserting from the top of the assemblies a set of small detectors in these positions, spatial profiles of the neutron and gamma-ray fluxes can be obtained. These profiles are largely invariant for fuel assemblies without defects but are rather sensitive to cases where fuel pins are missing or replaced.

In figure 2-7 the model geometry considered in this study is shown. The positions and configurations of the detectors are the same used for SINRD, with the difference that in this case the polyethylene is removed and the measurements are performed under water. Also the type of detector responses are the same as the SINRD analysis.

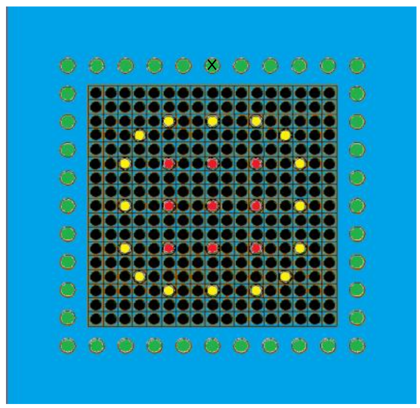

Figure 2-7: Model geometry for PDET analysis (Rossa, 2019).

The figure 2-8 shows a prototype of the detector constructed by Lawrence Livermore National Laboratory (LLNL), used for the analysis of PWR 17x17 fuel assemblies. This prototype exploits ^{235}U fission chambers to detect neutrons and ionization chambers do detect gamma rays.

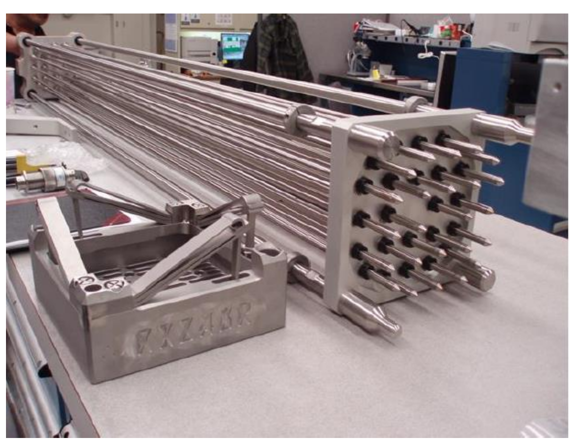

Figure 2-8: Prototype of PDET detector (Ham, 2013).

2.4 Description of the databases used

The detector responses of the NDA techniques described in the previous sections were organized in separate databases for the data analysis with machine learning models. The databases were developed performing a set of Monte Carlo simulations for each type of detector used in this study.

As mentioned before the responses generated from each simulation were normalized using the value of the response from the detector marked by a cross and situated in the external position. Subsequently the average value for each position (i.e. central, peripheral, or external) was calculated.

For the complete fuel assemblies 196 simulation were performed combining the following parameters:

- Initial enrichment, that can assume the following values: 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0%;
- Burnup, that can assume the following values: 5, 10, 15, 20, 30, 40, 60 GWd/t_{hm};
- Cooling time, that can assume the following values: 1, 5, 10, 50 years.

All the fuel pins have same material composition and have the same source strength. The characteristics of the fuel and the properties of the source were all taken from SCK•CEN reference spent fuel library (Rossa, 2013).

All these simulations were performed to highlight the connection between the irradiation history of the fuel and the detector responses.

Another set of simulations was performed to obtain the detector responses from 107 symmetric and asymmetric diversion scenarios. For SINRD and PDET analysis only the pin replacement was considered in which some fuel pins inside the assemblies were removed and replaced with dummies made of stainless steel. For the Fork detector we considered both replacement scenarios and diversion scenarios, in which the fuel pins are removed without being replaced by dummies, filling the empty spaces with water.

A total of 963 simulations were performed considering a fixed cooling time of 5 years and combining the other parameters:

- Initial enrichment of the fuel, that can assume the following values: 2.0, 3.5, 5.0%;
- Burnup, that can assume the following values: 10, 30, 60 GWd/t_{hm};

In the picture 2-9 3 different examples of scenarios considered in Monte Carlo simulation are shown, each with a replacement of 50% of the fuel pins. The dummies are represented by the grey squares while the fuel by the white squares and the crosses mark the guide tubes positions in which the detectors are inserted.

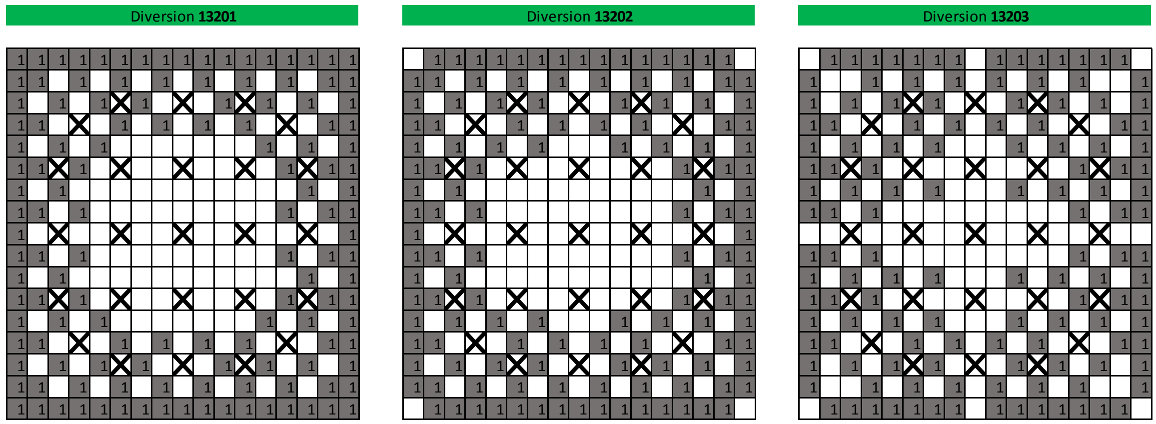

Figure 2-9: Example of diversion scenario with 50% replacement.

The databases generated by the Monte Carlo simulations are subdivided in 6 classes for each type of detector, depending on the percentage of replaced pins inside the fuel assembly. Going down from databases A to F they become more accurate and are able to distinguish replacement or diversion of less fuel pins. Moving from class 6 in which are considered only replacement scenarios in which more than 50% of fuel pins are replaced, to class 1 that are able to distinguish replacement in which less than 10% of the fuel pins are missing.

The details of the class subdivision are the following:

- Class 0: complete fuel assemblies (196 simulations);
- Class 6: diversion/replacement with >50% fuel pin missing (99 simulations);
- Class 5: diversion/replacement with 40-50% fuel pin missing (144 simulations);
- Class 4: diversion/replacement with 30-40% fuel pin missing (144 simulations);
- Class 3: diversion/replacement with 20-30% fuel pin missing (189 simulations);
- Class 2: diversion/replacement with 10-20% fuel pin missing (216 simulations);
- Class 1: diversion/replacement with <10% fuel pin missing (171 simulations);

Table 2-1: Details of the classes included in the databases.

	Classes included in the database						
Database name	Class 0	Class 6	Class 5	Class 4	Class 3	Class 2	Class 1
Database A	Yes	Yes	No	No	No	No	No
Database B	Yes	Yes	Yes	No	No	No	No
Database C	Yes	Yes	Yes	Yes	No	No	No
Database D	Yes	Yes	Yes	Yes	Yes	No	No
Database E	Yes	Yes	Yes	Yes	Yes	Yes	No
Database F	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The classes included in the different databases are shown in Table 2-1. For example, with the database A it is only possible to distinguish between complete fuel assemblies (class 0) or replacement/diversion with more than 50% of fuel pins missing (class 6). By including additional classes, up to database F, the model is asked to classify the records with less and less fuel pins replaced or missing.

As mentioned in the previous chapters, the databases contain the detector responses in addition to the parameters used for Monte Carlo simulations and the number of dummies with the corresponding class.

In tables 2-2 and 2-3 are shown some extracts from the databases for the Fork detector and SINRD to highlight the structure of the databases. The detector responses will be used as predictors in the machine learning algorithms whereas the class will be the response of the model.

Table 2-2: Extract of the diversion database A for Fork detector.

Number of Dummy Pins	Current (nA)	NwithCd (count/sec)	NwithoutCd (count/sec)	Class
0	1.222E-08	2.551	5.496	0
0	1.625E-08	4.795	10.276	0
0	2.418E-08	15.566	33.509	0
0	3.207E-08	43.880	93.272	0
0	4.727E-08	194.208	416.689	0
180	2.666E-08	0.923	1.586	6
136	2.827E-08	1.413	2.594	6
132	2.399E-08	1.248	2.512	6
132	2.514E-08	1.252	2.515	6
132	2.660E-08	1.264	2.500	6

Current = response of the γ detector, NwithCd = response of the fission chamber with Cd i.e. the Fast neutrons and NwithoutCd = output of the fission chamber without Cd and represents the total number of neutrons.

Table 2-3: Extract of the replacement database F for SINRD, the detector responses are divided according to the position of the detector.

Dummy Pins	Cen-TH	Cen-FA	Cen-RES	Cen-P	Per-TH	Per-FA	Per-RES	Per-P	Ext-TH	Ext-FA	Ext-RES	Ext-P	Class
0	1.1651	0.9656	1.1484	0.9837	1.7229	0.8552	1.6109	0.8982	3.6512	0.4520	2.9984	0.3989	0
0	1.1700	0.9643	1.1585	0.9839	1.7525	0.8530	1.7106	0.8994	3.7819	0.4500	3.5391	0.3998	0
132	1.2761	0.8870	1.3696	0.8722	2.3422	0.6475	2.6574	0.6140	6.4831	0.2895	6.3694	0.2279	6
132	1.2518	0.9730	1.1989	1.0010	2.1395	0.8820	1.9414	0.9582	6.0364	0.3699	5.0006	0.3072	6
120	1.1511	1.1384	1.0446	1.4020	1.9435	1.1581	1.5007	1.5967	5.5626	0.6761	3.2018	0.8262	5
120	1.1982	1.0315	1.1242	1.0790	2.3240	0.8331	1.9756	0.8387	6.7627	0.4249	4.2762	0.3666	5
94	1.2502	0.9949	1.1738	1.0258	2.2112	0.9330	1.8433	0.9983	6.3521	0.5470	4.0009	0.5253	4
96	1.2914	0.9662	1.2447	0.9940	2.3489	0.8647	2.0397	0.9073	7.2971	0.4213	4.8352	0.3584	4
63	1.2757	0.9445	1.3051	0.9457	2.4277	0.7746	2.5710	0.7355	7.2173	0.3865	6.6581	0.2974	3
68	1.2318	0.9475	1.2482	0.9681	2.0397	0.7923	2.1640	0.8175	5.6906	0.3419	5.7344	0.2652	3
32	1.2020	0.9530	1.2335	0.9764	1.9202	0.8004	2.1469	0.8334	4.7510	0.4073	5.4654	0.3707	2
32	1.1823	0.9516	1.2066	0.9764	1.8061	0.7957	2.0191	0.8333	4.1920	0.4026	4.8620	0.3706	2
12	1.2374	0.9675	1.2044	0.9833	2.0616	0.8760	1.8878	0.9196	5.5804	0.4577	4.3858	0.3874	1
16	1.2631	1.0031	1.2020	1.0290	2.1709	0.9645	1.9722	1.0489	6.6243	0.5259	5.7757	0.4700	1

TH = thermal neutrons detected by the bare $_{235}$U fission chamber, RES = 0.3 eV resonance neutrons detected with $_{239}$Pu fission chambers using Gd and Cd filters, FA = fast neutrons detected by the bare $_{238}$U fission chamber and P are the Gamma-rays detected by the ionization chamber. Cen = central position of the detectors, Per = peripheral position of the detectors and Ext = external position of the detectors. All the responses are dimensionless due to the normalization.

3 Machine learning

3.1 Validation scheme

Several machine learning models were developed in this thesis, and the validation scheme allows to evaluate the accuracies of the models generated to make prediction. Instead of using the validation scheme provided from the classification learner inside the MATLAB function, a separate script was implemented to calculate the accuracy and the correspondent standard deviation.

The validation scheme adopted is a 5-fold cross validation (Mitchell, 1997). This validation scheme used the following procedure:

- The original database is divided into 5 random groups, each one of them generated taking 1 random row of the original database at time until the original is empty and all the groups are full;
- Four of the five datasets are used inside the algorithm to train the model, for this reason are called training data;
- The excluded group is used for the validation, the model previously generated use this dataset to make predictions;
- Then the accuracy is calculated counting the number of correct predictions, comparing the class predicted with the correct one present inside the group used for validation:

$$Error = \frac{Number\ of\ incorrect\ predictions}{Total\ number\ of\ observations}$$

  The accuracy of the model can be calculated both on the training and validation set; however, in this thesis we decided to evaluate the models using only the validation dataset, as a measure to assess the capability of the model to generalize with unknown data;
- Then this last three points are repeated until all five groups will be used for validation and all possible combination of four group out of five will be used to train the model;
- All the previous steps are repeated 5 times, each time taking a new random assignment of the observations in the different groups. At the end of the process, a total of 25 resulting accuracies are obtained which are used to calculate the average accuracy value and the correspondent standard deviation.

The validation scheme described above will be repeated changing in case of decision trees up to 20 as maximum number of nodes, and in case of KNN up to 50 number of neighbors.

3.2 Model used

3.2.1 Decision tree

The decision tree (Mitchell, 1997) is one of the easiest models used in machine learning to visualize the decision procedure to make classification of data. This technique is useful in many fields to make decision for example to predict if a loan is safe or risky, or as in this study to predict the class of a fuel assembly as shown in figure 3-1.

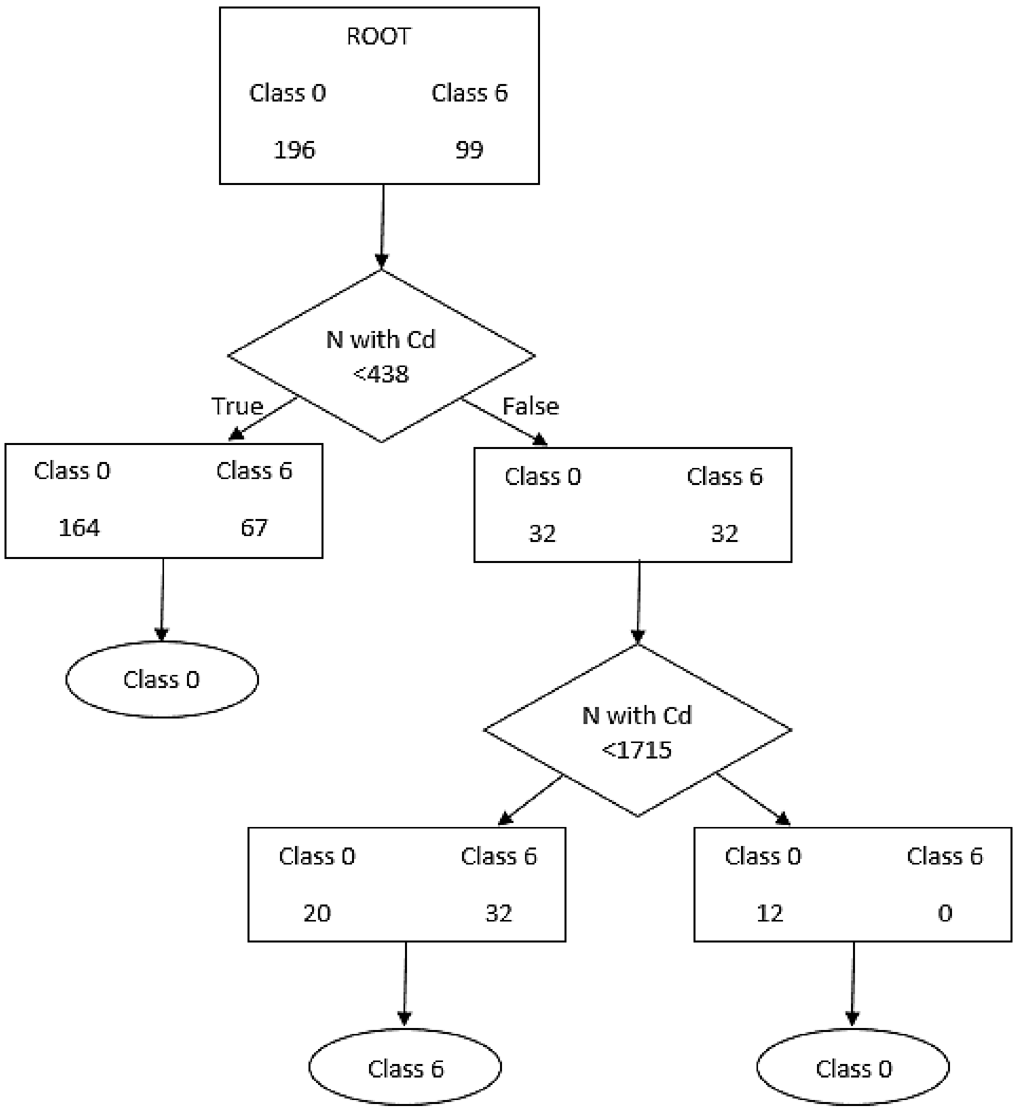

Figure 3-1: Decision tree for database A Fork detector diversion case.

This is a simple example of decision tree for the Fork detector using the database A, in which the final classification is based on only one feature (N with Cd) limiting the maximum number of splits to two. A decision tree starts with the so-called root, which contains the total number of observations in the problem. As shown in the figure the N with Cd diamond box is the splitting condition and represents a so-called node of the decision tree. Each node is connected with a square box containing the number of observations for each class before the splitting condition, and two other square boxes containing the observations for each class after the split is made. The square boxes can then lead to a so-called leaf node, where a decision is made on the class of the observations, or to another node of the tree.

In the case considered as example for the Figure 3-1, the root of the decision tree is the total number of simulations for the two classes (196 observations with class 0 and 99 with class 6). From the first node, the tree is split in two branches which in one case end with the leaf node assigning all observations as class 0, while the other branch continues with another node.

The split of the tree was done using N with Cd as features and the two classes for the predictions are class 0 and class 6. The graph show that:

- From the left branch of the first node (N with Cd<438) there are 164 cases belonging to class 0 and 67 cases belonging to class 6;
- From the left branch of the second node (N with Cd <1715) there are 20 cases belonging to class 0 and 32 cases belonging to class 6;
- From the right branch of the second node (N with Cd >1715) there are 12 cases belonging to class 0 and 0 cases belonging to class 6.

From these numbers the decision tree makes the predictions in the leaf nodes, choosing the greatest of the two numbers and giving as output the correspondent class. It is also possible to evaluate the classification error committed using this technique to make prediction. From the left branch of the first node it is possible to observe that the final result is the class 0, with 164 correct classifications and 67 mistakes because 67 cases of class 6 are classified as class 0. From the left branch of the second node the predicted class is class 6, with 32 correct classifications and 20 mistakes. In the last branch the predicted class is class 0, with 12 correct classifications and 0 mistakes.

The construction process of a decision tree is a step-by-step procedure which starts from the choice of the best feature to split data. A cost function is used on all possible features as node for the split and computes the correspondent classification error; the selected feature is the one with the lowest classification error. This is called greedy algorithm due to its recursion to find the *"cheapest"* feature to decrease the cost. The most common cost function used for this purpose in the classification tree is the Gini impurity (MATLAB, 2019), which tries to make splits generating groups of the same class. The Gini impurity or Gini score derived from the following formula:

$$G = 1 - \sum_{k} p_k^2$$

Where p_k indicates the percentage inside a group of elements belonging to class k. The purity G is 0 if all the elements inside the group belong to the same class, this means that the node gives as output from its branches observations belonging to one class only, with no classification error.

Another cost function that can be used is the Twoing rule (MATLAB, 2019), which is based on the idea to simplify a multiclass problem in a two classes problem looking for a grouping that generates a decrease in the impurity of the node using a split that maximize the differences of information between the two groups created. The following function must be maximized to find the best feature:

$$P(L)\,P(R)\left(\sum_{i}|L_k - R_k|\right)^2$$

Where *P(L)* and *P(R)* indicate, respectively, the percentage of observations that generate the left and the right branch of the node and L_k and R_k are the fraction of observations that belong to class *k* in the left and in the right branch of the node, respectively (MATLAB, 2019).

The last method is the maximum deviance reduction (MATLAB, 2019) or cross entropy, that is similar to the Gini Index and uses the *"disorder"* in the data as quality index to find the best split. More disorder means an increase in the uncertainty due to more complex data. This method looks for a split that minimizes this *"disorder"* generating a node without impurity. The following function must be minimized to find the best feature:

$$-\sum_{k} p_k * log_2(p_k)$$

Where p_k indicates the percentage inside a group of elements belonging to class k.

The splitting procedure continues until some conditions are reached to avoid the construction of large decision trees, which are very complex to interpret and can lead to overfitting in the data and consequently unreliable predictions. There are some rules that can be adopted to stop the splitting of the tree and that can help in the choice between different trees:

- Set the maximum depth of the tree i.e. the longest way starting from the root to the final leaf. In this study MATLAB does not allow directly to set the depth of the tree but it is possible to set the maximum number of splits of the tree;
- Set a minimum number of elements inside a leaf node to make a classification. If the number of observations is lower than this threshold, the classification will not be made;
- Neglect spits which do not lead to a decrease in the classification error;
- When comparing trees with same classification errors, but different model complexity (e.g. number of nodes), select the tree with lowest level of complexity to protect against overfitting.

The use of the decision tree as machine learning algorithm has the following advantages:

- The model is simple and easy to interpret, at any time it is possible to see the procedure adopted by the tree to make the final classification following the branches of the graph;
- The model can use directly the values in the input database without the need for normalization or other pre-processing;
- The model is able to work well also with huge dataset;
- The model is useful to select features and to decide which are the more relevant because the tree show which are the features most used in the splitting nodes.

Nevertheless, decision trees present also some problems:

- This kind of algorithm is not very robust, the tree can change dramatically changing even slightly the training dataset leading to different classification (Gupta, 2017);
- It is not unusual that the algorithm generate a very complex tree (high depth) which lead to overfitting, defined as *"the production of an analysis that corresponds too closely or exactly to a particular set of data, and may therefore fail to fit additional data or predict future observations reliably"* (OxfordDictionaries, 2019);
- The greedy algorithms are not always able to find the best decision tree because are the results of consecutive local optimizations that do not always lead to a global increase of accuracy (Gupta, 2017).

In this study the features used within the algorithms are the detectors responses provided by the database. Both single features and combinations of different features were used to generate the decision trees. The leaves of the tree will be the class of the fuel assembly based on the number of missing pins.

Figure 3-2 shows an example of decision tree from this study generated by MATLAB using all the responses of the Fork detector for replacement database A limiting the maximum number of splits to 10.

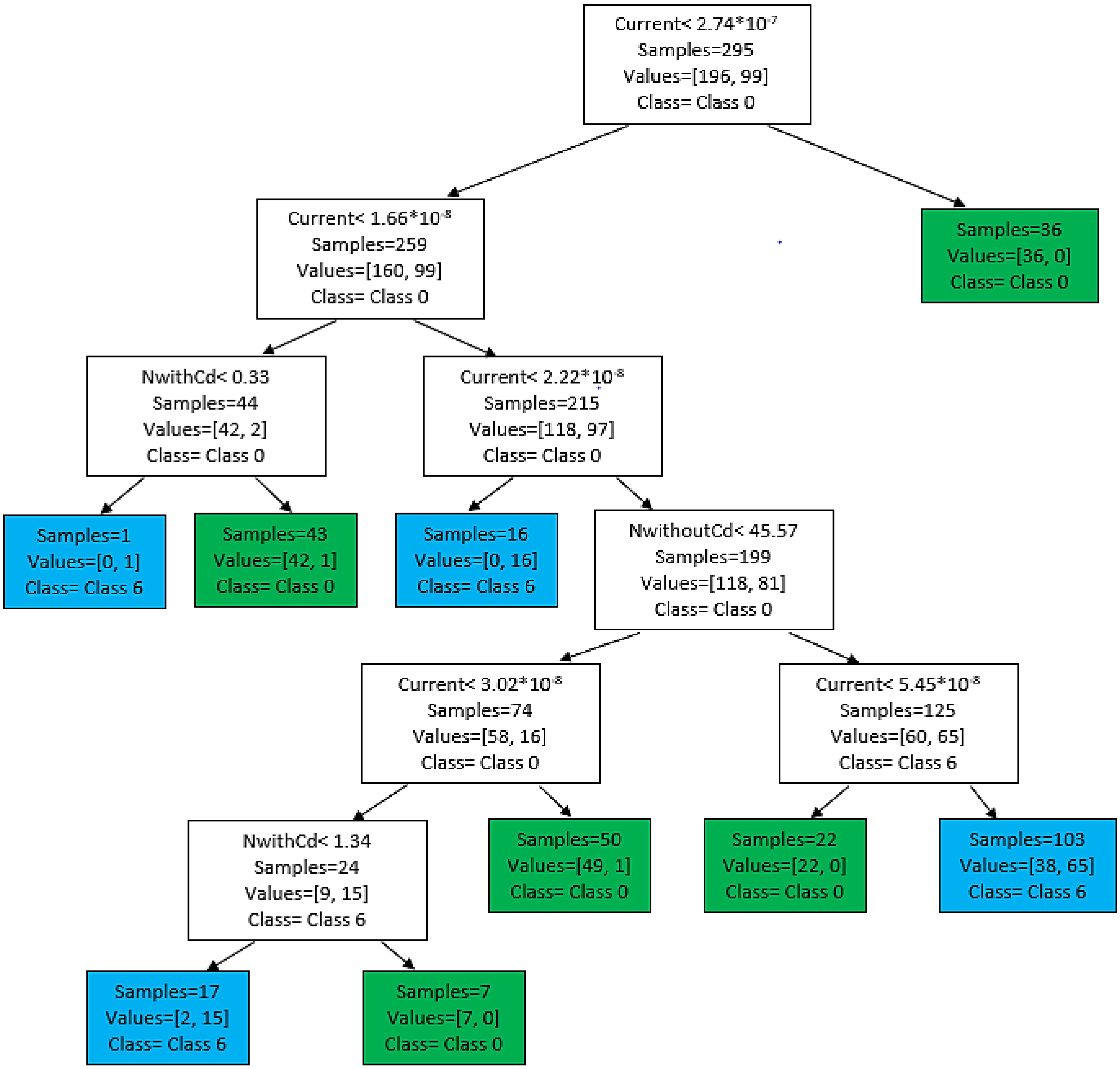

Figure 3-2: Decision tree for Fork detector. The final classification is highlighted in green for class 0 and in blue for class 6.

3.2.2 KNN

The k nearest neighbor (KNN) (Iggane, 2012) is another type of machine learning algorithm used to solve classification problems. This algorithm is based on the concept that similar data are closer to each other so this proximity can be used to predict the unknown class of a query point. It is very useful for example for the prediction of the houses prices, using the known sales data and comparing the features of these sold houses with the one under interrogation, it is possible to infer the price finding the one that is the most similar. This is simplest case of KNN algorithm, in which only one neighbor is considered, called for this reason 1-NN classification, because the prediction is made using only one data point with the minimum distance from the query point. Figure 3-3 shows an example from this study, in which the star represents the query point while the blue and the orange points are a selection of data from the database A of the Fork detector. In the example two features are considered, N with Cd and N without Cd. As shown in the figure 3-3 if only one neighbor is considered the final classification will be class 6 because this is the class of the closest observation to the query point. If five neighbors are considered the final classification will be class 0 because there is one point of class 6 close to the query point, but the closest four other observations belong to class 0. The predicted class corresponds to the majority of the classes of the k points nearest to the query point.

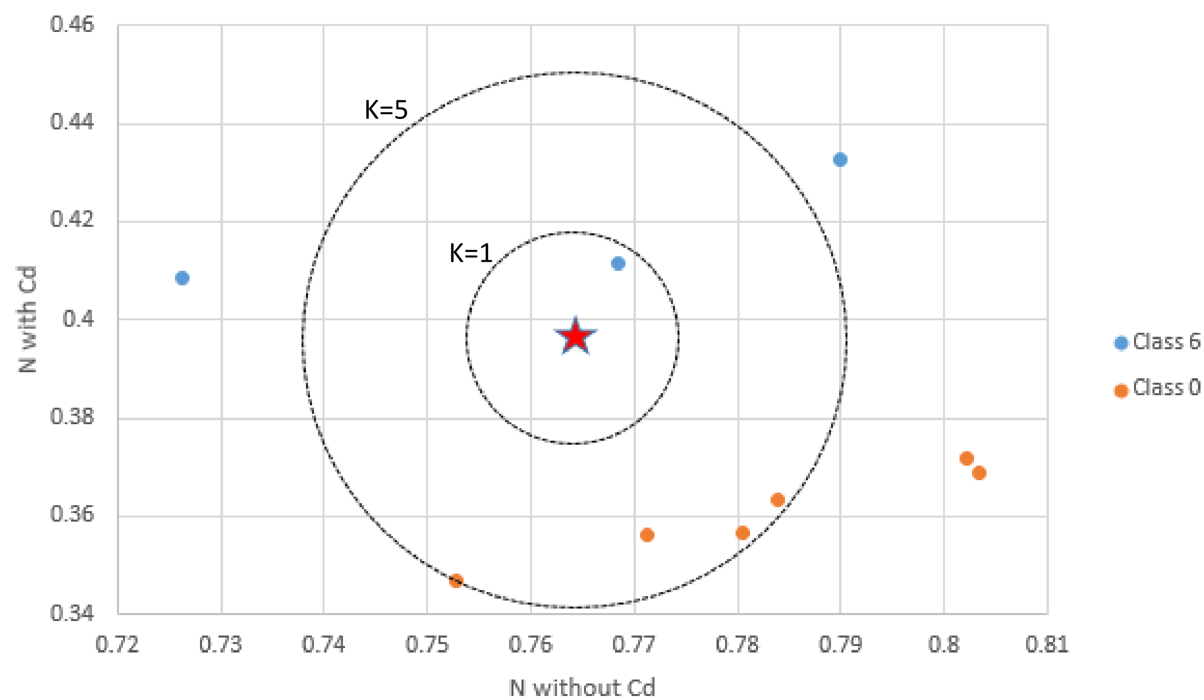

Figure 3-3: Example of KNN classification for database A Fork detector diversion case.

There are many ways to compute the distance between the query point and the other points of the dataset, and the approached used in this study will be described in chapter 3.3.2.

The KNN algorithm works using the following steps:

- Choosing the number K of neighbors used to make predictions;
- Selecting the relevant features of the input database;

- Based on the selected features a space of points is generated;
- The distance between the query point and each single point is calculated;
- The calculated distances are sorted from the smallest to the largest;
- The first K distances are selected;
- The algorithm returns the class of the query point as the more frequent class of the K points selected in the previous step.

The suggested way to choose the optimal K for the database under interrogation is to run the algorithm changing the number of neighbors and observing which is the K that minimizes the number of incorrect classifications maintaining the reliability of the prediction.

The problem with choosing only one neighbor is the unreliability of the prediction. Taking as example the previous figure, using only one neighbors the final classification will be class 6 even if the query point is surrounded by many points of class 0.

On the contrary, choosing a large value of K increases the number of incorrect classifications and consequently the error, due to the more crowded space in which the distances are calculated and a great amount of neighbors with different classes.

The correct choice is to increase gradually the number of neighbors to increase the reliability of the model thanks to the comparison with more points. When the number of incorrect classifications starts to increase is the signal that the chosen K is too large.

This type of algorithm is, as for the decision tree, easy to interpret and to implement. The issues found with the KNN algorithm are evident when the problem to be solved needs to deal with large amount of data in short time. The computational time increases significantly with the amount of input data making it preferable to use faster algorithm that can make more reliable predictions in shorter times.

3.2.3 Discriminant analysis

The last type of machine learning algorithm analyzed is the discriminant analysis (Li,2006). This algorithm uses the input training dataset to generate boundaries which divide the different responses classes. To generate the boundaries the first step is to calculate the mean vector and the covariance matrix of each classes considering the groups of data points (features of the database or predictors) distributed as the Normal function (Gaussian distribution). The mean corresponds to the center of the distribution, while the covariance matrix provides the shape of each class distribution. The next step is to construct the boundaries between classes, so that given a new data point as input it is possible to classify it based on its position respect to the border. The equations of the boundaries depend only on the mean vectors and covariance matrices and if the distributions have the same shape it means that they have the same covariance matrix. The boundaries thus generated are linear, greatly simplifying the procedure to determine the function of the boundary because it can be calculated using the mean vectors and a single covariance matrix. For this reason, is called linear discriminant analysis.

Figure 3-4 shows an example from this study, in which it is possible to observe the linear boundaries that divide the three classes allowing to predict the response of new data depending on each position within the boundaries.

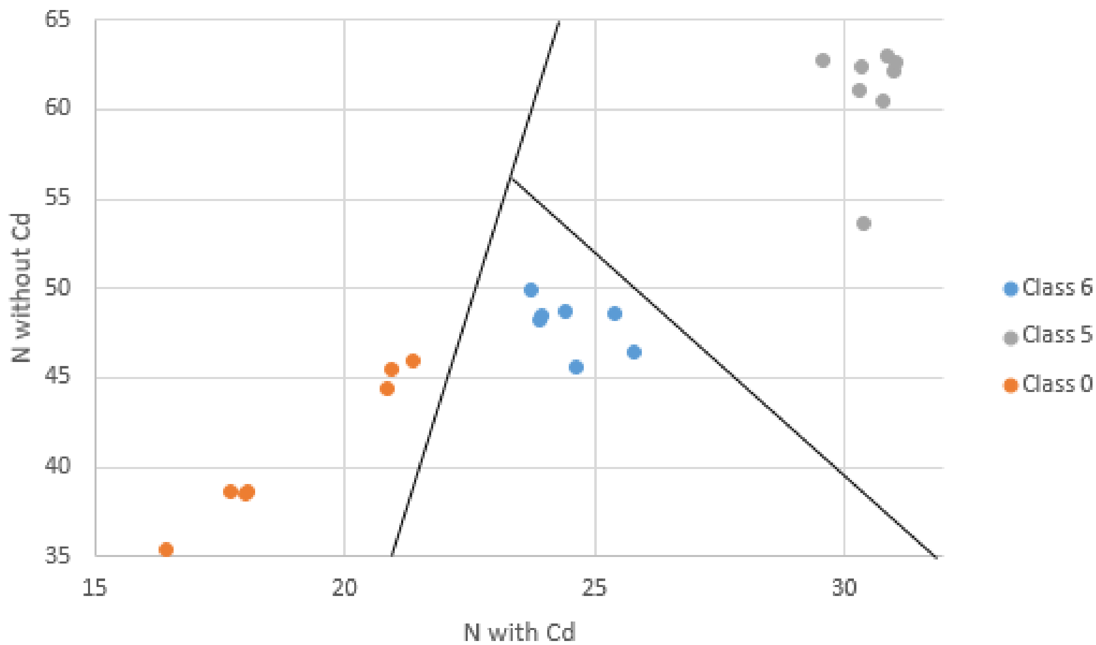

Figure 3-4: Example of linear discriminant analysis for database B Fork detector diversion case.

However, it is not always possible to assume that the covariance matrixes are equal among the classes. In such cases the boundaries generated are not linear but are quadratic function. This implies more calculation to determine the equations for the boundary and consequently more computational time and more memory usage especially if there are many response classes and predictors. In this case the algorithm is called Quadratic discriminant analysis.

The main fields of application of this technique are:

- marketing, in which is used to classify customers and products using the sales data,
- face recognition, in which due to the large amount of pixels present in an image in used to filter the relevant features to simplify the procedure of the final classification;
- medicine, in which is used to classify the severity of a disease according to the features provided by previous studies on groups of patients divided in base on the state of the disease.

3.3 Machine learning in MATLAB (classification learner)

The classification learner app of MATLAB was used to generate classification models according to several machine learning algorithms (MATLAB, 2019). Giving as input the database of spent fuel described in chapter 2.4 and choosing as predictors the detector responses and as response of the model the class, this app generates the model. The MATLAB function associated at this model can be exported to the MATLAB workspace to be further modified changing some parameters of the machine learning algorithm and selecting the number of input features i.e. the detector responses.

3.3.1 Decision tree

The first algorithm used inside the classification learner was the decision tree, that is one of the simplest and more easily interpretable. The characteristics of this algorithm are:

- Prediction speed: fast, means that the model makes predictions in 0.01 second;
- Memory usage: small, means that the model uses 1 MB of memory;
- Interpretability: easy, because it is possible to determine how the final classification is achieved by viewing the decision tree and following its branches;
- Model flexibility: depends on the maximum number of splits of the tree. High flexibility models (high number of splits, up to 100) adapt better to more general cases due to the higher number of leaves which allow a better distinction between classes, but the complexity increases and can lead to overfitting of the data.

The classification learner allows to change the maximum number of splits of the tree and to choose between 3 split criteria:

- Gini's diversity index, that measures the node impurity;
- Maximum deviance reduction, that measures the node impurity;
- Twoing rule, that permits to increase the node purity maximizing its expression.

After selecting the features and setting the maximum number of splits to 20 it is possible to generate the MATLAB function that will be used inside the MATLAB script that contains the validation scheme, to train the model and make predictions with the model created. This script gives as output also the accuracies (the percentage of the correct predictions) of the model as function of the number of splits. The validation scheme was described in chapter 3.1, which described how the database is used to make predictions.

This procedure will be repeated for each class of database and for each type of detector to assess which is the most accurate and how the accuracies evolve proceeding in more detailed databases. To assess which are the most accurate detector responses or combination of them, the MATLAB function has been modified by changing a vector of boolean variables associated with the features used by the script to create the model and make predictions. In this way we can consider all possible combinations of type of responses and detector positions for SINRD and PDET, while for the Fork detector there is only a combination of detector responses type because they are independent from the position.

3.3.2 KNN

The second machine learning algorithm used inside the classification learner was the K Nearest Neighbor or KNN (MATLAB, 2019). This classifier has certain characteristics:

- Prediction speed: medium, means that the model makes predictions in 1 second;
- Memory usage: medium, means that the model uses 4 MB of the memory;
- Interpretability: easy to medium, because it is not immediate like the case of decision tree but is it possible to understand how the classification is made based on the distance between points;
- Model flexibility: depends on the number of selected neighbors. On the one hand, increasing the number of neighbors causes a decrease in model flexibility as well as an increase in the time needed to achieve fitting, one the other hand, decreasing the number of neighbors can lead to overfitting of the database.

The KNN classifier allows to change a lot of settings in the MATLAB workspace, generating several models to analyze and find the most accurate. It is possible to change the distance metric, i.e. the way in which the distances between points are calculated. In this study 6 different distance metrics were considered:

- Euclidean, which corresponds to the length of the straight line that connects two points;
- City block, which is derived summing the absolute differences of the Cartesian coordinates of two points;
- Chebychev, *"which is a metric defined on a vector space where the distance between two vectors is the greatest of their differences along any coordinate dimension"* (Abello, 2002);
- Minkowski, which is a generalization of Euclidean distance. In this study was considered a cubic distance so the exponent was set to 3;
- Mahalanobis, which is derived counting the number of standard deviations from the query point and the mean value of the total distribution of neighbors points;
- Cosine, which is calculated as the difference between 1 and the cosine of the angles between the points assumed as vector (MATLAB, 2019).

Another parameter changed in this study is the distance weight, where weights are assigned to the observation points. When the distance between the query point (point that needs to be classified) and the point under consideration (point from training data) is large the function assigns a small weight value to this point because it assumes it is less relevant for the final classification, while when the distance is small the weight increases. The distances are evaluated from the differences between the features (detector response) of the query point and the features of the considered points, but are dependent on the type of distance metric used. The classification learner provides three options:

- Equal, when no weights are assigned;
- Inverse, when the weights are assigned to the points, then the class of each of them is multiplied by its weight and then all these products are summed together. The sum is divided by the sum of all distances;
- Quadratic inverse, when the weights are assigned to the points, then the class of each of them is multiplied by its weight and then all these products are summed together. The sum is divided by the sum of the distance squared.

For this study we considered only the first two options as distance weights.

The Classification learner app gives also the option to choose between standardized and unstandardized data, but in this study only unstandardized data was considered.

The procedure used with KNN is the same of the decision tree, with the difference that the options of the classification learner to be modified are different from the previous case. All the accuracies were calculated using all the distance metric listed previously for both distance weights. This algorithm was used to calculate only the accuracies with the database F, but it was applied for every type of detector and for the same combination of features, as explained in chapter 3.3.1.

3.3.3 Discriminant analysis

The last machine learning algorithm used with classification learner is the discriminant analysis (MATLAB, 2019). This algorithm has the following characteristics:

- Prediction speed: fast, means that the model makes predictions in 0.01 second;
- Memory usage: depends on the type of boundaries used, for linear is small, means that the model uses 1 MB of the memory, for non-linear (Quadratic discriminant) is large, means that the model uses 100 MB of the memory;
- Interpretability: easy, because it is easy to understand the final prediction of the class of a point due to subdivision of the points using boundaries that separate the classes;
- Model flexibility: low for both cases due to the presence of boundaries.

For the discriminant analysis it is possible to change two settings:

- The type of discriminant: linear in which the algorithm generates linear boundaries to separate the classes, and non-linear in which non-linear boundaries like ellipse, parabola or hyperbola are generated;
- The covariance structure: full if the complete matrix is used or diagonal if only the diagonal of the matrix is considered to determine the shape of the distribution.

The discriminant analysis was applied for all class1 databases considering the four possible combination of settings:

- Linear discriminant with Full covariance matrix;
- Linear discriminant with Diagonal covariance matrix;
- Quadratic discriminant with Full covariance matrix;
- Quadratic discriminant with Diagonal covariance matrix.

As for the other two methods all possible combination of features has been considered as will be shown in the chapter with the results.

4 Results

This chapter will show the results of this study using the different type of machine learning algorithms described previously. To reduce the length of the thesis, for PDET and SINRD only the results obtained for the external detector positions and for all positions are reported. However, the text comments also cases where significant differences were observed for models including other detector positions.

The table 4.1 is the legend for all the results and indicate the range of accuracy in function of the color assumed by the cell of the table.

Table 4-1: Legend for the results.

COLOR	ACCURACY
	<75%
	>=75 & <80%
	>=80% & <85%
	>=85% & <90%
	>=90% & <95%
	>=95% & <100%
	100%

4.1 Decision tree

The tables of this chapter show the accuracies in function of the number of splits obtained using the decision tree as machine learning algorithm. The maximum number of splits increased up to 20 as explained in the previous chapter and the cost function used is the Gini`s Index for all classes because the first tests showed that the split criterion did not influence the values of accuracy.

4.1.1 Databases A

4.1.1.1 Fork detector

The table 4-2 shows the accuracies calculated using the database A of the Fork detector in the diversion case. It is possible to observe an increasing trend of the accuracy with the number of splits, that stabilizes around 10 or 12 splits. The best results using a single feature are obtained from the current, reaching accuracy values up to 84%. Combining the current with another feature or using all the features allows to reach values of accuracy up to 93%. The standard deviation calculated for the accuracies of the diversion case is included between 3% and 8%.

The table 4-3 shows the accuracy calculated using the database A of the Fork detector in the replacement case. As in the diversion case it is possible to observe an increasing trend of the accuracies with the number of splits, that stabilizes around 10 or 12 splits. The best results using a single feature are obtained again from the current, reaching values up to 80%. Combining the current with another feature or using all the features allows to reach values of accuracy up to 87%.

The standard deviation calculated for the accuracies of the replacement case is included between 3% and 9%. Comparing the results for replacement and diversion, in the replacement cases the values of accuracy are lower than in the diversion cases, reaching differences up to 12% using NwithCd and NwithoutCd as features in the decision tree.

4.1.1.2 PDET

In the tables 4-4 and 4-5 the results for PDET are shown considering the external positions of the detectors and using all the positions of the detectors respectively.

From the results using the detectors in central positions it was noticed that the majority of the accuracies are greater than 95% in particular for the single detector responses fast neutrons (FA) and for the gamma-rays (P), and further combinations that involve these features. The results of the peripheral positions are similar compared to the central position, although there is a slight increase of accuracies included between 2% and 6% for the single detector response thermal neutrons (TH) and resonance neutrons (RES).

From the table 4-4 it is possible to observe the accuracies for the external positions. The results are similar compared to the central and peripheral positions, with only a decrease in the accuracies for the single feature TH, that passes from values up to 92% for central and peripheral positions, to a maximum value around 84% for the external positions.

The results from the combination of two or more features are similar compared to the values obtained with a single feature. Only an increase of the accuracies was noticed for the single features TH and RES which reach values up to 97%, as can be observed from the table 4-5.

The standard deviation calculated for the accuracies shown in Tables 4-4 and 4-5 is within 6%.

4.1.1.3 SINRD

In the tables 4-6 and 4-7 the results for SINRD are shown considering the external positions of the detectors and using all the positions of the detectors respectively.

Analyzing the results we observed that considering detectors in central positions the majority of the results are greater than 95% in particular for the single features FA and P, and the combinations that involve these features. From the comparison of the results in peripheral positions with the central and external positions a decrease between 5% and 10% was noticed in the accuracies for some values of maximum number of splits between 5% and 10%. This was observed both using single features and their combinations.

The table 4-6 shows the accuracies using the external detector positions. The results are larger compared to the values of the peripheral positions and they are similar to the ones obtained for the central positions. The use of P as single feature, or several combinations of features reached an accuracy of 100%.

Combining more than one position the results are similar compared with each other, with only an increase of the accuracies for the single features TH and RES and their combination, reaching accuracy values around 85-90% as shown in table 4-7. The standard deviation calculated for the accuracies of SINRD is within 7%. In general, it was observed that SINRD reaches values of the accuracies globally slightly lower than PDET.

Table 4-2: Decision tree database A Fork detector diversion.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	61.8%	62.6%	66.4%	64.3%	66.4%	66.4%	66.4%
2	64.5%	64.2%	68.3%	64.7%	67.9%	72.6%	69.6%
3	65.6%	66.4%	67.0%	67.7%	68.5%	72.0%	72.0%
4	66.2%	66.3%	72.2%	70.3%	72.8%	75.0%	73.7%
5	67.0%	69.0%	76.5%	71.8%	79.9%	81.1%	82.8%
6	68.5%	68.9%	77.1%	72.3%	82.8%	81.2%	82.1%
7	66.4%	70.1%	77.2%	72.5%	82.6%	83.5%	83.0%
8	66.8%	69.4%	77.8%	73.6%	86.5%	84.9%	86.0%
9	65.2%	70.0%	81.5%	74.0%	87.9%	84.9%	87.3%
10	68.0%	72.5%	80.5%	75.3%	88.9%	86.8%	87.1%
11	70.4%	70.6%	82.6%	77.2%	89.3%	88.7%	89.8%
12	69.0%	72.9%	82.4%	79.6%	92.0%	90.8%	92.3%
13	69.0%	71.5%	83.8%	80.3%	91.6%	91.9%	91.9%
14	69.7%	71.3%	84.2%	78.9%	91.9%	92.9%	91.8%
15	67.1%	71.1%	83.9%	82.8%	93.2%	92.7%	92.9%
16	68.9%	71.3%	82.4%	82.7%	92.1%	92.6%	92.2%
17	68.4%	72.9%	81.8%	82.6%	92.6%	93.5%	92.5%
18	69.3%	71.8%	82.6%	82.8%	93.1%	93.0%	92.3%
19	69.8%	72.1%	82.8%	84.0%	91.9%	93.4%	92.3%
20	71.2%	74.0%	83.1%	86.6%	92.1%	92.3%	92.1%

Table 4-3: Decision tree database A Fork detector replacement.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	67.5%	63.9%	66.4%	65.2%	66.4%	65.9%	65.1%
2	66.0%	63.5%	65.7%	65.6%	68.1%	68.1%	67.5%
3	66.6%	65.8%	67.9%	66.8%	68.9%	70.3%	70.0%
4	66.3%	66.5%	66.8%	68.5%	71.6%	71.6%	70.9%
5	66.7%	68.7%	67.0%	69.5%	75.9%	74.8%	74.0%
6	67.2%	67.9%	68.5%	70.4%	74.9%	75.7%	76.7%
7	67.3%	69.3%	68.1%	70.0%	78.8%	78.4%	78.2%
8	68.3%	70.0%	70.2%	71.7%	80.5%	81.2%	79.5%
9	67.9%	71.2%	73.0%	71.6%	80.3%	81.1%	79.7%
10	69.1%	71.9%	75.3%	73.3%	81.5%	83.5%	80.0%
11	69.4%	69.2%	77.6%	72.6%	82.6%	82.4%	82.6%
12	68.9%	72.2%	76.9%	71.2%	82.9%	83.1%	81.6%
13	67.9%	70.9%	77.9%	72.4%	82.7%	83.2%	82.6%
14	68.9%	71.5%	78.6%	72.9%	82.3%	84.1%	84.4%
15	68.1%	70.4%	79.0%	71.5%	82.0%	85.0%	83.9%
16	69.6%	73.2%	80.1%	71.0%	84.3%	85.8%	83.4%
17	67.7%	71.7%	78.5%	71.9%	84.8%	86.0%	84.6%
18	67.5%	72.2%	76.9%	73.0%	85.4%	85.8%	86.2%
19	68.9%	71.1%	77.7%	73.1%	85.1%	87.9%	85.4%
20	69.1%	73.7%	77.0%	74.4%	84.9%	86.8%	85.8%

Table 4-4: Decision tree database A PDET external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	84.1%	90.8%	78.2%	84.7%	90.8%	83.6%	82.5%	90.8%	90.8%	84.7%	90.8%	90.8%	82.6%	90.8%	90.8%
2	82.8%	96.6%	96.5%	100.0%	96.3%	93.2%	96.3%	100.0%	100.0%	100.0%	100.0%	100.0%	96.6%	100.0%	100.0%
3	83.1%	96.6%	96.5%	100.0%	96.6%	95.5%	98.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.4%	100.0%	100.0%
4	82.9%	95.8%	96.3%	100.0%	97.3%	96.7%	99.1%	100.0%	100.0%	100.0%	100.0%	100.0%	98.6%	100.0%	99.9%
5	81.8%	96.0%	96.2%	100.0%	96.9%	97.4%	99.4%	100.0%	100.0%	100.0%	100.0%	100.0%	98.3%	100.0%	100.0%
6	82.0%	94.6%	95.1%	100.0%	97.2%	98.0%	98.6%	100.0%	100.0%	100.0%	100.0%	99.9%	98.8%	100.0%	100.0%
7	81.6%	95.4%	95.3%	100.0%	97.2%	97.4%	99.4%	100.0%	100.0%	100.0%	100.0%	100.0%	98.6%	100.0%	100.0%
8	82.4%	95.3%	94.2%	100.0%	97.3%	97.6%	99.4%	100.0%	100.0%	100.0%	100.0%	100.0%	98.4%	100.0%	100.0%
9	82.3%	94.9%	95.1%	100.0%	97.2%	97.4%	98.9%	100.0%	100.0%	100.0%	100.0%	100.0%	99.4%	100.0%	100.0%
10	81.2%	94.9%	94.7%	100.0%	97.2%	97.6%	99.2%	100.0%	100.0%	100.0%	100.0%	100.0%	98.5%	99.9%	100.0%
11	82.2%	94.9%	94.6%	100.0%	97.1%	97.4%	99.1%	100.0%	100.0%	100.0%	100.0%	100.0%	98.8%	100.0%	100.0%
12	82.3%	94.8%	94.8%	100.0%	97.3%	97.4%	98.6%	100.0%	100.0%	100.0%	100.0%	100.0%	98.5%	99.9%	100.0%
13	82.4%	94.8%	95.1%	100.0%	97.0%	97.4%	99.2%	100.0%	100.0%	100.0%	100.0%	100.0%	98.9%	100.0%	99.9%
14	81.8%	95.0%	94.9%	100.0%	97.3%	97.8%	99.3%	100.0%	100.0%	100.0%	100.0%	100.0%	99.3%	100.0%	100.0%
15	83.1%	94.8%	94.5%	100.0%	97.4%	97.2%	99.2%	100.0%	100.0%	100.0%	100.0%	100.0%	99.2%	100.0%	100.0%
16	82.3%	94.2%	94.2%	100.0%	97.6%	97.4%	99.0%	100.0%	100.0%	100.0%	100.0%	100.0%	98.5%	100.0%	100.0%
17	81.2%	94.8%	95.0%	100.0%	96.5%	97.3%	99.2%	100.0%	100.0%	100.0%	99.9%	100.0%	98.8%	100.0%	100.0%
18	82.4%	94.6%	94.8%	100.0%	96.5%	97.6%	99.1%	100.0%	100.0%	100.0%	100.0%	99.9%	98.7%	100.0%	100.0%
19	81.8%	94.5%	95.4%	100.0%	97.3%	97.7%	99.3%	100.0%	100.0%	100.0%	100.0%	100.0%	98.5%	100.0%	100.0%
20	81.6%	94.8%	95.2%	100.0%	97.4%	97.1%	99.2%	100.0%	100.0%	100.0%	99.9%	100.0%	98.4%	100.0%	100.0%

Table 4-5: Decision tree database A PDET all positions.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	83.2%	90.8%	83.4%	82.3%	90.8%	81.6%	81.2%	90.8%	90.8%	82.2%	90.8%	90.8%	80.6%	90.8%	90.8%
2	92.5%	97.6%	99.7%	100.0%	97.6%	94.4%	97.6%	100.0%	100.0%	99.9%	100.0%	99.9%	95.9%	100.0%	100.0%
3	95.0%	97.6%	100.0%	100.0%	98.6%	96.5%	98.7%	100.0%	99.9%	100.0%	100.0%	100.0%	98.0%	100.0%	100.0%
4	96.1%	97.2%	100.0%	100.0%	98.5%	97.6%	98.8%	100.0%	100.0%	100.0%	100.0%	100.0%	99.2%	100.0%	100.0%
5	96.6%	97.6%	100.0%	100.0%	98.3%	98.2%	99.1%	100.0%	99.9%	100.0%	100.0%	100.0%	99.1%	100.0%	100.0%
6	96.7%	97.4%	100.0%	100.0%	98.0%	98.7%	99.1%	100.0%	100.0%	99.9%	100.0%	100.0%	99.3%	100.0%	100.0%
7	95.9%	96.9%	100.0%	100.0%	98.5%	98.0%	99.1%	100.0%	99.9%	99.9%	100.0%	100.0%	98.8%	100.0%	100.0%
8	96.8%	96.8%	100.0%	100.0%	98.0%	98.2%	99.5%	100.0%	100.0%	100.0%	100.0%	100.0%	99.4%	100.0%	100.0%
9	96.5%	96.9%	100.0%	100.0%	97.9%	98.0%	99.0%	100.0%	100.0%	100.0%	100.0%	100.0%	98.8%	100.0%	100.0%
10	95.9%	96.8%	100.0%	100.0%	97.5%	98.4%	99.1%	100.0%	100.0%	99.9%	100.0%	100.0%	99.1%	100.0%	100.0%
11	97.1%	97.1%	99.8%	100.0%	98.2%	98.7%	99.3%	100.0%	100.0%	100.0%	100.0%	100.0%	99.4%	100.0%	100.0%
12	96.2%	97.0%	100.0%	100.0%	98.0%	98.4%	99.6%	100.0%	100.0%	100.0%	100.0%	100.0%	99.2%	100.0%	100.0%
13	96.3%	96.8%	100.0%	100.0%	98.2%	98.4%	99.5%	100.0%	100.0%	99.5%	100.0%	100.0%	99.0%	100.0%	100.0%
14	97.1%	96.8%	100.0%	100.0%	97.9%	98.7%	99.2%	100.0%	100.0%	100.0%	100.0%	100.0%	99.1%	100.0%	100.0%
15	96.9%	96.9%	100.0%	100.0%	97.8%	98.3%	99.0%	100.0%	100.0%	99.9%	100.0%	100.0%	99.2%	100.0%	100.0%
16	95.8%	96.7%	100.0%	100.0%	98.3%	98.5%	99.6%	100.0%	100.0%	100.0%	100.0%	100.0%	98.8%	100.0%	100.0%
17	96.3%	96.7%	100.0%	100.0%	98.4%	98.4%	99.1%	100.0%	100.0%	99.9%	100.0%	100.0%	99.5%	100.0%	99.9%
18	97.0%	97.0%	100.0%	100.0%	98.0%	98.8%	99.3%	100.0%	100.0%	99.9%	100.0%	100.0%	98.9%	100.0%	100.0%
19	96.4%	97.0%	100.0%	100.0%	98.3%	98.6%	98.8%	100.0%	100.0%	99.9%	99.9%	100.0%	99.2%	100.0%	99.7%
20	96.6%	97.1%	100.0%	100.0%	98.1%	98.8%	99.0%	100.0%	100.0%	99.9%	100.0%	100.0%	99.1%	100.0%	100.0%

Table 4-6: Decision tree database A SINRD external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	66.4%	73.2%	81.7%	84.1%	72.8%	82.0%	84.7%	81.8%	84.1%	81.7%	81.8%	84.7%	82.6%	82.0%	82.8%
2	65.9%	73.9%	94.2%	100.0%	75.0%	93.8%	100.0%	94.0%	100.0%	100.0%	94.1%	100.0%	99.9%	99.7%	99.8%
3	66.2%	74.7%	94.0%	100.0%	76.3%	95.1%	100.0%	94.1%	100.0%	99.8%	95.0%	100.0%	99.9%	99.8%	100.0%
4	68.2%	72.6%	94.3%	100.0%	76.4%	95.4%	100.0%	94.4%	100.0%	99.7%	95.5%	100.0%	100.0%	99.9%	99.8%
5	68.2%	71.0%	94.2%	100.0%	77.8%	96.5%	100.0%	95.0%	100.0%	99.9%	95.9%	100.0%	99.9%	99.7%	99.9%
6	69.2%	73.6%	94.4%	100.0%	76.0%	96.9%	100.0%	95.1%	100.0%	99.9%	95.8%	100.0%	100.0%	99.9%	100.0%
7	68.1%	73.1%	93.5%	100.0%	76.2%	97.1%	100.0%	94.6%	100.0%	99.8%	96.1%	100.0%	100.0%	100.0%	99.9%
8	69.3%	72.9%	93.9%	100.0%	76.9%	96.7%	100.0%	94.7%	100.0%	99.9%	96.7%	100.0%	99.9%	99.9%	99.9%
9	68.9%	73.8%	93.6%	100.0%	77.0%	97.3%	100.0%	95.2%	100.0%	99.7%	96.0%	100.0%	100.0%	99.7%	100.0%
10	69.5%	71.7%	93.3%	100.0%	76.8%	96.8%	100.0%	94.2%	100.0%	99.8%	96.1%	100.0%	99.8%	99.8%	99.7%
11	68.1%	71.8%	92.5%	100.0%	76.7%	96.5%	100.0%	93.4%	100.0%	99.8%	96.3%	100.0%	100.0%	99.7%	100.0%
12	67.9%	71.9%	93.7%	100.0%	77.9%	96.5%	100.0%	94.1%	100.0%	99.8%	97.4%	100.0%	99.7%	100.0%	99.9%
13	67.6%	73.2%	93.2%	100.0%	77.2%	97.0%	100.0%	93.7%	100.0%	99.9%	95.9%	100.0%	99.9%	99.7%	100.0%
14	68.4%	70.6%	93.6%	100.0%	78.4%	96.6%	100.0%	94.7%	100.0%	99.5%	97.3%	100.0%	100.0%	99.8%	100.0%
15	67.5%	71.2%	92.9%	100.0%	77.8%	96.7%	100.0%	94.2%	100.0%	99.9%	96.6%	100.0%	100.0%	99.9%	100.0%
16	68.0%	72.9%	93.0%	100.0%	77.4%	96.7%	100.0%	94.5%	100.0%	99.8%	97.1%	100.0%	100.0%	100.0%	100.0%
17	68.6%	71.3%	93.2%	100.0%	78.9%	96.9%	100.0%	94.3%	100.0%	99.9%	96.5%	100.0%	100.0%	99.8%	99.9%
18	67.6%	72.5%	93.4%	100.0%	77.2%	96.4%	100.0%	93.4%	100.0%	100.0%	97.4%	100.0%	99.9%	99.8%	100.0%
19	68.4%	73.2%	93.2%	100.0%	77.7%	95.6%	100.0%	94.1%	100.0%	99.9%	97.4%	100.0%	100.0%	99.9%	99.9%
20	69.1%	71.1%	92.5%	100.0%	79.4%	97.1%	100.0%	94.2%	100.0%	99.6%	97.2%	100.0%	99.9%	99.8%	100.0%

Table 4-7: Decision tree database A SINRD all positions.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	73.2%	73.5%	84.0%	82.6%	73.9%	84.4%	82.4%	83.9%	82.6%	81.9%	84.3%	83.0%	80.7%	83.0%	82.3%
2	72.7%	84.7%	96.1%	100.0%	84.2%	96.7%	100.0%	97.1%	100.0%	99.7%	97.6%	100.0%	99.9%	99.7%	99.8%
3	76.6%	83.9%	99.7%	100.0%	84.8%	99.1%	100.0%	99.6%	100.0%	99.7%	99.1%	100.0%	99.8%	99.3%	99.8%
4	78.4%	84.7%	99.0%	100.0%	84.2%	99.7%	100.0%	99.3%	100.0%	99.7%	99.4%	100.0%	99.7%	99.7%	99.6%
5	78.0%	86.6%	99.4%	100.0%	84.5%	99.7%	100.0%	99.5%	100.0%	99.8%	99.3%	100.0%	99.8%	99.9%	99.8%
6	80.1%	87.3%	99.5%	100.0%	84.2%	99.6%	100.0%	99.3%	100.0%	99.7%	99.6%	100.0%	99.7%	99.9%	99.9%
7	81.3%	88.5%	99.6%	100.0%	86.0%	99.7%	100.0%	99.6%	100.0%	99.9%	99.5%	100.0%	99.8%	99.9%	99.9%
8	82.0%	88.3%	99.6%	100.0%	87.6%	99.7%	100.0%	99.2%	100.0%	99.5%	99.7%	100.0%	99.9%	99.9%	99.8%
9	82.8%	88.8%	99.5%	100.0%	88.1%	99.7%	100.0%	99.5%	100.0%	99.8%	99.6%	100.0%	99.9%	99.8%	99.9%
10	84.0%	89.3%	99.2%	100.0%	88.5%	99.5%	100.0%	99.7%	100.0%	99.5%	99.5%	100.0%	99.9%	99.9%	99.5%
11	84.7%	89.2%	99.3%	100.0%	89.4%	99.5%	100.0%	99.6%	100.0%	99.7%	99.5%	100.0%	99.7%	99.7%	99.9%
12	85.4%	89.1%	99.1%	100.0%	89.2%	99.6%	100.0%	99.5%	100.0%	99.5%	99.7%	100.0%	99.7%	99.9%	99.9%
13	85.4%	89.6%	99.7%	100.0%	89.2%	99.6%	100.0%	99.7%	100.0%	99.9%	99.3%	100.0%	99.8%	99.9%	99.7%
14	87.0%	88.7%	99.6%	100.0%	89.2%	99.5%	100.0%	99.3%	100.0%	99.7%	99.6%	100.0%	99.8%	99.9%	99.8%
15	86.4%	89.6%	99.5%	100.0%	89.4%	99.7%	100.0%	99.4%	100.0%	99.9%	99.7%	100.0%	99.8%	99.9%	99.9%
16	87.3%	88.9%	99.5%	100.0%	90.2%	99.7%	100.0%	99.5%	100.0%	99.9%	99.7%	100.0%	99.9%	99.8%	99.8%
17	85.9%	89.7%	99.4%	100.0%	89.4%	99.6%	100.0%	99.2%	100.0%	99.9%	99.6%	100.0%	99.9%	99.8%	99.9%
18	87.1%	89.5%	99.6%	100.0%	89.4%	99.7%	100.0%	99.7%	100.0%	99.7%	99.7%	100.0%	99.8%	99.8%	99.7%
19	88.1%	89.4%	99.7%	100.0%	90.0%	99.5%	100.0%	99.5%	100.0%	99.6%	99.5%	100.0%	99.7%	99.7%	99.9%
20	87.9%	89.9%	99.5%	100.0%	89.7%	99.7%	100.0%	99.5%	100.0%	99.8%	99.6%	100.0%	99.8%	99.8%	99.8%

4.1.2 Databases B

4.1.2.1 Fork detector

The tables 4-8 and 4-9 show the accuracies calculated using the database B of the Fork detector respectively for the diversion and replacement cases. It is possible to observe an increasing trend of the accuracies with the number of splits, that stabilizes around 10 or 12 splits. As for the databases A the best results as single feature are obtained from the current, but with a relevant decrease of the values compared to the previous class passing from a maximum value of 84% to 61% for the diversion cases and from 80% to 61% for the replacement cases. The best results for both diversion and replacement are obtained again with the combination of the current with another feature or using all features. No significant differences in the accuracies were observed between the results for diversion and replacement.

The standard deviation calculated for the accuracies of the diversion case is included between 4% and 7%, whereas for the replacement case is included between 4% and 8%.

4.1.2.2 PDET

In this chapter the results for PDET database B are described, focusing on the detectors in external positions and taking all the position of the detectors.

From the results it was observed that there are no relevant differences in the accuracies using one detector position, as the values tend to assume the same trend in particular after 10 splits. An example is showed in table 4-10 for the external positions. Compared to database A, using the database B only the single feature P is able to reach accuracies of 100% for central and external positions.

The results from the combinations of two and three positions (Table 4-11) are similar compared with each other and show an increase between 5% and 10% in the accuracy for the single features TH and RES and their combination compared to the values obtained with a single position (Table 4-10).

The standard deviation calculated for the accuracies of PDET is within 8%.

4.1.2.3 SINRD

This chapter describes the results for SINRD database B, focusing on the detectors in external positions and taking all the position of the detectors.

Considering only one detector position it was observed that there are small differences between the accuracies of the three positions, with the results for the central positions that are lower than for the other positions. In this case only with the external positions it is still possible to reach accuracies of 100% for the single feature P and the combination of TH with P as shown in the table 4-12.

The results from the combinations of two and three positions (Table 4-13) are similar compared with each other and show an increase in the accuracy for the first two single features TH and RES and its combination compared to those of a single position (Table 4-12). As shown in the table 4-13 only the single feature P reaches accuracies of 100%.

The standard deviation calculated for the accuracies of SINRD is within 7%.

Also for the database B the SINRD technique reaches accuracies slightly smaller than PDET.

Table 4-8: Decision tree database B Fork detector diversion.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	44.5%	42.4%	42.5%	43.6%	42.9%	44.1%	43.1%
2	45.8%	46.0%	49.8%	46.9%	49.8%	49.7%	49.5%
3	49.0%	47.9%	47.9%	46.8%	47.6%	47.0%	47.5%
4	50.5%	48.2%	57.5%	49.6%	58.4%	58.3%	58.7%
5	50.8%	48.7%	58.0%	50.7%	63.4%	60.6%	61.1%
6	51.2%	48.7%	61.4%	51.2%	65.4%	64.7%	63.4%
7	53.2%	50.0%	60.9%	53.4%	66.4%	66.3%	66.2%
8	52.5%	52.8%	61.1%	53.8%	65.2%	68.8%	67.2%
9	53.9%	52.5%	59.9%	55.0%	67.2%	68.7%	69.5%
10	54.8%	51.6%	62.3%	54.6%	68.0%	68.2%	68.9%
11	54.6%	52.5%	61.3%	55.6%	69.2%	68.2%	70.0%
12	53.9%	53.0%	61.5%	55.2%	68.4%	69.2%	69.2%
13	55.0%	52.9%	60.5%	55.4%	68.7%	70.3%	69.5%
14	53.3%	52.6%	61.0%	54.9%	68.9%	70.1%	69.9%
15	55.5%	52.2%	60.7%	56.0%	69.8%	70.3%	70.3%
16	55.4%	52.9%	61.0%	57.8%	69.5%	72.3%	71.1%
17	55.4%	54.0%	61.1%	58.5%	69.4%	72.2%	71.4%
18	55.9%	53.8%	60.9%	59.6%	71.0%	71.4%	71.2%
19	55.6%	54.7%	60.4%	58.8%	70.3%	72.2%	73.3%
20	56.4%	54.4%	60.7%	58.3%	70.9%	73.7%	73.4%

Table 4-9: Decision tree database B Fork detector replacement.

#splits	N with Cd accuracy	N without Cd accuracy	Current accuracy	N with Cd N without Cd accuracy	N with Cd Current accuracy	N without Cd Current accuracy	N with Cd N without Cd Current accuracy
1	43.0%	42.4%	41.9%	43.0%	42.7%	43.6%	42.0%
2	44.9%	45.4%	48.8%	44.5%	50.3%	50.2%	50.3%
3	47.8%	48.8%	48.1%	45.6%	49.4%	49.9%	49.7%
4	47.3%	47.6%	47.8%	48.1%	47.1%	47.3%	45.7%
5	49.3%	48.2%	55.5%	48.4%	50.5%	52.0%	49.8%
6	47.7%	50.1%	56.1%	48.7%	55.8%	56.4%	55.6%
7	48.4%	52.3%	58.5%	50.7%	58.6%	57.9%	59.4%
8	52.1%	52.9%	59.8%	52.1%	63.8%	61.8%	61.5%
9	49.5%	54.0%	58.4%	52.7%	64.8%	65.4%	65.8%
10	52.3%	52.8%	57.8%	51.0%	66.2%	66.7%	65.5%
11	51.8%	53.4%	58.4%	51.7%	65.8%	66.0%	67.7%
12	50.1%	53.1%	58.6%	54.3%	66.2%	67.7%	65.9%
13	51.9%	53.7%	60.0%	53.2%	66.4%	67.0%	67.4%
14	51.4%	53.5%	59.6%	52.7%	66.6%	67.6%	67.4%
15	51.2%	53.4%	61.0%	53.4%	66.0%	69.1%	67.0%
16	51.2%	54.6%	61.4%	52.3%	65.4%	67.2%	67.5%
17	51.1%	54.2%	60.8%	53.5%	67.5%	67.7%	67.3%
18	51.8%	53.1%	60.3%	53.2%	66.1%	69.7%	68.9%
19	50.3%	54.4%	59.2%	52.8%	67.2%	70.9%	67.2%
20	50.3%	54.3%	61.0%	54.3%	65.8%	68.5%	67.5%

Table 4-10: Decision tree database B PDET external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	65.5%	70.3%	69.3%	69.2%	70.5%	68.8%	67.7%	70.1%	70.2%	69.2%	70.2%	69.9%	68.5%	70.2%	70.1%
2	66.1%	73.9%	79.2%	81.5%	74.0%	77.2%	79.4%	76.4%	76.5%	81.6%	75.9%	75.3%	80.9%	75.7%	76.2%
3	65.9%	74.0%	83.7%	83.7%	73.2%	83.1%	82.4%	81.3%	80.3%	85.5%	80.4%	79.8%	85.8%	81.0%	80.6%
4	67.1%	72.6%	85.2%	84.4%	73.6%	82.6%	83.8%	83.5%	83.2%	84.3%	83.0%	83.4%	85.1%	83.9%	83.8%
5	65.5%	72.7%	85.6%	83.2%	72.3%	85.1%	83.7%	87.3%	86.1%	84.2%	87.0%	85.9%	84.9%	87.4%	87.0%
6	66.7%	71.7%	85.5%	86.6%	72.5%	86.0%	87.6%	87.3%	87.3%	85.5%	87.5%	87.0%	85.8%	87.5%	86.7%
7	66.6%	72.1%	86.1%	90.0%	72.0%	87.5%	91.2%	88.3%	90.0%	88.5%	88.9%	90.1%	89.3%	88.6%	88.2%
8	65.3%	73.0%	87.8%	92.5%	72.9%	89.8%	93.0%	91.0%	90.3%	90.1%	91.0%	90.5%	91.0%	91.2%	90.7%
9	65.1%	73.3%	86.9%	91.8%	73.8%	90.3%	93.9%	91.3%	91.6%	89.6%	91.9%	91.0%	92.5%	91.4%	91.3%
10	65.6%	72.9%	87.3%	97.9%	74.0%	89.5%	97.4%	92.0%	93.1%	91.3%	93.2%	93.5%	93.9%	93.0%	92.5%
11	65.2%	73.3%	88.7%	100.0%	74.5%	91.6%	97.2%	93.6%	96.4%	96.6%	94.2%	96.3%	96.5%	93.8%	94.3%
12	65.2%	73.0%	89.9%	100.0%	75.6%	91.8%	99.2%	93.4%	98.0%	98.9%	94.6%	98.3%	97.3%	95.6%	95.0%
13	65.1%	72.1%	89.7%	100.0%	75.4%	92.5%	99.3%	94.5%	99.5%	99.2%	94.2%	99.6%	98.1%	97.7%	96.7%
14	64.7%	73.3%	90.7%	100.0%	73.9%	92.5%	99.5%	94.8%	99.7%	99.1%	94.6%	99.6%	98.5%	98.6%	98.7%
15	64.0%	73.9%	91.5%	100.0%	76.3%	93.0%	99.3%	94.9%	99.5%	99.0%	93.8%	99.6%	98.7%	98.7%	98.5%
16	64.6%	73.4%	92.4%	100.0%	75.6%	92.7%	99.7%	95.1%	99.5%	99.2%	94.4%	99.1%	98.8%	98.7%	98.4%
17	63.9%	73.8%	92.4%	100.0%	75.5%	93.5%	99.3%	95.6%	99.4%	99.1%	94.4%	99.4%	98.5%	98.6%	98.5%
18	65.3%	73.7%	92.4%	100.0%	74.0%	93.3%	99.5%	95.1%	99.7%	98.9%	94.7%	99.5%	98.8%	98.6%	98.8%
19	64.9%	73.9%	91.7%	100.0%	74.6%	93.9%	99.4%	95.0%	99.6%	99.0%	94.0%	99.5%	98.7%	98.8%	98.7%
20	64.5%	72.9%	92.3%	100.0%	73.2%	93.1%	99.5%	95.5%	99.7%	99.0%	93.7%	99.6%	98.1%	98.3%	98.4%

Table 4-11: Decision tree database B PDET all position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	66.2%	70.4%	69.3%	69.2%	70.0%	67.9%	69.2%	70.3%	70.2%	69.2%	70.2%	70.0%	68.5%	70.4%	70.4%
2	71.2%	74.8%	78.7%	81.5%	74.3%	78.2%	80.2%	76.3%	76.2%	81.5%	76.4%	76.5%	80.5%	76.7%	76.4%
3	70.2%	73.8%	83.4%	85.1%	73.6%	81.4%	83.0%	80.5%	79.7%	85.6%	80.6%	79.2%	85.7%	81.1%	81.6%
4	70.4%	73.4%	84.5%	88.1%	73.4%	83.9%	86.7%	83.6%	82.8%	85.5%	84.0%	82.7%	86.6%	84.0%	83.8%
5	70.8%	73.6%	87.7%	87.3%	74.3%	85.9%	89.3%	86.6%	86.1%	84.7%	87.3%	84.7%	85.0%	86.6%	86.9%
6	73.2%	73.6%	87.3%	88.2%	75.6%	86.4%	89.0%	87.7%	87.8%	85.7%	87.2%	86.7%	86.6%	87.3%	86.8%
7	73.6%	74.6%	88.6%	89.9%	76.4%	87.3%	91.3%	88.7%	90.4%	88.9%	89.0%	89.3%	89.7%	88.8%	89.2%
8	73.8%	75.3%	90.3%	93.5%	76.1%	89.9%	94.4%	91.2%	90.5%	90.9%	91.3%	90.8%	91.7%	91.1%	91.0%
9	73.9%	78.1%	92.0%	95.7%	77.9%	91.8%	95.7%	91.7%	91.7%	93.1%	91.4%	91.9%	93.1%	91.6%	91.3%
10	74.4%	76.4%	92.8%	98.0%	77.0%	93.3%	96.4%	92.7%	94.0%	94.8%	92.5%	93.4%	93.4%	92.4%	92.0%
11	74.9%	77.3%	93.7%	99.6%	77.8%	93.5%	98.1%	94.5%	96.6%	96.6%	93.8%	95.6%	95.2%	93.9%	94.0%
12	74.9%	78.6%	95.0%	100.0%	79.0%	95.4%	98.1%	95.2%	98.2%	98.3%	95.0%	97.6%	97.7%	94.9%	95.3%
13	75.2%	78.4%	97.5%	100.0%	80.2%	96.2%	98.9%	95.6%	99.3%	99.2%	95.4%	99.0%	98.1%	96.4%	96.1%
14	77.1%	79.9%	98.1%	100.0%	80.1%	96.5%	98.3%	97.7%	99.3%	99.6%	96.8%	99.3%	98.0%	97.9%	98.2%
15	77.8%	80.0%	98.2%	100.0%	80.7%	97.6%	99.3%	97.8%	99.3%	99.6%	97.1%	99.3%	98.2%	98.0%	97.6%
16	78.3%	80.3%	98.3%	100.0%	80.2%	97.0%	98.7%	97.7%	99.2%	99.3%	96.9%	99.3%	97.8%	98.3%	98.5%
17	78.4%	81.0%	98.1%	100.0%	80.9%	96.5%	98.3%	97.3%	99.4%	99.5%	97.4%	99.1%	98.1%	98.7%	97.7%
18	76.5%	81.5%	98.4%	100.0%	81.8%	97.9%	98.6%	97.4%	99.2%	99.5%	97.2%	99.0%	98.5%	98.2%	97.9%
19	78.8%	81.7%	98.4%	100.0%	80.1%	97.5%	99.3%	97.2%	99.2%	99.3%	97.6%	99.2%	98.8%	98.0%	98.5%
20	78.7%	83.6%	97.9%	100.0%	81.0%	97.5%	98.7%	98.0%	98.6%	99.5%	97.0%	99.2%	98.1%	97.9%	98.0%

Table 4-12: Decision tree database B SINRD external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	43.0%	47.1%	68.8%	69.2%	42.1%	68.8%	69.2%	68.6%	69.3%	68.9%	68.7%	69.2%	68.8%	68.9%	69.0%
2	44.5%	50.2%	75.4%	81.5%	55.3%	75.9%	81.6%	75.1%	81.5%	81.3%	75.4%	81.5%	81.3%	81.1%	81.1%
3	43.7%	49.9%	79.9%	83.7%	54.1%	79.5%	82.6%	80.1%	82.0%	84.6%	79.0%	83.3%	85.2%	84.8%	84.6%
4	46.2%	49.2%	82.9%	84.4%	58.9%	82.4%	84.7%	82.3%	85.1%	83.9%	82.6%	85.1%	84.0%	84.6%	84.5%
5	44.6%	49.8%	82.4%	83.2%	59.3%	82.0%	83.3%	82.6%	83.1%	83.0%	82.0%	83.4%	83.9%	82.9%	83.5%
6	45.9%	49.9%	82.4%	86.6%	58.7%	82.5%	86.0%	81.8%	86.4%	86.3%	81.6%	86.1%	85.6%	85.8%	86.5%
7	45.4%	48.5%	82.6%	90.0%	58.7%	83.3%	90.5%	82.1%	89.7%	88.6%	83.1%	90.2%	90.0%	89.0%	88.6%
8	44.7%	49.0%	82.4%	92.5%	59.2%	84.0%	92.3%	82.8%	92.5%	91.0%	83.4%	92.2%	91.0%	90.6%	90.3%
9	44.4%	48.5%	82.5%	91.8%	59.0%	83.6%	91.8%	83.5%	91.6%	90.7%	83.5%	92.0%	91.2%	90.4%	90.9%
10	44.4%	48.9%	82.5%	97.9%	57.8%	83.4%	97.5%	83.5%	96.7%	94.5%	83.6%	96.2%	95.4%	94.3%	94.7%
11	44.8%	49.2%	84.3%	100.0%	58.6%	85.9%	100.0%	84.6%	99.0%	98.4%	84.8%	98.6%	98.4%	98.1%	97.8%
12	43.7%	48.2%	86.5%	100.0%	58.6%	88.7%	100.0%	86.5%	99.6%	99.0%	87.7%	99.9%	99.0%	98.1%	99.0%
13	43.3%	48.6%	87.5%	100.0%	57.6%	89.3%	100.0%	87.2%	99.5%	98.8%	87.9%	99.1%	98.9%	98.2%	98.6%
14	45.1%	49.1%	86.2%	100.0%	58.1%	88.6%	100.0%	87.6%	99.6%	99.0%	87.8%	99.8%	99.1%	98.9%	98.7%
15	45.0%	49.6%	86.6%	100.0%	58.6%	89.2%	100.0%	87.6%	99.7%	99.0%	89.2%	99.8%	98.9%	98.9%	98.4%
16	44.2%	48.2%	87.7%	100.0%	57.8%	89.2%	100.0%	87.4%	99.5%	99.2%	89.1%	99.5%	99.0%	98.8%	98.5%
17	43.9%	48.4%	87.9%	100.0%	58.6%	90.0%	100.0%	89.8%	99.7%	99.0%	89.7%	99.9%	99.0%	98.5%	98.6%
18	44.6%	49.0%	87.7%	100.0%	58.3%	90.9%	100.0%	88.7%	99.9%	98.7%	89.5%	99.6%	99.2%	98.2%	98.3%
19	44.4%	47.6%	88.8%	100.0%	57.1%	91.4%	100.0%	89.8%	99.6%	99.1%	89.4%	99.5%	98.8%	98.6%	98.8%
20	44.0%	48.6%	88.0%	100.0%	58.2%	90.6%	100.0%	89.2%	99.7%	98.9%	90.5%	99.8%	99.0%	98.5%	98.5%

Table 4-13: Decision tree database B SINRD all positions

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	42.4%	51.6%	68.7%	69.3%	44.2%	68.7%	69.2%	68.6%	69.2%	69.0%	68.8%	69.2%	69.0%	69.0%	69.0%
2	48.3%	58.9%	74.9%	81.5%	55.4%	75.7%	81.6%	74.6%	81.5%	81.2%	74.6%	81.5%	81.1%	81.3%	81.1%
3	49.0%	58.5%	77.7%	85.1%	55.5%	77.9%	84.6%	78.1%	84.9%	84.3%	78.0%	84.4%	83.7%	83.8%	84.3%
4	53.7%	60.3%	79.2%	87.3%	59.2%	79.9%	87.1%	79.5%	88.9%	86.7%	79.7%	88.0%	85.0%	87.3%	87.9%
5	54.1%	61.4%	82.5%	86.9%	63.1%	82.9%	87.3%	82.3%	90.4%	85.5%	82.1%	90.2%	84.9%	88.2%	88.8%
6	55.3%	63.0%	83.9%	88.3%	64.4%	84.0%	88.0%	83.0%	90.4%	87.3%	83.9%	91.4%	86.9%	89.3%	89.1%
7	55.0%	64.3%	85.9%	90.1%	64.0%	85.3%	90.9%	85.3%	93.3%	89.1%	84.5%	92.8%	88.7%	91.4%	90.5%
8	53.8%	67.1%	86.9%	93.9%	64.7%	85.7%	94.0%	86.8%	96.1%	91.3%	86.9%	94.4%	91.6%	91.7%	92.9%
9	55.8%	66.2%	88.6%	96.4%	64.8%	88.7%	96.0%	88.7%	96.3%	93.9%	88.4%	95.8%	93.7%	93.9%	93.7%
10	55.9%	67.2%	89.2%	97.9%	64.7%	88.5%	97.4%	87.6%	97.0%	95.9%	89.0%	96.5%	95.6%	93.7%	93.8%
11	57.6%	68.1%	90.5%	99.2%	65.6%	90.2%	99.0%	89.8%	98.1%	96.0%	89.5%	98.5%	96.3%	96.3%	95.8%
12	57.0%	68.5%	91.0%	100.0%	65.7%	91.2%	99.9%	90.5%	98.4%	98.1%	90.8%	98.0%	97.4%	96.9%	96.0%
13	57.3%	68.7%	93.6%	100.0%	67.2%	92.3%	99.2%	91.1%	98.7%	99.0%	91.8%	98.6%	98.1%	97.1%	98.0%
14	57.0%	68.2%	94.3%	100.0%	67.7%	92.9%	99.3%	92.0%	98.7%	99.3%	92.9%	98.5%	98.4%	97.8%	97.2%
15	58.6%	70.2%	95.0%	100.0%	67.6%	94.9%	99.5%	92.8%	98.5%	98.9%	93.7%	98.3%	98.6%	97.4%	97.6%
16	60.0%	69.4%	94.3%	100.0%	68.7%	94.4%	99.4%	94.0%	98.6%	99.0%	93.8%	98.3%	98.2%	97.8%	97.0%
17	58.0%	70.2%	95.3%	100.0%	66.6%	94.7%	99.0%	93.7%	98.6%	99.0%	92.8%	98.4%	98.3%	97.6%	97.4%
18	59.1%	71.3%	95.4%	100.0%	69.7%	94.8%	99.5%	95.0%	98.7%	99.4%	93.7%	98.5%	98.1%	97.5%	97.4%
19	62.7%	71.9%	94.2%	100.0%	68.5%	94.5%	99.5%	94.1%	98.6%	99.2%	93.9%	98.8%	97.9%	98.0%	97.6%
20	61.9%	72.2%	94.9%	100.0%	69.2%	95.2%	99.9%	93.9%	98.8%	99.5%	93.1%	98.6%	98.0%	98.1%	97.4%

4.1.3 Databases C

4.1.3.1 Fork detector

The tables 4-14 and 4-15 show the accuracies calculated using the database C of the Fork detector respectively for the diversion and replacement cases. As for the previous databases the best results using a single feature are obtained from the current but with a further decrease of the accuracies up to 52% for the diversion and 51% for replacement due to the increasing complexity of the database. The best results for both diversion and replacement are obtained again with the combination of the current with another feature or taking all features. There is no relevant difference in the accuracies between the diversion and replacement, with the maximum difference around 5% in favor of the diversion using as features NwithoutCd and the current or using all features.

The standard deviation calculated for the accuracies of the diversion case is between 3% and 6%, whereas for the replacement case is between 3% and 7%.

4.1.3.2 PDET

The tables 4-16 and 4-17 show the results for PDET database C, using respectively the detectors in external positions and taking all the detectors positions.

The accuracies calculated considering only one position show no relevant differences with each other and they tend to assume similar trends that fall within the calculated standard deviation. An example is shown in the table 4-16 for the detectors in the external positions. Compared to the previous databases it is no longer possible to reach accuracies of 100%; the maximum values are around 92% using as features FA and P in the peripheral positions, or P either alone or in combination with FA in external position.

The results using the combinations of positions do not show relevant differences with each other and present a slight increase, reaching values of accuracy up to 99% for the feature P using peripheral and external positions, and maximum value of 98% reached using all positions.

The standard deviation calculated for the accuracies of PDET with this database is included between 2% and 7%.

4.1.3.3 SINRD

In this chapter the results for SINRD database C are described, focusing on the detectors in external positions (Table 4-18) or considering all detectors positions (Table 4-19).

No relevant differences were observed between the results taking a single position, and as for the previous cases they tend to assume similar trends considering the calculated standard deviation. The values obtained for the external positions show slightly lower results with respect to central and peripheral positions. Compared to the previous classes it is no longer possible to reach accuracies of 100%, with the maximum values around 88% using as feature P either alone or in combinations with some other features.

The results obtained with the combination of more than one position are similar compared with each other and the best results are obtained from the combination of peripheral and external positions or taking all positions, reaching values between 96% and 99% using more than 18 splits.

The standard deviation calculated for the accuracies of SINRD is included between 1% and 6%.

Table 4-14: Decision tree database C Fork detector diversion.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	32.2%	31.0%	32.4%	32.1%	30.8%	32.0%	31.3%
2	32.2%	32.7%	35.9%	32.5%	34.1%	34.9%	35.0%
3	35.0%	34.2%	38.4%	33.6%	37.6%	38.9%	38.5%
4	36.2%	35.6%	40.4%	35.5%	39.0%	39.0%	38.5%
5	36.4%	36.0%	39.4%	37.8%	37.9%	38.6%	38.2%
6	37.6%	35.9%	45.6%	37.0%	43.0%	41.6%	41.8%
7	35.2%	36.3%	46.5%	39.3%	42.3%	42.4%	42.8%
8	40.3%	38.5%	47.3%	38.7%	44.5%	45.4%	44.7%
9	39.1%	38.1%	46.4%	38.1%	48.9%	49.2%	47.5%
10	39.8%	40.4%	46.5%	39.0%	49.3%	50.0%	50.3%
11	40.1%	40.5%	45.1%	41.0%	52.5%	51.6%	51.7%
12	41.4%	41.4%	45.8%	39.6%	53.1%	51.9%	51.5%
13	42.0%	40.4%	47.1%	40.1%	54.0%	54.5%	53.2%
14	42.9%	41.7%	47.6%	44.0%	54.4%	53.3%	53.0%
15	41.6%	42.1%	50.5%	43.3%	54.6%	54.3%	53.8%
16	41.9%	41.3%	50.2%	44.3%	55.2%	55.5%	54.2%
17	43.0%	42.7%	50.7%	44.6%	54.6%	56.3%	55.5%
18	43.1%	42.8%	51.6%	44.7%	55.9%	55.6%	58.0%
19	43.7%	44.1%	52.2%	47.1%	56.8%	57.0%	57.2%
20	45.5%	44.9%	51.7%	47.7%	57.3%	58.3%	58.1%

Table 4-15: Decision tree database C Fork detector replacement.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	32.7%	32.6%	32.5%	32.5%	31.7%	31.8%	32.1%
2	31.8%	31.1%	35.9%	31.7%	36.1%	35.2%	35.4%
3	32.5%	33.8%	36.6%	33.4%	35.1%	36.2%	35.8%
4	34.2%	35.7%	39.3%	34.1%	38.3%	38.1%	39.0%
5	34.4%	34.9%	39.4%	36.1%	37.6%	38.5%	38.8%
6	37.1%	36.7%	39.7%	37.5%	38.0%	38.6%	39.9%
7	37.8%	37.4%	43.7%	36.8%	41.6%	39.6%	39.4%
8	38.1%	37.0%	46.5%	37.3%	41.4%	42.8%	42.5%
9	37.4%	38.6%	46.3%	38.3%	45.6%	42.9%	41.9%
10	37.9%	37.4%	48.3%	37.6%	45.6%	43.7%	43.4%
11	38.3%	39.1%	48.7%	39.0%	49.4%	46.2%	47.7%
12	39.6%	38.9%	47.0%	39.1%	49.3%	50.3%	46.7%
13	39.1%	39.5%	47.4%	39.3%	50.9%	49.5%	49.9%
14	40.0%	41.0%	48.3%	40.0%	52.4%	50.9%	50.5%
15	42.0%	43.3%	48.9%	40.9%	52.9%	50.9%	51.1%
16	41.3%	41.8%	49.8%	40.7%	52.4%	53.0%	50.7%
17	40.9%	42.8%	51.1%	42.6%	52.2%	53.3%	52.4%
18	42.2%	43.5%	50.1%	42.7%	52.0%	53.4%	51.5%
19	42.1%	43.8%	50.7%	44.8%	54.0%	53.0%	52.4%
20	44.1%	45.3%	51.3%	43.5%	56.2%	54.7%	52.9%

Table 4-16: Decision tree database C PDET external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	47.9%	52.1%	52.0%	52.2%	52.1%	49.7%	49.7%	51.5%	52.2%	52.0%	52.3%	51.8%	48.8%	52.3%	52.4%
2	49.8%	54.9%	62.9%	66.0%	55.1%	56.7%	56.7%	56.1%	58.5%	65.5%	56.7%	58.4%	57.2%	58.2%	59.0%
3	50.1%	57.3%	66.6%	69.1%	56.0%	60.4%	60.6%	60.1%	61.7%	69.3%	60.7%	61.2%	60.0%	62.4%	61.9%
4	49.5%	57.0%	69.3%	73.2%	56.2%	61.2%	62.6%	64.7%	64.6%	73.3%	64.7%	64.8%	64.9%	66.0%	66.4%
5	49.5%	57.1%	69.6%	73.4%	56.2%	65.4%	67.2%	67.6%	66.2%	73.8%	66.9%	65.5%	67.7%	66.7%	66.8%
6	49.2%	55.3%	69.1%	76.0%	55.6%	68.2%	69.8%	67.4%	66.5%	73.5%	68.5%	65.9%	69.9%	67.7%	67.1%
7	49.0%	55.2%	70.2%	75.8%	56.1%	69.8%	72.6%	68.1%	67.6%	74.9%	69.6%	67.5%	72.5%	67.0%	67.1%
8	50.7%	55.0%	72.4%	75.0%	55.2%	72.1%	74.2%	70.3%	69.0%	75.0%	72.0%	70.9%	74.1%	69.1%	69.6%
9	49.2%	55.8%	73.0%	80.1%	56.8%	73.3%	72.0%	70.8%	70.2%	75.6%	71.6%	68.3%	75.4%	69.1%	69.5%
10	49.6%	55.2%	73.3%	79.8%	55.7%	73.6%	76.2%	72.3%	73.6%	78.9%	72.0%	73.6%	75.1%	71.6%	70.5%
11	49.7%	55.8%	72.7%	81.4%	55.7%	73.1%	76.2%	71.4%	75.6%	81.1%	72.4%	75.6%	76.8%	73.0%	73.4%
12	50.3%	56.2%	73.6%	83.6%	56.5%	74.7%	77.2%	72.8%	74.8%	81.3%	74.5%	75.4%	77.6%	75.1%	75.9%
13	51.1%	55.7%	75.6%	86.5%	57.1%	75.6%	80.8%	77.0%	78.6%	83.8%	75.1%	77.7%	79.8%	77.3%	77.2%
14	50.2%	56.8%	76.5%	88.4%	56.9%	76.0%	80.2%	78.6%	79.3%	86.5%	78.1%	78.4%	81.5%	78.8%	79.5%
15	50.1%	56.1%	75.4%	88.1%	57.0%	75.1%	81.9%	79.3%	78.9%	88.3%	79.5%	78.9%	81.3%	79.6%	80.1%
16	49.3%	57.0%	75.8%	89.0%	56.4%	77.9%	82.1%	80.7%	80.0%	88.1%	79.7%	79.7%	82.2%	80.8%	80.2%
17	49.0%	56.1%	73.7%	89.4%	56.9%	78.1%	83.1%	80.6%	82.2%	88.9%	81.2%	83.2%	82.9%	81.9%	82.0%
18	48.5%	57.1%	75.1%	90.8%	55.8%	78.0%	84.0%	83.2%	83.7%	90.0%	82.8%	84.5%	84.8%	84.5%	84.5%
19	49.5%	56.0%	76.6%	91.2%	55.9%	80.6%	82.8%	82.3%	86.1%	91.4%	84.2%	85.7%	85.9%	85.8%	85.9%
20	50.0%	55.3%	79.4%	92.9%	56.5%	81.7%	86.1%	82.7%	87.6%	92.7%	84.8%	86.2%	86.0%	88.4%	87.8%

Table 4-17: Decision tree database C PDET all positions.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	49.3%	51.9%	50.4%	51.1%	52.4%	47.8%	50.4%	51.8%	52.4%	51.2%	52.3%	52.3%	49.8%	52.3%	52.4%
2	52.3%	55.7%	62.2%	63.0%	55.3%	57.8%	61.0%	57.2%	57.6%	62.8%	57.2%	58.4%	60.8%	58.5%	57.9%
3	51.8%	57.2%	64.2%	65.9%	57.0%	60.0%	61.9%	59.0%	58.9%	65.8%	58.4%	59.8%	63.0%	61.0%	59.1%
4	52.8%	58.1%	67.1%	70.1%	58.6%	63.2%	68.2%	62.7%	63.0%	68.7%	63.5%	62.8%	66.4%	64.2%	64.1%
5	54.5%	56.7%	67.9%	73.3%	58.0%	66.6%	69.3%	67.6%	67.1%	71.8%	66.9%	67.7%	68.5%	69.2%	68.7%
6	56.0%	57.7%	71.3%	74.0%	57.4%	69.3%	70.5%	69.7%	71.4%	77.0%	69.2%	71.1%	73.5%	69.8%	70.5%
7	58.0%	58.4%	73.5%	76.0%	58.7%	71.2%	73.2%	70.2%	72.3%	78.8%	70.4%	71.6%	76.5%	70.5%	70.3%
8	59.4%	59.7%	78.2%	77.5%	60.4%	73.4%	77.5%	71.4%	72.6%	80.0%	70.4%	72.2%	76.8%	70.9%	71.4%
9	59.1%	60.2%	79.5%	78.3%	61.4%	75.1%	76.9%	71.9%	73.9%	80.0%	71.6%	72.7%	78.4%	72.7%	71.4%
10	59.1%	61.8%	79.8%	82.6%	61.7%	75.2%	80.7%	72.8%	74.7%	81.5%	72.2%	74.6%	77.8%	72.2%	72.1%
11	59.9%	61.3%	79.0%	85.5%	62.1%	76.4%	81.9%	72.5%	75.3%	83.1%	72.1%	74.8%	82.5%	73.8%	73.6%
12	59.1%	63.7%	80.5%	86.1%	62.0%	76.6%	84.3%	73.9%	76.3%	84.4%	73.4%	76.6%	82.2%	75.7%	75.6%
13	59.6%	62.4%	82.3%	87.8%	63.2%	79.3%	85.7%	74.9%	80.1%	86.6%	73.6%	80.7%	84.0%	77.1%	77.4%
14	60.3%	64.1%	83.7%	89.5%	63.7%	78.3%	87.2%	77.2%	81.7%	87.9%	76.8%	80.4%	85.6%	80.0%	78.0%
15	60.3%	64.1%	83.8%	91.8%	62.8%	79.5%	87.5%	77.8%	82.8%	90.8%	78.2%	84.1%	86.6%	80.0%	80.8%
16	59.9%	65.0%	85.1%	92.7%	64.3%	80.3%	87.9%	78.2%	84.3%	92.8%	80.0%	86.1%	90.3%	82.9%	81.3%
17	61.1%	64.7%	86.8%	94.8%	65.0%	82.2%	89.8%	81.9%	86.2%	94.5%	81.7%	83.7%	90.8%	83.6%	80.8%
18	63.2%	64.5%	87.4%	96.3%	65.7%	82.2%	92.7%	82.5%	88.0%	94.9%	82.0%	87.8%	90.4%	85.1%	84.8%
19	61.4%	65.9%	89.9%	97.7%	65.6%	84.3%	92.8%	84.2%	89.5%	96.1%	83.8%	88.1%	91.4%	85.8%	84.0%
20	63.2%	66.6%	90.3%	98.0%	65.7%	84.9%	93.0%	85.7%	89.3%	97.1%	84.8%	90.4%	92.4%	86.3%	86.4%

Table 4-18: Decision tree database C SINRD external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	32.0%	36.5%	51.7%	52.1%	30.8%	51.7%	52.1%	51.6%	52.1%	51.7%	51.7%	52.1%	51.8%	51.7%	51.8%
2	30.9%	36.4%	59.3%	64.5%	38.1%	60.0%	64.5%	59.8%	64.5%	64.1%	59.9%	64.5%	64.1%	64.1%	64.0%
3	31.5%	36.5%	62.8%	67.1%	38.3%	63.2%	67.6%	63.0%	67.6%	67.1%	62.9%	67.6%	67.3%	67.2%	67.2%
4	33.9%	37.7%	66.6%	71.3%	41.4%	66.6%	71.0%	66.4%	71.2%	71.3%	66.5%	71.4%	71.1%	70.9%	70.8%
5	33.5%	36.8%	66.2%	72.0%	41.4%	65.8%	71.3%	66.6%	71.5%	71.5%	66.3%	71.9%	71.1%	71.6%	70.5%
6	33.4%	36.7%	65.9%	71.0%	42.1%	66.1%	71.6%	66.1%	71.1%	70.9%	65.9%	71.4%	71.2%	71.1%	71.3%
7	32.9%	37.5%	67.4%	73.9%	42.9%	68.0%	73.7%	67.9%	74.5%	72.5%	66.8%	73.2%	73.1%	72.7%	72.6%
8	32.3%	36.5%	67.5%	75.8%	43.5%	68.0%	75.3%	68.6%	75.7%	75.1%	66.5%	75.1%	75.4%	75.4%	75.4%
9	34.7%	37.8%	67.9%	74.1%	43.6%	67.6%	75.5%	67.7%	74.8%	74.3%	66.8%	74.2%	74.1%	74.0%	73.7%
10	34.6%	37.0%	67.2%	74.4%	43.3%	67.9%	74.8%	68.0%	76.4%	74.1%	67.7%	75.1%	74.6%	74.6%	73.8%
11	32.8%	37.4%	67.4%	75.8%	44.9%	68.6%	75.6%	67.8%	75.6%	77.6%	66.4%	75.4%	78.2%	76.4%	76.9%
12	33.0%	38.1%	70.1%	79.1%	44.4%	70.1%	78.3%	69.4%	78.1%	79.0%	67.7%	79.6%	77.8%	78.3%	78.5%
13	33.0%	37.2%	71.6%	78.5%	43.9%	73.4%	79.2%	71.8%	77.9%	78.3%	72.1%	78.0%	78.2%	78.8%	79.3%
14	33.3%	36.9%	71.9%	79.0%	45.0%	73.1%	79.4%	71.3%	78.5%	80.3%	72.2%	79.9%	79.8%	79.4%	80.3%
15	33.5%	36.2%	71.2%	80.2%	44.7%	72.0%	78.7%	69.7%	79.7%	79.6%	72.1%	79.8%	80.4%	80.1%	80.2%
16	33.4%	37.4%	70.7%	81.0%	44.4%	73.0%	80.6%	70.6%	80.2%	81.6%	72.5%	80.0%	81.8%	81.4%	80.8%
17	33.5%	37.5%	70.8%	81.9%	44.7%	72.4%	82.1%	69.7%	81.9%	82.7%	71.5%	81.3%	83.4%	84.2%	84.1%
18	33.6%	37.2%	70.6%	85.0%	45.4%	72.4%	84.9%	71.0%	83.3%	85.1%	71.9%	83.8%	85.7%	84.5%	85.6%
19	33.8%	37.1%	70.5%	86.1%	44.5%	72.0%	85.4%	70.5%	85.6%	85.9%	71.2%	84.9%	86.4%	85.9%	85.5%
20	33.3%	36.4%	71.1%	87.3%	45.0%	71.9%	87.7%	69.7%	87.5%	87.5%	71.5%	86.3%	88.0%	87.3%	87.7%

Table 4-19: Decision tree database C SINRD all positions

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	31.0%	39.8%	51.7%	50.7%	31.4%	51.8%	50.9%	51.7%	50.6%	50.4%	51.8%	50.7%	49.6%	50.8%	51.2%
2	35.1%	45.9%	63.0%	64.0%	35.6%	63.0%	62.9%	63.1%	63.6%	64.2%	63.0%	63.0%	64.2%	63.6%	63.3%
3	37.3%	47.8%	65.7%	66.3%	37.3%	65.8%	66.2%	65.8%	65.8%	66.0%	65.4%	66.8%	65.9%	65.3%	66.9%
4	35.9%	48.5%	67.9%	68.4%	43.0%	68.0%	70.0%	68.2%	69.7%	68.7%	67.8%	69.8%	69.3%	69.4%	69.2%
5	34.0%	50.1%	70.9%	70.9%	46.0%	70.6%	71.4%	71.1%	71.8%	71.1%	70.9%	72.0%	71.2%	71.8%	70.4%
6	35.5%	49.1%	70.3%	73.1%	47.3%	70.7%	74.7%	69.4%	72.8%	72.3%	70.5%	74.6%	72.7%	72.5%	72.6%
7	39.5%	52.0%	72.3%	74.8%	47.8%	72.8%	74.5%	71.5%	74.8%	75.2%	71.0%	74.5%	74.3%	73.9%	73.5%
8	40.2%	52.7%	74.4%	77.0%	48.1%	74.9%	76.7%	74.7%	76.6%	76.4%	73.6%	76.3%	76.4%	76.2%	76.6%
9	39.1%	53.8%	77.4%	80.3%	48.9%	77.7%	80.1%	77.1%	81.1%	80.4%	78.1%	79.6%	79.9%	79.2%	80.1%
10	39.1%	54.1%	78.1%	83.0%	49.9%	78.1%	82.1%	78.3%	82.2%	82.4%	78.7%	83.9%	81.0%	81.5%	82.1%
11	40.7%	53.9%	78.3%	84.6%	50.5%	77.4%	84.4%	79.0%	84.4%	83.4%	78.9%	84.4%	83.0%	83.4%	84.0%
12	41.6%	54.5%	79.0%	85.3%	50.2%	78.8%	85.3%	78.7%	86.1%	85.4%	77.9%	85.4%	83.6%	85.1%	84.4%
13	41.8%	55.5%	78.9%	86.7%	52.5%	78.5%	88.1%	78.5%	87.4%	85.1%	78.1%	87.4%	86.2%	86.3%	86.1%
14	40.7%	55.5%	78.7%	89.6%	52.3%	78.3%	89.1%	78.5%	89.0%	87.4%	79.3%	90.0%	87.2%	88.8%	87.2%
15	41.5%	54.0%	78.8%	91.7%	54.2%	79.4%	91.4%	79.6%	91.0%	89.0%	79.5%	90.2%	89.9%	89.2%	89.7%
16	41.1%	55.9%	79.9%	92.8%	54.5%	79.6%	92.9%	80.3%	92.0%	91.1%	80.1%	92.6%	91.7%	90.3%	91.4%
17	42.6%	56.3%	80.1%	93.1%	53.9%	78.5%	94.0%	80.4%	93.5%	91.6%	81.1%	94.0%	92.1%	91.2%	90.7%
18	43.5%	55.9%	81.3%	94.8%	53.3%	80.6%	95.2%	81.5%	94.0%	94.4%	81.5%	94.6%	93.3%	92.3%	92.9%
19	42.1%	55.7%	82.5%	95.8%	54.5%	80.8%	95.7%	82.9%	94.2%	94.9%	81.8%	94.5%	93.7%	93.4%	94.6%
20	43.2%	55.4%	83.3%	97.0%	53.9%	81.7%	96.2%	82.6%	96.0%	94.7%	83.1%	95.9%	95.4%	95.2%	94.3%

4.1.4 Databases D

4.1.4.1 Fork detector

The tables 4-20 and 4-21 show the accuracies calculated using the database D of the Fork detector, respectively for the diversion and replacement cases. Unlike the previous databases, similar accuracy values were obtained for all cases using only one feature, with maximum values around 41% for diversion and 43% for replacement. The best results for both diversion and replacement are obtained again with the combination of the current with another feature or using all features. There is no relevant difference in the accuracies between the diversion and replacement, with the maximum differences around 5% in favor of the diversion using all features.

The standard deviation calculated for the accuracies of the diversion case is included between 3% and 5%, whereas for the replacement case is included between 3% and 6%.

4.1.4.2 PDET

The tables 4-22 and 4-23 show the results for PDET database D, using respectively the detectors in the external positions and taking all the detectors positions.

From the results was observed that using the peripheral and external positions the accuracies show similar patterns, while using the central positions the accuracy follows the same trend but after 10 splits the increase is smaller compared to the other two positions. Comparing with the databases B and A is no longer possible to reach accuracies of 100%, the maximum values are around 80% using as features FA and P in peripheral positions and P either alone or in combination with FA in external positions as shown in table 4-22.

The results using the combinations of positions shows similar trends with the lowest accuracies for the combination of peripheral and central positions and reach maximum values around 87% using P as feature and taking the detector responses in peripheral and external position together or using all positions as shown in table 4-23.

The standard deviation calculated for the accuracies of PDET is included between 2% and 5%.

4.1.4.3 SINRD

In this chapter the results for SINRD database D are described, focusing on the detectors in external positions (Table 4-24) and taking all the detectors positions (Table 4-25).

The results using a single position show similar trends and it is no longer possible to reach accuracies of 100%. The maximum values are around 76% and they are lower compared with the accuracies of PDET for this class.

The results using the combinations of more positions shows similar patterns among them, with the highest accuracies that reach values around 88% taking all positions as shown in table 4-25.

The standard deviation calculated for the accuracies of PDET is included between 2% and 5%.

Table 4-20: Decision tree database D Fork detector diversion.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	27.3%	25.6%	29.9%	26.5%	29.9%	29.9%	29.9%
2	28.7%	27.3%	33.5%	28.0%	33.5%	33.6%	33.6%
3	28.3%	28.1%	32.4%	28.9%	32.6%	33.8%	33.2%
4	31.2%	31.2%	34.3%	31.2%	35.0%	35.1%	35.2%
5	34.3%	31.2%	35.2%	30.9%	34.6%	35.8%	36.4%
6	32.8%	32.2%	36.4%	31.8%	35.9%	37.6%	37.4%
7	33.0%	32.3%	36.9%	31.9%	37.6%	38.0%	38.5%
8	34.5%	31.5%	36.0%	34.6%	37.8%	40.1%	39.4%
9	34.3%	32.4%	37.6%	34.4%	39.6%	40.6%	41.0%
10	34.7%	32.6%	38.7%	36.3%	40.7%	41.6%	42.8%
11	36.5%	33.7%	39.1%	33.9%	43.0%	42.3%	43.1%
12	36.0%	34.1%	38.8%	34.2%	43.5%	44.6%	44.0%
13	35.7%	34.7%	38.9%	36.8%	44.3%	45.2%	45.2%
14	36.7%	36.0%	39.3%	37.9%	46.1%	45.7%	47.1%
15	39.2%	36.3%	39.4%	39.1%	46.9%	46.5%	48.1%
16	38.5%	37.8%	38.6%	40.5%	47.1%	46.4%	48.5%
17	37.4%	37.8%	40.5%	39.5%	48.5%	48.1%	49.1%
18	39.9%	38.8%	41.0%	40.8%	49.3%	48.5%	49.2%
19	39.4%	37.7%	42.8%	41.8%	49.0%	48.6%	50.2%
20	40.9%	38.7%	41.9%	42.7%	49.9%	49.8%	51.6%

Table 4-21: Decision tree database D Fork detector replacement.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	25.6%	26.3%	29.9%	25.9%	29.9%	29.9%	29.9%
2	27.3%	27.7%	33.7%	27.6%	33.7%	33.7%	33.7%
3	28.0%	28.8%	33.9%	27.8%	33.7%	33.6%	33.7%
4	31.5%	31.0%	35.0%	30.7%	34.1%	34.0%	34.5%
5	31.3%	30.9%	35.2%	31.4%	34.6%	33.9%	34.7%
6	31.9%	31.9%	35.6%	31.2%	35.5%	35.7%	35.5%
7	32.9%	32.4%	37.8%	33.6%	35.7%	36.9%	37.0%
8	33.3%	32.0%	38.0%	33.5%	37.4%	37.3%	37.4%
9	34.0%	32.5%	38.2%	32.5%	39.5%	37.9%	38.5%
10	34.0%	32.0%	40.0%	33.1%	38.0%	38.5%	39.2%
11	33.8%	33.7%	39.6%	33.0%	39.3%	39.1%	40.6%
12	34.0%	34.5%	40.7%	34.3%	39.9%	39.4%	40.2%
13	35.0%	35.1%	40.4%	35.7%	40.7%	40.8%	41.0%
14	36.0%	36.0%	41.8%	37.5%	42.8%	40.8%	43.3%
15	35.9%	36.6%	41.5%	38.0%	44.4%	42.9%	42.6%
16	37.7%	36.7%	42.8%	37.6%	44.9%	43.1%	44.8%
17	37.9%	38.1%	42.5%	39.1%	44.7%	45.4%	45.5%
18	37.9%	38.8%	42.4%	38.5%	45.9%	45.8%	44.3%
19	38.2%	38.6%	43.3%	37.8%	46.3%	45.7%	46.2%
20	38.9%	37.9%	43.1%	39.1%	46.9%	46.0%	45.8%

Table 4-22: Decision tree database D PDET external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	36.0%	38.6%	37.8%	41.7%	38.4%	37.2%	41.7%	38.2%	38.0%	41.7%	38.0%	38.5%	41.2%	38.0%	38.1%
2	37.5%	43.7%	45.8%	52.2%	43.6%	46.2%	51.7%	41.4%	41.9%	52.2%	41.4%	42.2%	51.7%	41.9%	43.0%
3	39.3%	47.2%	49.3%	56.9%	47.4%	49.9%	55.9%	46.2%	48.8%	55.8%	46.3%	49.0%	55.4%	47.7%	46.4%
4	37.2%	46.9%	51.5%	59.6%	47.3%	50.7%	57.8%	49.7%	52.4%	57.6%	51.0%	53.0%	57.2%	51.4%	51.0%
5	37.7%	46.7%	55.8%	59.3%	46.1%	55.7%	62.1%	53.2%	56.7%	61.0%	53.6%	55.5%	60.7%	54.0%	53.0%
6	38.0%	47.2%	55.6%	59.8%	46.2%	57.0%	61.9%	57.2%	58.9%	62.6%	56.8%	58.0%	62.9%	57.3%	57.2%
7	36.8%	46.7%	56.2%	62.9%	45.8%	57.7%	64.1%	58.0%	60.8%	63.1%	57.6%	61.2%	64.5%	59.6%	59.5%
8	37.5%	47.6%	57.6%	66.4%	45.9%	58.3%	65.2%	61.6%	64.8%	63.4%	61.7%	64.9%	65.1%	63.1%	64.0%
9	37.5%	46.8%	57.8%	66.9%	47.0%	57.6%	67.0%	63.3%	66.6%	65.1%	64.2%	67.0%	66.8%	66.7%	64.9%
10	36.2%	47.4%	57.5%	65.1%	46.6%	59.3%	67.5%	65.4%	67.8%	65.6%	65.0%	68.4%	68.9%	67.2%	66.5%
11	37.1%	48.0%	58.5%	68.3%	46.6%	59.5%	67.9%	65.5%	69.7%	66.2%	66.5%	69.5%	68.3%	68.4%	69.0%
12	37.3%	47.0%	58.2%	70.5%	47.8%	58.9%	69.6%	67.3%	71.3%	68.5%	66.8%	71.2%	69.2%	68.1%	69.0%
13	37.7%	47.7%	59.2%	73.1%	45.9%	60.4%	69.9%	67.7%	71.8%	70.7%	65.9%	70.4%	69.7%	69.9%	68.9%
14	37.6%	46.6%	60.0%	75.5%	47.0%	60.8%	70.7%	68.5%	72.1%	71.6%	68.2%	72.0%	71.4%	69.9%	70.1%
15	37.8%	47.5%	60.0%	77.3%	46.4%	61.4%	71.3%	68.9%	72.8%	74.3%	67.7%	72.2%	71.8%	70.1%	71.7%
16	39.0%	47.1%	60.8%	76.9%	47.2%	63.8%	72.9%	69.0%	72.9%	74.5%	69.6%	73.0%	71.9%	71.4%	71.1%
17	37.8%	47.7%	60.8%	77.1%	47.0%	62.7%	74.7%	70.6%	73.8%	78.2%	69.0%	73.3%	73.6%	71.6%	71.8%
18	38.7%	47.5%	60.5%	78.4%	47.1%	64.2%	73.5%	70.3%	74.0%	78.8%	69.1%	73.1%	75.7%	72.6%	72.6%
19	38.2%	46.4%	61.8%	79.1%	47.4%	65.8%	74.7%	71.0%	73.7%	80.6%	70.0%	74.2%	76.0%	73.6%	73.4%
20	38.9%	47.2%	62.3%	80.5%	46.9%	64.8%	76.7%	70.7%	74.1%	80.8%	70.9%	75.0%	76.9%	75.3%	73.9%

Table 4-23: Decision tree database D PDET all positions.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	36.0%	38.2%	37.1%	41.7%	38.2%	37.1%	41.7%	37.1%	37.9%	41.7%	38.5%	38.3%	41.7%	38.6%	38.2%
2	38.9%	40.7%	47.5%	51.6%	40.1%	47.9%	52.1%	41.8%	42.4%	52.2%	41.0%	42.0%	52.2%	43.5%	42.3%
3	41.1%	47.6%	54.5%	57.3%	46.6%	53.4%	57.9%	48.6%	48.6%	57.5%	48.4%	48.6%	57.8%	49.2%	48.9%
4	44.1%	48.2%	58.3%	61.0%	48.9%	58.2%	60.8%	51.8%	52.3%	60.1%	51.7%	51.9%	60.4%	51.8%	52.9%
5	44.5%	49.6%	62.5%	64.0%	50.4%	62.8%	63.0%	54.2%	56.1%	63.2%	53.7%	55.2%	62.9%	54.5%	56.1%
6	46.7%	50.1%	62.9%	66.5%	50.2%	65.2%	65.5%	55.3%	57.1%	65.7%	55.7%	57.9%	65.8%	55.9%	57.0%
7	45.7%	50.9%	67.4%	68.7%	49.7%	67.3%	67.3%	58.9%	59.6%	69.1%	58.0%	59.3%	68.4%	59.4%	59.1%
8	47.7%	51.9%	69.9%	70.8%	52.5%	69.4%	70.1%	61.5%	63.1%	71.7%	60.8%	62.7%	71.2%	61.4%	63.0%
9	47.7%	52.2%	70.1%	72.2%	52.9%	69.7%	71.3%	65.8%	65.0%	72.2%	65.9%	65.1%	71.6%	66.2%	66.2%
10	49.2%	53.2%	71.0%	72.7%	54.2%	69.6%	72.6%	68.3%	67.2%	72.3%	68.7%	67.6%	72.7%	67.9%	68.3%
11	49.0%	52.8%	71.5%	74.2%	54.2%	70.3%	72.4%	70.8%	68.2%	73.5%	71.3%	68.5%	72.1%	69.5%	69.4%
12	47.9%	53.5%	71.9%	75.3%	54.6%	70.3%	74.6%	70.9%	69.0%	74.1%	70.9%	69.5%	72.6%	68.0%	69.5%
13	49.3%	54.1%	72.2%	77.2%	54.2%	71.1%	77.0%	70.8%	70.7%	75.6%	70.6%	71.3%	73.2%	70.0%	68.7%
14	49.0%	53.3%	72.3%	78.6%	54.7%	71.3%	77.9%	70.8%	71.5%	75.8%	70.0%	73.4%	75.6%	71.3%	71.3%
15	50.0%	54.5%	74.7%	80.3%	54.7%	73.9%	78.6%	72.7%	72.9%	76.9%	71.8%	73.0%	75.8%	73.4%	71.6%
16	49.8%	56.2%	75.4%	81.1%	55.8%	74.0%	79.0%	73.3%	74.8%	78.4%	73.8%	74.0%	77.0%	73.2%	72.7%
17	51.3%	54.8%	75.7%	82.7%	55.3%	74.5%	80.6%	73.0%	75.1%	79.1%	72.8%	76.1%	77.9%	73.5%	72.5%
18	51.1%	55.3%	77.3%	85.0%	56.1%	76.4%	82.2%	73.2%	75.6%	81.3%	73.2%	76.5%	78.7%	73.6%	74.8%
19	51.7%	55.6%	77.6%	85.7%	56.7%	77.3%	84.3%	73.1%	77.3%	83.3%	73.8%	77.4%	81.4%	76.0%	76.1%
20	51.6%	57.3%	78.8%	87.0%	56.0%	77.9%	85.3%	74.9%	79.7%	85.7%	75.1%	77.9%	82.6%	77.4%	77.4%

Table 4-24: Decision tree database D SINRD external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	27.3%	26.1%	37.1%	41.7%	26.8%	36.5%	41.7%	37.4%	41.7%	41.7%	37.5%	41.7%	41.2%	41.7%	41.7%
2	25.2%	28.2%	43.3%	50.5%	28.9%	43.4%	50.6%	43.2%	50.0%	50.6%	43.8%	50.3%	50.8%	50.3%	50.7%
3	25.5%	27.8%	47.3%	55.1%	28.8%	46.6%	55.1%	46.0%	53.8%	54.8%	46.3%	54.9%	54.2%	54.6%	53.7%
4	24.5%	27.2%	49.4%	58.0%	28.8%	48.8%	57.7%	49.7%	58.1%	56.8%	48.9%	57.6%	56.9%	57.3%	56.7%
5	25.6%	28.7%	52.9%	57.5%	31.2%	52.0%	58.0%	51.5%	57.2%	57.6%	52.1%	56.2%	58.8%	58.2%	57.9%
6	26.3%	29.1%	52.7%	58.0%	34.4%	51.8%	58.2%	53.0%	57.5%	59.5%	52.7%	57.5%	59.4%	58.5%	58.0%
7	26.6%	28.8%	53.3%	58.4%	34.1%	53.0%	58.2%	54.0%	57.5%	60.6%	53.1%	57.2%	60.2%	60.3%	59.2%
8	26.1%	29.0%	54.0%	60.7%	34.6%	53.6%	59.9%	53.3%	59.2%	62.4%	55.5%	59.8%	61.9%	60.5%	61.8%
9	26.4%	28.9%	54.7%	64.4%	35.2%	53.2%	63.6%	54.6%	63.7%	63.1%	56.3%	64.2%	63.5%	62.8%	63.0%
10	27.1%	28.0%	54.5%	65.3%	36.0%	54.0%	64.2%	55.2%	64.8%	64.7%	56.1%	64.4%	64.6%	65.1%	64.5%
11	26.1%	29.5%	54.6%	65.0%	37.0%	55.0%	63.5%	54.8%	64.0%	64.5%	56.2%	63.9%	64.2%	64.2%	64.5%
12	27.7%	28.3%	55.8%	65.2%	37.7%	55.0%	65.2%	55.2%	64.5%	64.0%	57.0%	64.6%	63.6%	63.6%	64.1%
13	26.7%	28.3%	56.3%	66.2%	36.6%	55.3%	65.8%	55.2%	65.6%	64.2%	57.0%	65.6%	63.5%	65.3%	64.7%
14	26.7%	28.3%	57.1%	66.1%	36.4%	55.9%	65.3%	57.0%	64.9%	68.5%	59.3%	65.5%	67.4%	67.6%	66.8%
15	27.5%	27.4%	56.8%	68.9%	36.2%	56.9%	67.7%	58.5%	67.6%	68.9%	58.4%	67.3%	69.8%	68.4%	70.1%
16	28.5%	28.3%	57.0%	72.3%	37.0%	56.7%	71.1%	57.1%	70.3%	70.5%	59.0%	70.1%	71.3%	70.1%	70.5%
17	27.3%	28.1%	57.1%	73.2%	36.1%	57.9%	73.6%	58.0%	70.8%	72.5%	61.0%	72.0%	71.9%	71.9%	72.0%
18	27.0%	27.8%	57.8%	76.2%	37.5%	57.3%	75.4%	57.4%	74.3%	72.5%	60.5%	74.1%	73.1%	71.3%	72.2%
19	28.0%	28.5%	57.7%	75.7%	36.1%	56.9%	75.5%	57.6%	73.7%	72.9%	60.3%	74.7%	73.3%	72.4%	72.8%
20	28.9%	28.4%	57.3%	76.5%	36.5%	58.5%	75.2%	57.5%	74.2%	73.4%	59.6%	75.1%	74.4%	73.0%	74.1%

Table 4-25: Decision tree database D SINRD all positions.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	26.8%	25.8%	37.5%	41.7%	25.7%	37.3%	41.7%	37.3%	41.7%	41.7%	36.8%	41.7%	41.2%	41.7%	41.7%
2	26.3%	31.7%	44.9%	50.3%	29.0%	45.1%	50.4%	44.7%	50.8%	50.5%	45.4%	50.1%	50.4%	50.4%	49.8%
3	27.1%	35.2%	50.4%	56.1%	30.4%	50.0%	55.8%	50.3%	56.2%	55.3%	49.7%	56.2%	56.6%	55.8%	56.6%
4	29.3%	37.0%	52.6%	60.1%	36.2%	52.5%	59.8%	52.5%	60.2%	59.7%	52.1%	59.9%	59.1%	60.4%	58.4%
5	29.3%	37.5%	54.7%	61.8%	36.6%	55.5%	61.7%	55.7%	62.1%	61.8%	56.2%	61.2%	61.6%	60.8%	62.3%
6	31.6%	38.9%	60.1%	63.5%	37.1%	57.9%	63.5%	59.1%	63.4%	63.7%	58.4%	64.0%	63.2%	62.9%	63.8%
7	31.9%	39.2%	61.4%	65.8%	38.1%	61.7%	65.3%	60.9%	65.6%	65.3%	61.3%	65.4%	65.6%	65.8%	65.8%
8	32.6%	40.6%	62.9%	67.6%	38.0%	63.9%	67.7%	63.2%	67.6%	67.6%	63.9%	67.7%	66.9%	67.8%	67.4%
9	33.4%	41.1%	66.3%	70.9%	38.3%	66.6%	70.4%	65.2%	70.4%	70.8%	65.1%	70.3%	70.4%	69.4%	70.4%
10	32.4%	42.4%	69.3%	72.9%	38.6%	68.1%	72.1%	69.5%	72.5%	73.0%	68.1%	72.3%	72.8%	72.4%	73.1%
11	32.7%	42.8%	69.1%	75.6%	40.5%	68.6%	76.0%	69.4%	75.5%	75.4%	70.1%	75.6%	75.9%	75.6%	75.1%
12	33.8%	42.9%	69.9%	76.7%	39.7%	69.5%	76.8%	71.1%	78.0%	76.1%	70.2%	78.5%	75.8%	76.2%	76.9%
13	32.7%	43.1%	70.3%	79.1%	41.2%	69.9%	79.4%	70.0%	80.5%	78.6%	70.7%	80.7%	79.1%	79.5%	79.8%
14	32.9%	43.9%	70.7%	80.2%	40.7%	71.2%	80.3%	70.6%	81.1%	80.2%	71.3%	80.8%	79.6%	79.8%	79.6%
15	32.6%	42.6%	72.9%	79.9%	41.0%	73.2%	80.7%	73.9%	81.5%	81.2%	73.7%	81.4%	80.4%	81.2%	81.1%
16	34.9%	43.7%	73.5%	81.4%	42.5%	73.5%	81.3%	74.8%	83.2%	80.6%	74.4%	82.7%	80.2%	81.9%	82.1%
17	35.4%	44.0%	75.0%	82.4%	42.6%	74.5%	82.6%	73.5%	83.8%	82.0%	74.1%	83.2%	82.1%	82.4%	82.5%
18	34.8%	44.4%	73.8%	85.1%	43.0%	75.0%	85.1%	75.1%	84.6%	84.0%	74.8%	85.0%	82.9%	84.0%	83.1%
19	36.4%	43.9%	74.9%	86.3%	42.5%	73.6%	86.3%	75.1%	86.7%	85.2%	75.8%	86.6%	85.1%	85.8%	85.2%
20	35.8%	44.7%	74.8%	88.0%	44.1%	75.6%	86.9%	75.7%	87.6%	86.7%	76.4%	87.5%	86.8%	86.8%	86.9%

4.1.5 Databases E

4.1.5.1 Fork detector

The tables 4-26 and 4-27 show the accuracies calculated using the databases E of the Fork detector, respectively for the diversion and replacement cases. As for database D all features used alone show similar accuracy values and trends. However, compared to database D, the current presents at some splits accuracies around 5% higher with respect to the other two features. Also globally the best results for both diversion and replacement are not evident because all the combinations of features show similar results with maximum values around 41% for diversion and 40% for replacement.

The standard deviation calculated for the accuracies of the diversion case is included between 2% and 4%, whereas for the replacement case is included between 2% and 5%.

4.1.5.2 PDET

In this chapter the results for PDET database E are described, focusing on the detectors in external positions (Table 4-28) and using all the detectors positions (Table 4-29).

The accuracies taking the detector responses in a single position present similar patterns with maximum differences around 5% between positions. As for databases D and C it is no longer possible to reach accuracies of 100%, with the maximum values around 70% using all the features in peripheral positions.

The results using the combinations of more positions shows similar trends with the highest accuracies using all positions that assume values around 78% for the combination FA-P and the combination TH-FA-P as shown in the table 4-29.

The standard deviation calculated for the accuracies of PDET is included between 3% and 5%.

4.1.5.3 SINRD

In this chapter the results for SINRD database E are described, focusing on the detectors in external position (Table 4-30) and using all the position of the detectors (Table 4-31).

The results show maximum differences around 5% of the accuracies calculated using the detector responses in one position. Similar trends were observed in all cases, with the values that fell within the calculated standard deviation. An example is shown in the table 4-30 for the external position. As for databases D and C it is no longer possible to reach accuracies of 100%, with the maximum values are around 65% using all the features in peripheral positions. The calculated accuracies for SINRD have lower values compared with the results of PDET.

The results using the combinations of more positions shows similar trends with the highest accuracies using all positions or the combination peripheral-external with maximum values around 76% as shown in the table 4-31.

The standard deviation calculated for the accuracies of PDET is included between 2% and 6%.

Table 4-26: Decision tree database E Fork detector diversion.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	22.8%	23.0%	26.1%	23.7%	26.1%	26.1%	26.1%
2	23.0%	23.5%	28.8%	23.7%	28.8%	28.9%	28.8%
3	24.0%	22.8%	29.2%	22.7%	28.5%	29.5%	29.8%
4	25.9%	24.7%	29.1%	27.0%	28.5%	30.1%	29.4%
5	26.5%	26.1%	29.6%	25.3%	30.3%	29.8%	30.4%
6	26.4%	26.5%	31.0%	26.4%	31.1%	32.3%	32.5%
7	26.9%	25.5%	29.9%	27.3%	31.9%	32.9%	32.4%
8	28.2%	28.0%	31.0%	29.1%	32.8%	32.9%	33.1%
9	28.2%	28.1%	31.1%	30.5%	33.1%	35.4%	33.8%
10	28.2%	28.0%	33.4%	29.3%	34.1%	34.4%	34.0%
11	28.7%	29.6%	33.1%	29.5%	34.9%	34.9%	34.2%
12	28.6%	29.2%	33.0%	30.7%	35.5%	35.3%	35.7%
13	29.0%	29.1%	34.3%	31.5%	36.6%	35.9%	35.0%
14	30.5%	29.8%	33.4%	30.7%	37.0%	36.2%	36.7%
15	30.6%	31.2%	34.4%	31.6%	36.1%	37.2%	37.7%
16	32.1%	32.5%	35.4%	31.5%	38.1%	38.1%	38.4%
17	31.7%	31.2%	35.5%	34.2%	38.0%	38.3%	39.5%
18	32.1%	31.5%	36.2%	32.0%	39.2%	39.4%	39.2%
19	31.1%	30.9%	36.4%	34.1%	39.8%	39.7%	38.9%
20	33.2%	32.3%	36.6%	34.4%	41.4%	40.5%	40.3%

Table 4-27: Decision tree database E Fork detector replacement

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	23.2%	22.7%	26.1%	23.7%	26.1%	26.1%	26.1%
2	23.0%	24.2%	28.9%	24.2%	28.8%	28.8%	28.8%
3	23.1%	23.3%	28.8%	24.9%	28.9%	28.8%	29.0%
4	25.3%	25.5%	29.6%	25.9%	28.7%	28.9%	29.3%
5	25.9%	26.3%	30.2%	26.5%	29.1%	28.8%	29.2%
6	26.4%	26.2%	30.0%	26.3%	30.5%	30.4%	30.2%
7	27.5%	26.1%	32.1%	27.4%	31.2%	31.8%	31.3%
8	27.7%	27.0%	30.8%	28.4%	32.0%	31.9%	31.7%
9	28.7%	28.4%	31.8%	29.4%	32.5%	31.6%	32.4%
10	28.8%	29.6%	31.8%	29.4%	33.8%	33.6%	33.1%
11	28.9%	29.4%	34.7%	30.0%	34.7%	34.2%	34.6%
12	29.1%	28.7%	35.7%	30.5%	35.8%	36.1%	35.8%
13	29.2%	29.9%	35.4%	30.5%	35.2%	35.8%	36.2%
14	30.3%	30.3%	34.7%	30.8%	36.2%	35.4%	35.9%
15	31.1%	30.6%	34.9%	32.4%	36.6%	36.8%	36.5%
16	31.5%	31.4%	36.2%	31.8%	37.1%	36.2%	36.7%
17	30.9%	31.7%	37.1%	33.1%	37.9%	37.8%	38.4%
18	31.7%	30.9%	37.4%	32.8%	37.9%	37.9%	38.9%
19	31.4%	32.5%	38.1%	33.5%	39.3%	38.2%	38.1%
20	31.5%	32.7%	37.4%	32.9%	38.6%	39.3%	40.6%

Table 4-28: Decision tree database E PDET external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	27.8%	28.8%	33.3%	31.2%	28.8%	32.7%	30.6%	28.7%	29.5%	31.2%	29.2%	29.1%	30.9%	29.0%	28.8%
2	29.8%	33.1%	38.9%	39.5%	33.3%	37.7%	38.8%	40.0%	39.1%	39.6%	39.4%	39.1%	38.9%	39.6%	39.3%
3	31.3%	35.4%	42.9%	42.8%	35.1%	41.6%	43.2%	42.9%	43.0%	42.6%	42.3%	43.0%	42.1%	43.1%	42.7%
4	30.8%	38.0%	45.4%	46.8%	37.1%	43.9%	47.1%	47.5%	48.3%	47.4%	47.4%	47.9%	46.3%	47.7%	47.4%
5	30.1%	37.8%	47.8%	51.8%	37.3%	46.9%	47.9%	50.4%	50.5%	50.2%	49.6%	49.8%	49.7%	50.0%	49.8%
6	29.6%	36.9%	47.9%	50.9%	36.6%	47.7%	50.5%	51.4%	51.8%	51.5%	51.2%	52.3%	51.4%	52.0%	51.2%
7	30.7%	36.8%	47.9%	52.7%	36.4%	49.7%	51.6%	53.0%	52.7%	53.2%	52.9%	53.0%	52.9%	52.4%	52.8%
8	29.2%	37.4%	51.2%	54.6%	36.5%	51.4%	52.1%	54.3%	55.5%	56.1%	54.3%	56.5%	55.1%	55.3%	54.7%
9	30.1%	37.8%	52.3%	57.2%	37.0%	53.1%	54.2%	55.0%	57.8%	56.8%	55.9%	57.5%	54.9%	57.0%	57.1%
10	29.3%	36.8%	52.1%	57.9%	36.3%	53.8%	54.9%	55.9%	57.6%	58.7%	56.0%	57.8%	56.9%	56.5%	57.1%
11	30.4%	37.1%	53.1%	57.9%	36.6%	55.2%	56.4%	56.5%	58.8%	57.7%	56.6%	58.2%	58.5%	56.9%	57.6%
12	30.4%	37.8%	53.2%	57.7%	36.6%	55.2%	56.5%	57.0%	59.5%	58.4%	57.2%	60.0%	58.7%	57.6%	57.7%
13	30.1%	37.7%	54.1%	57.3%	37.0%	54.7%	56.5%	57.4%	60.6%	58.4%	57.1%	59.6%	58.8%	58.5%	58.3%
14	30.0%	37.6%	52.7%	58.4%	36.9%	54.9%	57.6%	57.3%	59.8%	59.0%	57.1%	60.2%	59.3%	59.6%	58.4%
15	31.0%	36.7%	53.9%	58.8%	36.5%	54.4%	57.4%	58.2%	60.9%	59.6%	57.0%	60.5%	59.5%	58.1%	59.4%
16	31.1%	37.2%	54.5%	59.2%	36.6%	55.6%	58.7%	57.8%	60.8%	60.4%	57.8%	60.1%	61.4%	58.9%	58.9%
17	33.1%	36.9%	56.0%	61.7%	36.9%	57.2%	60.7%	59.0%	61.4%	61.7%	57.8%	60.7%	61.6%	58.9%	59.0%
18	31.1%	37.4%	56.4%	62.9%	37.0%	57.1%	61.8%	58.3%	61.0%	64.2%	58.2%	61.2%	63.3%	58.7%	59.7%
19	32.2%	37.1%	57.5%	64.5%	36.5%	57.9%	61.5%	58.4%	61.7%	64.0%	58.0%	61.2%	63.0%	59.9%	59.8%
20	31.7%	36.4%	58.0%	64.8%	36.3%	58.7%	61.0%	59.7%	62.5%	64.9%	58.6%	62.8%	63.5%	60.5%	60.6%

Table 4-29: Decision tree database E PDET all positions.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	27.8%	29.5%	33.5%	35.6%	29.4%	32.7%	34.5%	29.0%	28.5%	35.8%	29.6%	28.5%	35.7%	28.9%	28.7%
2	35.6%	38.7%	43.9%	46.4%	38.8%	43.6%	46.9%	41.9%	42.7%	46.7%	42.2%	42.6%	45.9%	42.7%	42.9%
3	36.7%	42.9%	48.4%	51.2%	43.1%	49.1%	50.8%	46.8%	47.0%	51.8%	46.3%	46.9%	50.6%	47.6%	46.5%
4	40.4%	46.8%	54.3%	57.1%	46.4%	55.0%	57.5%	50.0%	50.3%	56.5%	50.0%	50.9%	55.7%	51.0%	50.6%
5	39.7%	47.0%	58.8%	59.1%	47.5%	57.2%	59.0%	50.4%	51.9%	59.4%	50.3%	51.7%	58.7%	51.6%	51.7%
6	41.1%	46.8%	61.0%	59.2%	46.0%	60.4%	60.5%	52.3%	52.9%	61.0%	51.8%	52.7%	60.9%	52.7%	53.2%
7	41.7%	47.3%	61.5%	61.7%	47.2%	61.5%	60.4%	52.3%	54.4%	61.7%	52.3%	53.8%	62.0%	53.6%	53.9%
8	41.8%	48.6%	63.4%	63.0%	48.0%	63.6%	62.2%	54.1%	56.0%	63.1%	54.1%	55.9%	64.0%	54.7%	55.5%
9	42.7%	47.5%	65.4%	64.6%	49.2%	65.2%	64.2%	55.9%	57.6%	66.0%	55.6%	56.8%	65.4%	56.7%	57.8%
10	44.9%	48.9%	68.5%	66.3%	49.7%	68.1%	65.5%	57.7%	59.2%	68.2%	59.1%	59.1%	68.1%	59.3%	59.5%
11	43.3%	48.4%	68.6%	69.1%	49.1%	68.4%	68.7%	59.6%	60.4%	68.5%	60.0%	60.2%	67.9%	60.8%	59.9%
12	43.6%	49.2%	68.7%	70.3%	48.8%	67.7%	69.4%	60.3%	60.3%	70.2%	61.5%	61.5%	68.0%	61.2%	60.4%
13	44.0%	49.5%	69.6%	70.9%	49.9%	69.7%	71.2%	61.4%	61.5%	70.0%	61.1%	61.1%	70.4%	59.9%	61.9%
14	44.4%	48.8%	69.8%	72.7%	49.6%	70.5%	71.1%	61.2%	62.6%	71.8%	61.7%	62.9%	70.5%	63.0%	61.5%
15	44.3%	49.2%	71.7%	73.1%	50.4%	70.6%	73.0%	63.1%	64.9%	72.7%	62.8%	63.5%	72.4%	63.5%	63.5%
16	43.9%	49.8%	71.5%	73.3%	50.3%	71.4%	73.0%	64.3%	65.9%	73.8%	64.5%	64.8%	72.9%	65.4%	65.0%
17	45.3%	49.7%	72.0%	74.5%	49.2%	72.6%	74.6%	64.8%	66.6%	74.7%	66.0%	66.7%	74.9%	65.6%	65.3%
18	45.6%	50.2%	73.7%	75.9%	51.3%	72.6%	75.6%	67.5%	68.1%	76.0%	67.9%	67.6%	75.4%	67.1%	66.5%
19	45.3%	50.5%	74.5%	76.4%	50.3%	75.3%	75.9%	68.1%	67.9%	77.3%	67.6%	67.7%	76.1%	66.9%	67.9%
20	45.7%	50.3%	75.9%	78.0%	50.5%	75.2%	77.3%	68.1%	68.0%	78.7%	67.0%	68.7%	78.5%	68.2%	68.6%

Table 4-30: Decision tree database E SINRD external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	22.3%	23.9%	28.7%	31.4%	21.7%	29.1%	31.3%	28.3%	31.3%	31.2%	28.4%	31.4%	31.7%	31.5%	31.2%
2	22.2%	23.5%	33.2%	38.0%	23.2%	33.0%	38.3%	33.1%	37.5%	38.1%	33.1%	38.3%	39.0%	38.1%	37.7%
3	22.5%	22.8%	36.9%	41.4%	23.3%	37.1%	40.9%	36.6%	42.0%	41.3%	36.9%	41.0%	41.6%	42.2%	41.5%
4	22.6%	22.2%	39.3%	45.4%	25.4%	39.8%	45.4%	38.9%	44.6%	45.3%	38.9%	44.3%	44.8%	45.0%	45.0%
5	22.9%	22.8%	42.1%	50.1%	26.5%	42.7%	50.5%	42.9%	50.1%	48.7%	41.8%	49.9%	49.4%	49.0%	49.8%
6	23.7%	22.2%	46.0%	50.2%	27.0%	44.1%	50.7%	45.3%	50.7%	50.6%	43.4%	50.3%	51.2%	50.7%	50.3%
7	24.6%	23.2%	45.7%	50.8%	28.2%	43.8%	50.3%	45.8%	50.9%	50.7%	44.5%	50.9%	51.6%	51.0%	51.2%
8	23.5%	22.3%	46.2%	52.0%	28.2%	43.9%	52.1%	45.8%	51.7%	52.1%	44.3%	52.8%	52.3%	52.3%	52.8%
9	23.0%	22.5%	47.5%	53.0%	28.1%	46.2%	53.1%	45.9%	52.0%	53.3%	44.9%	52.4%	52.9%	52.5%	53.1%
10	23.6%	22.9%	47.2%	53.8%	29.3%	47.0%	54.4%	46.4%	53.5%	53.9%	45.7%	54.0%	54.1%	53.1%	52.1%
11	23.5%	22.1%	47.1%	54.6%	30.4%	46.6%	54.0%	46.7%	53.3%	53.6%	45.4%	53.9%	52.3%	52.8%	52.9%
12	24.8%	22.8%	45.4%	53.1%	31.5%	47.9%	53.6%	45.7%	53.7%	53.1%	45.0%	54.0%	53.1%	52.6%	52.2%
13	23.5%	23.7%	47.4%	54.4%	30.1%	48.4%	53.5%	46.0%	53.5%	52.8%	46.7%	53.1%	52.9%	52.6%	52.7%
14	23.1%	23.6%	48.1%	54.5%	31.5%	48.9%	53.9%	47.0%	53.7%	54.8%	48.5%	53.7%	55.5%	54.5%	55.2%
15	24.3%	24.0%	47.7%	55.5%	32.0%	49.6%	55.5%	48.0%	54.2%	56.8%	50.8%	54.6%	56.3%	55.8%	58.5%
16	24.5%	23.5%	49.7%	56.6%	32.3%	50.3%	57.2%	47.6%	56.7%	57.9%	51.0%	57.7%	56.9%	57.4%	59.0%
17	23.7%	22.6%	48.5%	59.0%	31.6%	49.3%	58.4%	47.6%	58.4%	58.9%	52.0%	60.2%	58.2%	58.6%	60.5%
18	23.6%	23.9%	48.2%	59.9%	32.0%	49.6%	58.3%	48.6%	58.9%	59.2%	52.7%	61.4%	59.0%	60.2%	62.0%
19	24.5%	23.7%	48.5%	60.1%	32.4%	50.3%	58.7%	48.0%	59.9%	60.6%	53.0%	61.1%	60.4%	60.7%	62.6%
20	23.9%	23.5%	48.3%	61.4%	31.5%	49.4%	60.4%	48.4%	60.4%	60.5%	52.9%	62.0%	61.0%	60.8%	62.0%

Table 4-31: Decision tree database E SINRD all positions.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	22.6%	22.8%	33.5%	36.2%	22.3%	33.3%	35.8%	33.4%	35.8%	35.3%	34.1%	36.2%	35.9%	35.8%	36.2%
2	21.7%	25.0%	42.2%	46.6%	22.8%	41.3%	47.2%	41.3%	47.2%	45.9%	41.1%	47.1%	47.2%	46.3%	46.0%
3	23.8%	27.3%	45.4%	52.4%	24.2%	45.5%	52.2%	46.2%	52.4%	51.5%	45.9%	52.4%	51.9%	51.9%	51.8%
4	26.3%	31.3%	48.2%	57.7%	26.2%	49.0%	57.4%	48.1%	58.1%	57.5%	48.7%	57.7%	56.7%	57.4%	57.4%
5	27.2%	31.0%	53.5%	59.3%	27.0%	53.3%	58.2%	52.1%	58.7%	58.7%	52.8%	59.0%	58.8%	58.9%	57.8%
6	29.4%	30.8%	53.2%	59.9%	30.6%	53.9%	59.3%	53.2%	59.9%	60.2%	53.7%	60.0%	60.5%	59.9%	59.9%
7	28.7%	32.2%	55.7%	61.8%	30.9%	55.4%	61.5%	55.2%	61.2%	61.7%	55.4%	61.3%	60.3%	61.2%	61.6%
8	29.3%	32.4%	57.1%	63.6%	32.8%	58.6%	63.6%	57.0%	63.3%	63.5%	56.9%	63.6%	62.9%	63.4%	62.7%
9	28.6%	33.4%	58.4%	64.8%	34.2%	59.0%	64.8%	57.8%	64.8%	64.0%	58.5%	65.5%	64.2%	64.8%	64.9%
10	28.2%	34.1%	59.0%	66.2%	34.5%	59.1%	65.3%	59.0%	65.4%	66.0%	59.3%	65.9%	66.4%	65.6%	65.2%
11	29.1%	35.2%	60.0%	66.6%	35.3%	59.5%	67.3%	60.1%	67.3%	67.3%	59.8%	66.7%	66.4%	65.4%	66.8%
12	28.9%	34.4%	60.3%	68.6%	34.9%	61.0%	67.6%	60.5%	67.6%	68.2%	60.1%	68.0%	66.7%	66.9%	67.5%
13	28.3%	35.7%	60.0%	69.2%	35.3%	61.2%	69.0%	60.9%	68.8%	68.8%	61.0%	69.0%	68.2%	68.4%	69.2%
14	28.2%	35.1%	61.3%	70.2%	35.6%	61.0%	69.3%	62.6%	70.5%	70.3%	61.1%	71.0%	70.1%	70.3%	69.5%
15	28.6%	37.0%	62.7%	72.1%	36.0%	62.9%	71.8%	62.7%	72.2%	71.4%	62.6%	72.0%	71.1%	70.7%	70.8%
16	28.4%	36.2%	63.6%	72.9%	36.9%	63.2%	73.0%	63.5%	73.1%	71.6%	63.2%	72.0%	72.4%	72.2%	72.5%
17	29.5%	36.9%	64.5%	73.2%	37.0%	63.2%	73.4%	63.9%	73.3%	72.5%	63.7%	74.3%	73.9%	73.0%	73.0%
18	28.0%	37.0%	64.5%	74.0%	37.1%	65.0%	74.8%	65.0%	73.9%	73.0%	64.1%	74.4%	73.4%	73.8%	74.4%
19	29.2%	37.8%	65.6%	75.1%	36.7%	65.2%	75.3%	64.8%	75.3%	74.2%	65.0%	75.1%	75.2%	74.9%	74.3%
20	29.5%	37.8%	66.1%	75.3%	38.4%	65.6%	75.8%	66.0%	76.0%	75.4%	65.1%	75.5%	75.7%	75.6%	75.6%

4.1.6 Databases F

4.1.6.1 Fork detector

The tables 4-32 and 4-33 show the accuracies calculated using the databases F of the Fork detector, respectively for the diversion and replacement cases. There are similar trends for the accuracies calculated using only one feature, but the current presents at some splits accuracies around 5% higher with respect to the other two features up to values around 31%. It is not evident to find the case leading to the highest accuracies for both diversion and replacement because all the combinations of features show similar results with maximum values around 34% for diversion and 36% for replacement.

The standard deviation calculated for the accuracies of the diversion case is included between 2% and 4%, whereas in the replacement case is included between 2% and 3%.

4.1.6.2 PDET

In this chapter the results for PDET database F are described, focusing on the detectors in external positions (Table 4-34) and using all the detectors positions (Table 4-35).

The accuracies obtained using a single position of the detectors present similar patterns with maximum differences around 5% between the different positions with the peripheral one which presents the better results. As for databases E, D and C it is no longer possible to reach accuracies of 100% and the maximum values are around 66% using the combination TH-FA-P in peripheral positions.

The results using the combinations of more positions shows similar trends with the highest results using all positions with maximum accuracies around 73% for the combination FA-P as shown in table 4-35.

The standard deviation calculated for the accuracies of PDET is included between 2% and 4%.

4.1.6.3 SINRD

In this chapter the results for SINRD database F are described, focusing on the detectors in external positions (Table 4-36) and using all the detectors positions (Table 4-37).

The accuracies obtained using a single position of the detectors present similar patterns with maximum differences around 5% between the different positions, with the peripheral one which presents the best results. As for databases E, D and C it is no longer possible to reach accuracies of 100%, but the maximum values are around 60% using the combination RES-FA-P in peripheral positions. In general the accuracy values for SINRD are smaller compared with the results obtained for PDET.

The results using the combinations of more positions shows similar trends with the highest results using all positions with maximum accuracies around 71% for the feature P and its combinations with TH and FA as shown in table 4-37.

The standard deviation calculated for the accuracies of PDET is included between 2% and 4%.

Table 4-32: Decision tree database F Fork detector diversion.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	20.6%	20.5%	22.3%	20.5%	22.3%	22.3%	22.3%
2	21.0%	21.3%	24.6%	21.5%	24.6%	24.6%	24.6%
3	21.9%	21.0%	24.6%	21.9%	25.3%	26.4%	26.2%
4	22.5%	21.0%	23.9%	20.8%	25.2%	27.3%	26.2%
5	22.4%	22.2%	24.9%	22.5%	26.5%	27.4%	27.6%
6	22.6%	21.4%	27.1%	22.6%	27.1%	27.6%	27.7%
7	23.2%	21.8%	26.4%	22.5%	27.8%	27.7%	28.3%
8	23.9%	23.7%	27.2%	23.8%	28.2%	27.0%	27.7%
9	24.2%	23.2%	27.6%	24.2%	29.2%	29.4%	29.6%
10	24.1%	23.3%	28.3%	24.0%	30.6%	30.2%	29.6%
11	24.5%	23.8%	28.9%	24.4%	30.2%	30.0%	29.7%
12	24.2%	23.5%	27.8%	25.5%	30.6%	30.6%	30.6%
13	25.1%	24.3%	29.2%	25.2%	30.9%	30.7%	30.2%
14	24.1%	24.5%	28.8%	26.2%	31.5%	31.3%	30.4%
15	25.2%	24.6%	29.5%	25.2%	32.4%	31.5%	32.3%
16	25.5%	24.5%	30.9%	26.2%	33.1%	31.5%	32.9%
17	25.3%	25.4%	30.3%	26.1%	32.9%	31.8%	32.7%
18	25.5%	25.3%	31.6%	27.7%	33.0%	33.2%	32.9%
19	26.3%	25.7%	30.9%	27.2%	33.7%	33.4%	32.8%
20	26.8%	25.9%	30.4%	26.3%	34.3%	33.7%	33.2%

Table 4-33: Decision tree database F Fork detector replacement.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
#splits	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	20.1%	20.5%	22.3%	20.6%	22.3%	22.0%	22.3%
2	20.6%	21.7%	24.6%	21.0%	24.6%	24.6%	24.1%
3	21.7%	21.8%	23.9%	21.1%	24.6%	24.5%	24.5%
4	20.9%	21.5%	25.1%	20.7%	24.7%	24.4%	24.7%
5	21.8%	21.2%	26.0%	21.3%	24.9%	25.4%	24.9%
6	22.3%	22.3%	26.2%	22.0%	25.6%	25.3%	26.1%
7	22.4%	22.3%	27.3%	21.6%	26.3%	27.3%	26.7%
8	23.6%	23.7%	27.4%	23.8%	27.3%	28.2%	27.7%
9	22.7%	23.7%	27.8%	24.0%	28.1%	28.2%	28.4%
10	22.7%	24.0%	28.3%	24.4%	27.7%	29.0%	29.0%
11	23.8%	24.1%	29.8%	23.6%	30.0%	29.7%	30.7%
12	23.7%	24.6%	29.4%	24.0%	31.1%	32.2%	30.9%
13	24.2%	24.5%	29.5%	24.5%	32.7%	32.0%	32.6%
14	24.1%	24.8%	30.0%	25.0%	32.7%	33.5%	33.3%
15	24.5%	24.8%	30.4%	24.9%	33.6%	32.9%	32.7%
16	24.6%	24.4%	31.0%	25.1%	32.6%	33.0%	34.0%
17	23.8%	25.5%	31.5%	24.5%	34.0%	32.7%	33.7%
18	24.6%	24.8%	31.3%	24.4%	34.5%	34.5%	33.9%
19	25.9%	25.4%	31.3%	25.1%	35.9%	33.8%	34.3%
20	25.5%	25.6%	31.7%	25.3%	36.2%	34.8%	35.2%

Table 4-34: Decision tree database F PDET external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	24.0%	25.0%	28.3%	26.6%	24.3%	27.3%	26.2%	25.4%	24.9%	26.6%	24.3%	24.3%	26.2%	25.4%	24.8%
2	26.7%	28.0%	32.6%	33.9%	28.0%	32.0%	33.8%	33.8%	33.0%	33.6%	33.4%	33.3%	33.8%	33.8%	34.3%
3	26.8%	29.9%	36.2%	36.3%	30.3%	35.9%	36.3%	36.0%	36.8%	38.2%	36.4%	36.7%	37.4%	35.9%	36.6%
4	26.5%	32.1%	37.7%	38.9%	31.6%	37.7%	37.9%	40.2%	40.4%	39.8%	40.8%	41.0%	39.4%	40.2%	40.8%
5	25.5%	32.0%	39.9%	40.6%	32.6%	38.5%	39.4%	42.6%	42.3%	42.1%	41.8%	42.2%	40.8%	42.4%	41.8%
6	25.7%	31.9%	39.2%	42.0%	32.0%	39.3%	43.4%	43.3%	43.4%	43.6%	44.2%	43.2%	43.0%	43.1%	43.2%
7	25.7%	32.3%	39.0%	44.5%	32.8%	40.7%	42.8%	44.4%	44.2%	44.6%	45.1%	45.0%	43.2%	44.2%	43.7%
8	25.7%	32.4%	42.1%	44.2%	32.3%	43.4%	44.6%	45.8%	47.0%	45.7%	44.7%	46.0%	45.1%	46.4%	46.0%
9	25.3%	32.1%	44.0%	46.2%	32.5%	44.5%	46.7%	47.0%	48.4%	45.9%	46.8%	48.1%	47.8%	47.2%	46.7%
10	25.0%	32.7%	43.3%	46.7%	31.7%	45.2%	46.2%	46.6%	48.4%	46.9%	47.5%	49.4%	47.6%	47.7%	47.7%
11	25.5%	31.9%	43.5%	46.6%	31.8%	45.6%	46.0%	47.5%	49.1%	47.9%	46.8%	50.1%	48.8%	49.3%	49.0%
12	24.9%	32.3%	44.2%	45.9%	32.2%	45.3%	47.0%	47.0%	49.6%	48.2%	47.3%	49.8%	49.6%	48.9%	49.0%
13	25.6%	31.8%	43.2%	46.2%	30.9%	45.0%	47.2%	47.6%	50.5%	48.2%	47.5%	50.0%	49.8%	50.2%	49.7%
14	25.5%	31.4%	43.8%	47.1%	31.4%	45.9%	47.6%	47.9%	50.7%	48.0%	47.4%	51.1%	49.8%	50.7%	49.0%
15	26.1%	31.1%	45.2%	46.8%	31.3%	46.0%	48.4%	48.2%	51.2%	48.7%	47.5%	50.9%	51.3%	51.5%	51.4%
16	25.8%	31.6%	45.7%	48.7%	31.8%	46.7%	50.0%	48.8%	51.6%	51.8%	48.7%	52.3%	52.8%	52.0%	51.1%
17	26.2%	31.4%	45.6%	50.3%	31.9%	47.4%	51.1%	49.1%	51.9%	53.0%	48.7%	51.6%	53.7%	52.8%	51.8%
18	26.2%	32.5%	46.3%	52.4%	31.4%	47.3%	50.8%	48.5%	52.3%	55.0%	48.6%	51.7%	53.1%	52.0%	53.3%
19	26.7%	31.4%	48.2%	53.5%	31.9%	48.6%	51.4%	48.5%	53.4%	55.6%	48.4%	53.0%	55.0%	51.9%	52.3%
20	26.2%	31.9%	48.0%	54.8%	31.2%	47.6%	52.0%	49.7%	54.0%	56.9%	48.9%	53.5%	54.0%	54.4%	53.4%

Table 4-35: Decision tree database F PDET all positions.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	23.4%	25.4%	27.1%	27.3%	24.3%	27.0%	27.6%	25.5%	24.9%	27.6%	24.7%	24.4%	27.3%	24.6%	24.2%
2	30.0%	33.3%	36.9%	36.7%	32.6%	37.3%	36.8%	34.8%	36.5%	36.8%	36.0%	36.4%	37.2%	36.2%	35.9%
3	31.7%	36.4%	41.1%	40.1%	36.9%	42.3%	41.1%	39.1%	39.8%	40.9%	39.0%	39.7%	41.8%	39.4%	40.1%
4	34.7%	40.3%	48.4%	48.5%	40.3%	48.6%	49.0%	43.0%	42.5%	48.9%	42.9%	43.2%	48.5%	43.4%	43.2%
5	34.9%	40.4%	52.7%	53.3%	41.3%	52.6%	52.2%	44.4%	48.9%	54.0%	43.6%	49.0%	53.7%	49.4%	49.0%
6	35.8%	41.7%	55.3%	53.9%	42.4%	55.0%	54.7%	45.4%	50.1%	56.2%	45.6%	50.2%	56.0%	50.5%	50.8%
7	35.8%	41.9%	58.6%	56.1%	41.6%	59.2%	56.5%	47.1%	52.0%	60.1%	45.9%	51.4%	59.3%	51.2%	50.3%
8	37.7%	42.1%	60.2%	58.1%	42.7%	60.1%	58.3%	51.7%	53.2%	60.8%	51.3%	52.8%	60.5%	52.5%	53.7%
9	37.4%	42.4%	61.4%	59.5%	44.2%	61.3%	59.8%	52.6%	54.0%	62.3%	52.6%	53.7%	63.0%	53.4%	53.5%
10	38.3%	43.7%	63.2%	61.4%	44.3%	62.8%	61.2%	54.0%	55.0%	64.9%	53.5%	55.3%	64.7%	54.5%	54.9%
11	38.3%	43.6%	65.8%	62.8%	44.1%	64.8%	63.5%	55.7%	56.7%	66.1%	55.5%	56.9%	65.9%	56.3%	56.4%
12	39.0%	44.1%	65.1%	64.3%	45.3%	65.2%	64.4%	57.7%	57.8%	66.7%	57.5%	57.2%	67.2%	58.8%	58.0%
13	39.2%	44.5%	65.7%	66.0%	45.7%	65.0%	65.5%	58.9%	57.4%	67.5%	57.7%	57.5%	67.6%	59.2%	58.9%
14	39.1%	44.9%	66.1%	66.9%	44.6%	66.1%	67.0%	57.9%	58.6%	69.3%	59.1%	58.6%	68.4%	58.8%	59.3%
15	40.1%	45.6%	66.6%	67.5%	45.9%	65.4%	68.5%	58.3%	60.6%	70.1%	59.3%	60.3%	70.3%	59.5%	58.7%
16	40.1%	45.2%	67.4%	69.6%	45.5%	67.0%	68.7%	59.1%	61.2%	71.2%	60.7%	62.2%	71.3%	61.6%	60.2%
17	39.3%	45.8%	68.0%	70.7%	46.4%	67.4%	70.2%	61.4%	63.2%	72.2%	60.8%	63.0%	72.1%	62.2%	62.3%
18	39.7%	46.0%	68.3%	70.8%	45.7%	68.2%	70.7%	61.6%	64.3%	73.0%	61.5%	64.3%	71.8%	62.5%	63.7%
19	39.8%	45.1%	68.7%	72.0%	46.4%	68.5%	71.7%	61.2%	64.2%	73.5%	62.1%	65.0%	73.7%	64.2%	62.8%
20	40.2%	46.8%	69.3%	72.4%	46.8%	69.8%	71.8%	62.4%	64.6%	73.5%	61.6%	65.0%	73.3%	64.7%	65.2%

Table 4-36: Decision tree database F SINRD external position.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	17.5%	20.4%	22.2%	26.3%	18.7%	22.9%	26.8%	22.4%	26.8%	26.2%	23.0%	26.8%	26.4%	26.9%	26.5%
2	17.6%	20.0%	27.0%	32.4%	20.4%	26.7%	32.5%	26.5%	32.2%	32.3%	26.8%	32.0%	31.9%	32.4%	32.3%
3	18.4%	20.1%	29.2%	35.3%	21.2%	29.8%	35.7%	29.3%	35.9%	36.3%	29.5%	36.0%	35.8%	35.5%	36.2%
4	19.3%	20.2%	33.8%	38.6%	22.8%	33.8%	37.9%	33.5%	38.3%	38.6%	33.7%	38.6%	37.7%	36.8%	37.9%
5	20.6%	19.7%	36.2%	41.1%	23.6%	36.5%	40.8%	35.8%	41.3%	40.3%	35.6%	41.2%	40.1%	40.8%	40.3%
6	20.3%	19.5%	37.8%	40.6%	23.6%	37.7%	41.2%	37.4%	41.5%	39.8%	37.8%	41.3%	40.1%	39.7%	40.1%
7	20.2%	19.0%	38.1%	40.4%	24.1%	37.9%	41.2%	37.7%	40.2%	40.8%	38.3%	41.3%	39.8%	40.5%	40.0%
8	21.2%	18.4%	39.6%	42.6%	25.5%	38.7%	42.6%	39.3%	41.4%	42.4%	39.1%	42.6%	41.4%	41.1%	41.2%
9	21.0%	19.0%	40.6%	43.1%	25.8%	40.9%	41.5%	39.7%	42.3%	42.9%	40.5%	42.7%	43.0%	42.7%	42.5%
10	20.3%	19.1%	40.0%	43.4%	25.9%	40.7%	44.3%	40.0%	43.5%	43.7%	40.5%	43.3%	43.5%	43.4%	43.8%
11	20.8%	18.8%	39.5%	45.0%	26.3%	40.0%	45.0%	40.1%	44.1%	44.9%	40.9%	44.7%	44.6%	44.0%	45.6%
12	20.4%	19.5%	40.1%	46.0%	26.2%	40.7%	45.2%	39.8%	46.0%	44.7%	40.8%	45.5%	45.6%	45.3%	45.0%
13	20.7%	19.6%	40.8%	45.8%	27.1%	40.6%	45.7%	40.4%	45.6%	46.5%	40.8%	44.9%	45.6%	45.2%	45.1%
14	20.8%	19.9%	39.6%	46.1%	26.3%	40.7%	45.7%	40.3%	45.1%	46.6%	41.1%	45.3%	45.7%	45.7%	45.8%
15	21.4%	19.8%	40.4%	46.2%	27.1%	41.2%	46.1%	40.3%	45.9%	47.2%	42.1%	45.2%	46.7%	46.8%	47.3%
16	20.6%	20.0%	40.5%	47.1%	27.2%	41.6%	48.1%	40.7%	46.7%	49.0%	41.9%	47.6%	48.0%	48.6%	48.7%
17	21.2%	20.0%	39.8%	49.2%	26.9%	40.8%	48.8%	40.9%	48.7%	48.9%	42.7%	48.5%	49.6%	49.1%	48.9%
18	21.3%	19.6%	40.3%	49.2%	27.5%	42.3%	49.0%	40.5%	49.2%	50.2%	42.4%	48.9%	50.0%	49.3%	49.9%
19	20.5%	19.9%	40.9%	50.7%	28.0%	41.8%	49.6%	40.4%	50.9%	50.8%	43.6%	49.7%	51.0%	50.7%	50.7%
20	21.0%	19.9%	40.2%	51.8%	27.8%	41.6%	51.8%	40.2%	51.5%	52.0%	43.3%	51.6%	51.3%	52.0%	50.9%

Table 4-37: Decision tree database F SINRD all positions.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# SPLITS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	17.4%	19.7%	26.7%	29.5%	18.0%	27.0%	29.4%	26.4%	29.5%	29.4%	26.2%	29.5%	29.4%	29.4%	29.4%
2	17.4%	21.6%	33.2%	37.9%	20.0%	33.3%	37.7%	34.0%	38.2%	38.2%	33.9%	37.7%	37.9%	37.3%	38.1%
3	19.3%	23.0%	37.7%	42.4%	21.7%	37.4%	42.1%	37.5%	42.5%	42.2%	36.9%	42.5%	42.6%	42.2%	42.3%
4	21.1%	26.2%	40.8%	49.7%	22.3%	41.3%	50.1%	40.2%	50.1%	49.6%	40.7%	49.8%	49.5%	49.9%	50.1%
5	23.0%	25.6%	44.3%	54.2%	24.2%	44.8%	54.8%	44.0%	54.4%	54.9%	43.5%	54.6%	54.9%	54.2%	54.5%
6	23.6%	26.2%	45.4%	55.7%	25.3%	44.8%	55.8%	45.8%	55.4%	55.1%	44.9%	55.4%	54.6%	55.5%	55.6%
7	23.6%	26.6%	47.3%	56.6%	25.2%	47.7%	56.7%	46.9%	56.6%	57.0%	46.6%	57.2%	57.1%	56.6%	56.6%
8	24.5%	27.2%	48.3%	57.3%	27.5%	48.6%	58.0%	48.2%	57.6%	58.3%	48.3%	57.8%	57.6%	57.6%	57.9%
9	24.8%	26.6%	50.0%	59.7%	28.4%	50.0%	59.7%	49.1%	59.6%	59.5%	49.0%	59.3%	59.8%	60.0%	58.9%
10	24.4%	27.8%	50.6%	60.4%	29.1%	50.3%	61.1%	50.6%	61.0%	61.1%	50.2%	60.6%	61.1%	60.3%	61.4%
11	25.1%	28.8%	50.9%	62.6%	28.2%	50.5%	62.4%	51.4%	63.1%	62.6%	50.9%	62.8%	62.3%	62.7%	62.5%
12	25.3%	29.9%	51.8%	63.1%	29.2%	50.6%	63.3%	51.9%	63.8%	62.7%	51.8%	63.6%	62.0%	63.1%	63.2%
13	25.1%	31.1%	51.8%	64.0%	29.5%	51.8%	63.2%	52.1%	63.4%	63.2%	51.3%	64.4%	63.8%	63.6%	63.1%
14	24.6%	30.7%	53.3%	64.9%	30.7%	53.1%	64.7%	52.2%	64.7%	64.1%	52.7%	64.9%	64.0%	64.3%	64.2%
15	25.5%	30.5%	54.4%	66.0%	31.0%	53.9%	65.8%	54.3%	65.8%	65.2%	54.0%	65.5%	65.3%	65.4%	65.5%
16	24.7%	31.7%	55.1%	67.4%	29.8%	54.5%	66.8%	54.2%	67.3%	67.2%	54.4%	66.9%	66.6%	66.2%	66.6%
17	24.5%	32.1%	55.9%	68.3%	31.1%	55.2%	67.6%	55.3%	68.0%	67.9%	55.5%	68.9%	68.0%	67.9%	67.5%
18	24.3%	33.6%	56.7%	68.6%	31.0%	55.7%	69.5%	56.6%	69.2%	68.8%	56.7%	69.2%	69.6%	69.6%	69.1%
19	25.4%	32.2%	56.4%	70.5%	32.5%	57.8%	69.6%	56.4%	70.3%	69.5%	56.9%	69.4%	69.6%	70.1%	69.7%
20	24.4%	32.6%	56.4%	71.2%	31.3%	57.5%	70.6%	56.9%	70.4%	70.6%	56.2%	70.5%	70.0%	70.4%	70.9%

4.2 KNN

4.2.1 Databases F (distance weight: Equal)

This chapter shows the accuracies calculated using the KNN method using the equal distance weight for databases F. As for the results of the decision tree, in order to reduce the length of this document, in the case of SINRD and PDET only the results for the detectors in external positions and taking all the positions of the detectors are shown. In this case the tables were cut at 30 neighbors to provide a more clear visualization. Increasing the number of neighbors above 30 the calculated accuracies are significantly lower. The results in this chapter are divided in three parts: the first with the accuracies calculated using the Fork detector databases, the second with the PDET database and the last with SINRD database. For each detector the accuracies were calculated using six different types of distance metric: Euclidean, City Block, Chebychev, Cubic, Mahalanobis and Cosine, but only the results obtained for Euclidean, Mahalanobis and Cosine will be shown to reduce the length of the document. The choice of these metrics is explained further in the following sections.

4.2.1.1 Fork detector

The tables from 4-38 to 4-43 show in order the results of the Fork detector database in the diversion case and then the accuracies calculated with the replacement database for the three distance metrics previous listed.

Comparing the results using Euclidean, City Block, Chebychev, and Cubic distance metric it was observed that using the same positions of the detectors the accuracies show similar pattern, and for this reason only the results for the Euclidean metric were reported in this thesis.

Starting from the results of the diversion database it was observed that unlike the results for the decision trees the current show the worst results as single feature for each distance metric except for the cosine, in which the accuracies using the three features have similar trends. In the other cases NwithCd and NwithoutCd show a similar trend that initially increases, reaching accuracies around 60% with about 10 neighbors, and then stabilizes or slightly decreases, and finally decreases with more than 30 neighbors. The accuracies calculated with 50 neighbors are around 40%. For the current this trend is less evident because the accuracy values oscillate around 30% and 40%.

Using the combinations of more features it is possible to observe that the combinations NwithCd-NwithoutCd and the combination of all the features show the best results for each distance metric expect for the Mahalanobis method in which the highest accuracies are provided by the single features NwithCd or NwithoutCd. For all other cases these two combinations provide the maximum values of the accuracies around 68% and as for the case of the single features after an initial increase they tend to stabilize and then they decrease to values around 40%. The combinations of one neutron feature (NwithCd or NwithoutCd) with the current show no relevant differences from the trend obtained using one single feature alone.

The same considerations can be applied for the replacement results, with a global slight decrease of the values of the accuracies. For example, the maximum accuracy value decreases from values near 68% to values around 63%.

The standard deviation calculated for the accuracies of the diversion case is included between 2% and 4%, whereas it is included between 2% and 3% for the replacement cases.

4.2.1.2 PDET

In this section the accuracies for PDET are analyzed focusing on the results of the three distance metrics listed in chapter 4.2.1. All the accuracies have a standard deviation within 4%.

As for the previous section, the results using the City Block, Chebychev, and Cubic distance metrics are not included in this thesis because they showed similar values and trends compared to the Euclidean distance metric.

Considering the results obtained using the Euclidean distance metric, the accuracies show a decreasing trend increasing the number of numbers of neighbors or in some case remain almost constant taking only one position of the detectors.

An example of this pattern is shown in table 4-44, in which it is possible to observe globally a decreasing trend except for the single features TH and RES that remain almost constant. The decreasing trend is more evident for features with higher accuracies: in fact, P decreases from accuracy values around 85% to 52% and the combination of FA and P, that provides the best accuracy results in the external positions, decreases from 89% to 57%.

Using all detector positions the Euclidean distance metric show better results reaching values of 100% for P and the combination FA-P. Unlike the external positions TH and RES show a decreasing trend but with higher values. Also the feature FA presents a relevant increase in the values compared to the single position.

The Mahalanobis distance metric shows slightly lower results compared to Euclidean both for single positions and combinations, but it is able to reach an accuracy of 100% with the feature P using all detectors positions.

The Cosine distance metric shows the worst results in particular using one single position. As shown in table 4-48 the accuracies are included between 15% and 40% for the single features and all combinations. Taking all detectors positions the results are more similar to the other distance metrics.

The standard deviation calculated for each distance metric are within 5%.

4.3.1.3 SINRD

The considerations made for PDET can be extended also to the results of the SINRD technique. The results show the same trends of PDET with some slightly lower values; for example as shown in table 4-50, the accuracy calculated with the feature combination FA-P shows a relevant decrease from 89% for PDET to 68% for SINRD. As for PDET the standard deviations calculated for each distance metric are within 5%.

Table 4-38: KNN database F Fork detector diversion Euclidean distance metric.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	53.0%	52.9%	35.2%	67.4%	53.1%	52.7%	67.5%
2	51.3%	50.9%	33.1%	63.4%	51.3%	50.5%	63.7%
3	56.5%	56.5%	35.9%	68.0%	56.4%	56.5%	67.8%
4	57.6%	57.7%	37.1%	67.0%	58.2%	57.5%	66.8%
5	59.4%	59.1%	37.7%	67.2%	59.2%	58.8%	66.5%
6	59.0%	59.3%	38.5%	65.8%	60.2%	59.7%	65.5%
7	61.1%	60.7%	39.4%	66.0%	60.0%	60.7%	65.5%
8	60.1%	61.1%	38.7%	64.7%	60.5%	61.1%	65.9%
9	60.8%	60.9%	39.2%	64.5%	60.5%	61.3%	64.6%
10	60.7%	61.2%	39.0%	64.0%	60.7%	61.2%	64.1%
11	60.5%	60.4%	38.8%	63.3%	60.7%	60.1%	62.7%
12	59.9%	59.7%	38.0%	63.1%	60.4%	60.5%	61.6%
13	60.6%	58.5%	38.6%	62.0%	60.1%	58.3%	61.5%
14	60.1%	58.3%	37.5%	61.2%	59.1%	58.8%	61.2%
15	59.8%	58.2%	36.0%	60.1%	59.9%	58.6%	60.8%
16	58.9%	57.6%	37.0%	59.8%	59.4%	57.7%	59.6%
17	58.5%	57.1%	35.7%	59.3%	58.9%	57.2%	59.1%
18	58.4%	56.7%	35.1%	58.0%	59.2%	56.9%	58.6%
19	59.3%	56.2%	34.1%	57.8%	59.1%	56.0%	57.3%
20	58.6%	56.2%	33.8%	57.6%	58.7%	56.1%	56.9%
21	58.0%	55.5%	34.0%	57.2%	58.1%	54.9%	57.8%
22	58.2%	55.6%	34.5%	57.5%	57.5%	55.3%	57.3%
23	57.9%	55.7%	33.2%	57.0%	57.5%	55.3%	56.6%
24	58.1%	55.2%	33.1%	56.8%	57.3%	55.3%	56.2%
25	57.4%	55.6%	32.7%	56.0%	57.5%	55.0%	55.9%
26	57.8%	55.1%	32.7%	56.5%	57.7%	54.2%	56.0%
27	57.5%	55.2%	32.5%	56.3%	57.4%	54.1%	56.6%
28	57.6%	54.2%	32.2%	56.5%	57.0%	54.2%	55.9%
29	57.1%	53.9%	32.8%	56.0%	57.0%	54.1%	55.4%
30	56.3%	53.7%	31.3%	55.9%	56.7%	54.5%	55.2%
31	55.9%	52.8%	32.4%	55.1%	55.6%	53.4%	54.7%
32	54.9%	53.5%	31.9%	55.1%	55.4%	52.8%	54.9%
33	54.7%	52.6%	31.1%	53.8%	54.4%	51.4%	54.4%
34	53.3%	52.0%	32.0%	53.1%	53.0%	51.6%	53.4%
35	52.8%	51.4%	32.0%	52.0%	53.5%	50.7%	53.2%
36	52.5%	50.4%	32.1%	52.0%	52.4%	50.4%	50.5%
37	51.5%	49.7%	31.3%	50.9%	51.5%	49.5%	50.4%
38	50.4%	49.7%	31.2%	49.5%	51.1%	48.7%	49.5%
39	49.2%	47.2%	30.4%	48.4%	49.9%	47.8%	48.6%
40	47.7%	47.2%	30.8%	47.4%	48.5%	46.9%	47.9%
41	47.1%	45.9%	30.4%	46.9%	47.8%	46.9%	46.4%
42	47.2%	45.0%	30.2%	46.1%	47.0%	45.6%	46.1%
43	46.0%	44.0%	30.6%	45.0%	45.9%	45.3%	44.7%
44	45.4%	44.2%	29.8%	44.0%	45.5%	43.4%	44.0%
45	44.2%	42.6%	30.9%	42.8%	44.4%	42.4%	42.5%
46	43.6%	42.6%	30.6%	41.8%	42.9%	42.0%	42.1%
47	42.4%	41.6%	30.3%	41.2%	43.0%	41.7%	40.5%
48	41.5%	41.3%	29.6%	40.6%	41.6%	41.0%	40.9%
49	41.3%	40.2%	30.0%	39.3%	40.7%	39.5%	40.5%
50	40.3%	39.0%	30.6%	39.5%	40.5%	39.2%	38.4%

Table 4-39: KNN database F Fork detector diversion Mahalanobis distance metric.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	52.5%	53.1%	36.2%	58.9%	59.2%	58.0%	55.3%
2	50.6%	51.0%	32.9%	54.1%	56.2%	54.8%	49.6%
3	58.4%	56.3%	36.6%	55.2%	57.2%	56.0%	52.2%
4	58.3%	57.3%	36.6%	53.8%	58.5%	56.5%	52.3%
5	59.2%	59.3%	38.4%	51.3%	57.7%	56.0%	52.6%
6	59.9%	60.2%	39.1%	50.6%	57.5%	55.5%	50.7%
7	59.9%	60.9%	38.9%	48.8%	56.9%	55.0%	52.2%
8	60.2%	61.1%	38.8%	47.2%	55.1%	53.6%	50.8%
9	60.8%	60.7%	39.6%	48.1%	55.1%	52.8%	50.0%
10	60.6%	60.9%	39.6%	46.9%	55.1%	53.3%	50.5%
11	60.6%	60.0%	39.2%	46.5%	54.3%	53.3%	49.9%
12	59.9%	59.9%	38.7%	45.7%	53.6%	51.9%	48.7%
13	60.5%	59.8%	37.8%	44.3%	52.3%	51.3%	48.7%
14	60.1%	59.2%	37.1%	44.2%	51.1%	50.4%	47.4%
15	59.3%	58.3%	36.8%	43.1%	51.5%	50.2%	46.3%
16	59.8%	58.0%	36.3%	42.6%	50.3%	49.7%	46.7%
17	59.0%	57.6%	36.0%	43.4%	49.6%	49.6%	45.6%
18	58.7%	56.4%	34.5%	42.6%	48.8%	48.2%	46.0%
19	58.7%	56.4%	34.0%	42.3%	47.9%	47.0%	45.6%
20	57.9%	55.5%	34.2%	41.7%	47.8%	47.9%	45.0%
21	58.6%	55.2%	33.9%	41.1%	46.5%	46.3%	44.5%
22	58.1%	55.0%	34.0%	41.2%	47.3%	46.1%	44.6%
23	57.9%	55.0%	33.3%	40.6%	47.3%	45.6%	44.7%
24	57.8%	55.0%	33.0%	41.0%	44.8%	45.3%	43.2%
25	57.3%	55.4%	33.3%	40.6%	46.0%	44.3%	42.4%
26	57.7%	54.9%	33.5%	38.9%	45.0%	43.5%	42.6%
27	58.2%	54.4%	33.3%	38.7%	44.7%	42.1%	43.1%
28	57.4%	54.3%	32.7%	39.0%	43.0%	42.4%	42.2%
29	57.0%	53.9%	32.0%	37.8%	41.6%	41.5%	41.3%
30	56.1%	54.4%	32.0%	38.4%	41.8%	41.3%	40.5%
31	56.3%	54.3%	31.3%	39.2%	40.9%	40.5%	40.6%
32	55.0%	52.8%	32.5%	38.8%	39.7%	40.1%	40.4%
33	55.4%	53.0%	32.9%	37.9%	40.1%	38.9%	40.1%
34	54.0%	51.4%	31.6%	37.7%	38.9%	38.3%	40.1%
35	52.7%	50.9%	31.3%	37.6%	38.9%	38.1%	40.0%
36	51.9%	50.7%	31.2%	38.0%	38.6%	38.0%	39.4%
37	52.0%	48.7%	30.4%	37.7%	37.4%	38.3%	39.6%
38	50.6%	48.5%	30.8%	37.3%	37.8%	37.3%	39.7%
39	48.7%	47.9%	30.6%	37.2%	37.1%	37.0%	39.3%
40	48.7%	47.2%	30.8%	37.4%	37.3%	37.0%	39.0%
41	47.3%	46.1%	31.4%	37.4%	37.4%	36.7%	39.0%
42	47.4%	45.5%	30.5%	36.5%	37.1%	36.0%	38.6%
43	45.2%	44.3%	30.0%	35.5%	35.5%	36.6%	39.1%
44	44.2%	43.7%	30.1%	37.0%	35.9%	35.6%	38.8%
45	45.2%	42.9%	30.1%	36.1%	36.0%	35.4%	38.5%
46	43.6%	41.7%	30.6%	35.7%	35.6%	35.1%	39.2%
47	42.3%	41.3%	30.1%	35.9%	35.5%	35.2%	38.5%
48	41.9%	40.2%	29.7%	36.2%	34.3%	34.2%	39.3%
49	41.1%	39.3%	29.6%	36.0%	34.2%	34.3%	38.2%
50	40.5%	39.3%	29.8%	35.5%	34.4%	33.4%	38.2%

Table 4-40: KNN database F Fork detector diversion Cosine distance metric.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	15.7%	15.2%	16.5%	29.3%	18.0%	13.7%	29.2%
2	15.8%	16.8%	15.6%	32.0%	17.1%	16.4%	31.5%
3	16.1%	15.2%	14.3%	32.3%	16.2%	16.7%	32.4%
4	14.8%	16.8%	15.3%	33.5%	16.2%	16.0%	33.4%
5	16.6%	15.4%	16.7%	34.2%	16.8%	16.9%	33.6%
6	15.7%	15.5%	16.0%	33.6%	14.9%	19.2%	34.2%
7	15.9%	16.2%	14.6%	34.7%	17.7%	17.9%	35.5%
8	15.1%	16.4%	16.4%	35.4%	17.0%	15.7%	35.4%
9	16.2%	16.7%	15.9%	36.8%	16.5%	17.6%	36.9%
10	16.8%	16.4%	14.9%	36.7%	17.5%	16.1%	36.7%
11	16.4%	14.5%	17.0%	38.3%	15.3%	17.1%	37.5%
12	15.9%	15.1%	15.1%	37.3%	19.1%	15.7%	37.0%
13	16.7%	16.2%	16.2%	37.5%	18.3%	16.7%	37.7%
14	16.0%	14.9%	15.9%	37.7%	17.4%	15.8%	38.0%
15	13.8%	15.3%	14.7%	38.1%	17.0%	16.0%	37.7%
16	16.5%	16.7%	15.6%	37.9%	17.1%	16.4%	38.4%
17	16.1%	14.5%	15.2%	38.7%	16.9%	16.0%	38.9%
18	16.2%	15.8%	15.7%	38.7%	16.7%	16.4%	38.9%
19	15.7%	17.7%	16.4%	37.9%	17.6%	18.2%	38.4%
20	15.9%	17.6%	16.4%	38.4%	18.2%	17.4%	38.7%
21	15.5%	15.9%	16.2%	38.8%	17.9%	16.9%	38.7%
22	15.7%	16.0%	16.2%	38.3%	16.5%	15.4%	37.9%
23	16.2%	16.9%	15.3%	39.5%	18.5%	16.3%	39.2%
24	17.1%	16.2%	14.6%	38.5%	15.1%	17.9%	39.5%
25	15.9%	15.9%	15.5%	38.9%	18.6%	16.0%	39.1%
26	15.8%	16.3%	16.6%	39.4%	17.2%	17.6%	39.5%
27	15.8%	14.3%	17.3%	39.2%	17.5%	16.9%	40.0%
28	16.3%	16.0%	16.2%	40.0%	16.7%	17.0%	39.5%
29	14.6%	16.0%	14.2%	39.5%	17.4%	17.6%	39.9%
30	15.7%	16.1%	16.3%	39.0%	17.6%	16.5%	39.1%
31	16.3%	15.7%	16.7%	39.6%	17.4%	16.9%	39.9%
32	15.6%	16.7%	15.7%	39.8%	17.3%	15.5%	39.4%
33	14.1%	17.1%	15.9%	39.4%	16.4%	14.9%	39.4%
34	16.4%	16.1%	16.3%	40.0%	17.9%	16.7%	39.5%
35	16.8%	16.1%	16.2%	39.2%	17.9%	16.8%	39.3%
36	16.0%	16.1%	16.2%	39.2%	17.5%	17.0%	39.7%
37	15.8%	16.1%	15.9%	39.7%	15.7%	16.5%	39.8%
38	17.0%	15.0%	17.0%	39.4%	17.8%	15.9%	39.4%
39	14.9%	15.2%	17.7%	39.8%	17.4%	17.6%	39.3%
40	16.4%	17.2%	15.4%	39.6%	17.2%	15.6%	39.2%
41	17.2%	15.9%	17.0%	39.9%	17.5%	16.1%	39.8%
42	15.0%	16.4%	15.0%	39.3%	17.4%	15.3%	39.6%
43	15.5%	16.1%	16.6%	39.9%	15.7%	16.1%	40.1%
44	16.6%	16.8%	17.2%	40.3%	18.4%	15.9%	40.1%
45	16.9%	15.5%	15.4%	39.6%	16.6%	18.4%	40.2%
46	16.1%	15.2%	15.8%	40.2%	18.1%	18.2%	39.4%
47	17.0%	17.2%	17.0%	40.2%	17.7%	18.2%	39.8%
48	16.6%	16.0%	16.5%	39.6%	16.3%	16.1%	40.0%
49	16.6%	17.4%	17.2%	40.3%	16.0%	15.8%	40.2%
50	16.3%	16.2%	17.3%	40.1%	18.2%	13.7%	40.5%

Table 4-41: KNN database F Fork detector replacement Euclidean distance metric.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	47.6%	52.1%	32.8%	60.7%	48.0%	52.6%	60.6%
2	46.1%	50.4%	31.7%	55.8%	45.5%	51.5%	57.1%
3	50.8%	56.5%	32.1%	61.7%	51.1%	56.6%	62.1%
4	53.3%	57.6%	33.3%	61.1%	53.7%	57.3%	61.9%
5	55.0%	59.1%	35.5%	62.7%	55.7%	58.8%	62.8%
6	56.2%	60.1%	37.3%	63.3%	56.6%	59.7%	62.9%
7	55.9%	60.4%	37.5%	62.9%	57.5%	60.6%	63.0%
8	57.4%	61.9%	38.2%	62.3%	57.3%	61.4%	62.0%
9	57.7%	60.7%	38.1%	62.5%	57.2%	61.5%	62.3%
10	56.5%	60.4%	38.9%	61.6%	57.2%	60.7%	61.7%
11	57.1%	59.7%	38.3%	61.0%	56.7%	60.5%	60.9%
12	55.7%	59.5%	38.7%	60.5%	56.1%	59.1%	60.6%
13	56.1%	59.1%	38.8%	59.2%	55.9%	59.4%	60.1%
14	55.7%	59.0%	37.5%	59.5%	55.5%	58.1%	59.0%
15	54.6%	58.3%	37.9%	58.5%	55.2%	57.8%	57.8%
16	55.2%	58.0%	38.6%	57.5%	54.6%	57.5%	58.1%
17	54.5%	56.7%	38.2%	56.7%	54.7%	57.4%	56.9%
18	54.3%	56.7%	37.8%	56.6%	53.9%	57.1%	56.1%
19	54.1%	55.9%	37.8%	55.6%	54.0%	56.6%	56.0%
20	54.1%	55.9%	37.5%	55.4%	53.2%	56.2%	55.7%
21	53.1%	55.8%	37.7%	55.2%	53.0%	56.0%	55.4%
22	52.8%	55.9%	37.4%	55.1%	52.8%	55.3%	55.2%
23	52.0%	55.6%	38.2%	54.6%	52.4%	55.0%	55.5%
24	52.5%	55.2%	37.3%	55.3%	52.3%	55.0%	54.9%
25	53.0%	55.1%	37.5%	54.7%	52.0%	55.3%	54.9%
26	51.9%	54.6%	37.3%	54.3%	52.6%	54.7%	54.8%
27	51.8%	55.3%	37.0%	54.6%	53.0%	54.8%	54.7%
28	52.0%	54.4%	36.8%	54.2%	51.7%	53.7%	54.4%
29	51.4%	54.8%	36.5%	53.7%	51.5%	54.5%	53.8%
30	51.5%	53.4%	37.0%	53.8%	50.9%	53.9%	54.2%
31	51.4%	53.4%	36.4%	53.9%	51.3%	53.8%	53.9%
32	50.8%	52.7%	36.0%	53.4%	50.7%	52.9%	53.7%
33	49.6%	53.3%	36.0%	52.3%	51.0%	52.9%	52.2%
34	49.4%	52.1%	36.1%	51.5%	49.4%	51.7%	52.4%
35	49.1%	50.3%	36.0%	51.6%	49.2%	51.0%	51.2%
36	48.2%	49.9%	36.7%	50.4%	48.4%	50.1%	50.0%
37	48.9%	50.1%	35.4%	49.0%	48.4%	49.3%	48.8%
38	46.5%	49.2%	36.5%	48.5%	47.1%	49.2%	48.6%
39	47.0%	48.6%	36.6%	47.9%	46.9%	47.6%	48.5%
40	46.6%	47.2%	35.1%	46.8%	47.0%	47.0%	46.3%
41	45.6%	45.3%	36.1%	45.7%	45.2%	46.3%	46.8%
42	45.8%	45.3%	36.2%	44.9%	44.9%	45.6%	45.5%
43	44.2%	44.5%	36.5%	44.0%	44.7%	44.5%	45.1%
44	43.2%	44.5%	36.2%	44.1%	43.8%	43.6%	43.1%
45	43.2%	43.6%	35.8%	43.1%	43.7%	42.6%	43.1%
46	42.6%	42.3%	35.3%	40.9%	42.4%	42.0%	41.9%
47	42.4%	40.7%	36.3%	41.7%	42.2%	41.7%	41.2%
48	41.2%	40.9%	35.9%	41.4%	41.3%	41.2%	41.1%
49	40.8%	39.2%	36.2%	39.8%	40.7%	40.1%	40.2%
50	40.0%	39.0%	36.8%	38.3%	41.0%	38.6%	39.8%

Table 4-42: KNN database F Fork detector replacement Mahalanobis distance metric.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	47.5%	52.9%	32.1%	50.4%	55.8%	55.0%	52.2%
2	45.6%	50.5%	32.0%	49.3%	52.7%	54.0%	49.3%
3	50.9%	55.9%	32.0%	48.7%	53.8%	53.4%	50.5%
4	53.8%	57.8%	33.2%	47.5%	54.2%	53.5%	49.5%
5	56.0%	59.1%	35.1%	47.0%	54.3%	54.3%	48.5%
6	56.7%	60.2%	37.4%	44.8%	53.6%	53.4%	48.4%
7	57.1%	60.7%	38.3%	44.3%	53.0%	53.2%	47.7%
8	56.8%	60.6%	38.5%	43.7%	52.9%	52.9%	46.3%
9	56.9%	60.5%	38.9%	42.7%	52.1%	52.6%	45.2%
10	56.7%	61.0%	38.4%	42.7%	51.7%	51.9%	44.9%
11	56.2%	60.5%	39.0%	41.2%	50.7%	50.7%	43.0%
12	56.4%	60.0%	39.1%	40.6%	50.6%	50.5%	42.7%
13	56.1%	59.2%	38.8%	39.0%	49.2%	50.3%	42.5%
14	55.9%	59.0%	38.1%	38.5%	49.2%	49.9%	41.4%
15	55.3%	57.8%	38.4%	37.7%	49.1%	48.6%	40.8%
16	54.9%	57.7%	38.1%	37.2%	48.5%	47.0%	41.2%
17	54.1%	56.6%	38.0%	37.5%	47.1%	47.5%	40.2%
18	53.8%	56.2%	38.1%	36.1%	46.5%	46.0%	39.6%
19	54.2%	56.6%	37.6%	35.5%	47.0%	45.8%	40.3%
20	53.0%	56.5%	38.6%	35.6%	45.3%	45.1%	39.3%
21	53.1%	55.0%	37.5%	34.8%	45.8%	44.8%	39.2%
22	52.7%	55.4%	37.8%	34.9%	45.7%	43.8%	39.0%
23	52.6%	55.5%	38.3%	34.2%	45.7%	43.7%	38.7%
24	52.2%	55.1%	37.6%	33.9%	44.2%	43.6%	38.6%
25	52.2%	55.0%	38.2%	34.1%	44.5%	43.0%	37.8%
26	52.3%	54.3%	37.1%	32.5%	44.1%	43.5%	38.5%
27	52.0%	54.3%	37.1%	33.1%	43.3%	42.8%	38.2%
28	51.7%	55.0%	36.8%	33.0%	42.9%	43.3%	37.6%
29	51.0%	53.8%	36.3%	32.5%	42.1%	42.1%	37.5%
30	51.2%	54.4%	36.5%	32.3%	43.1%	42.0%	37.0%
31	50.2%	53.7%	36.4%	32.5%	42.6%	41.6%	36.4%
32	51.7%	53.0%	36.7%	31.8%	43.0%	40.5%	37.3%
33	50.1%	52.6%	35.7%	32.0%	42.7%	42.2%	36.7%
34	49.7%	51.9%	36.1%	31.3%	42.9%	41.4%	36.6%
35	48.5%	51.7%	35.3%	32.4%	43.6%	41.8%	36.1%
36	48.5%	50.1%	35.3%	31.8%	41.9%	40.6%	36.8%
37	47.6%	49.3%	35.8%	31.5%	41.5%	40.4%	36.6%
38	46.9%	49.1%	36.1%	31.5%	41.8%	40.0%	36.8%
39	46.6%	48.4%	36.3%	31.0%	41.2%	40.2%	36.5%
40	46.9%	46.5%	35.7%	31.9%	41.4%	39.2%	36.7%
41	45.6%	46.2%	36.2%	31.4%	41.0%	39.2%	36.6%
42	44.3%	45.5%	36.1%	30.7%	40.3%	39.1%	35.9%
43	45.1%	43.8%	35.8%	31.2%	39.7%	38.6%	37.3%
44	44.5%	43.7%	36.7%	30.5%	39.6%	38.6%	36.3%
45	42.9%	43.1%	35.7%	30.5%	39.4%	38.7%	37.3%
46	42.5%	42.2%	36.7%	31.0%	39.3%	37.7%	37.5%
47	42.6%	41.2%	36.2%	30.5%	38.6%	38.3%	37.6%
48	41.5%	40.8%	36.3%	30.8%	39.1%	36.9%	36.5%
49	40.4%	40.0%	36.5%	31.6%	38.1%	37.9%	36.9%
50	40.2%	38.8%	35.8%	31.5%	37.7%	37.3%	37.3%

Table 4-43: KNN database F Fork detector replacement Cosine distance metric.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	14.1%	16.1%	15.2%	22.8%	16.1%	16.1%	23.6%
2	15.2%	16.0%	15.2%	25.2%	17.0%	16.6%	24.5%
3	15.1%	15.7%	14.7%	25.3%	17.9%	16.8%	25.0%
4	16.2%	14.3%	16.6%	25.4%	17.2%	15.4%	25.9%
5	16.1%	15.2%	16.3%	26.7%	16.8%	15.6%	26.1%
6	16.1%	16.3%	15.4%	26.3%	18.4%	16.4%	27.4%
7	16.0%	15.6%	13.5%	27.5%	17.1%	16.5%	27.2%
8	14.9%	16.4%	19.0%	28.0%	16.7%	15.5%	29.0%
9	14.8%	16.7%	14.4%	28.1%	17.3%	17.1%	28.0%
10	16.3%	15.7%	15.4%	28.5%	15.2%	16.9%	27.8%
11	15.1%	14.8%	14.0%	28.0%	18.0%	16.8%	27.5%
12	15.7%	16.8%	16.3%	28.6%	18.2%	16.3%	27.8%
13	15.6%	15.9%	14.8%	29.1%	17.2%	15.2%	28.5%
14	17.0%	16.3%	15.8%	27.8%	18.1%	16.3%	27.7%
15	13.8%	14.9%	15.9%	28.4%	18.0%	17.1%	28.3%
16	16.0%	14.9%	17.1%	28.0%	17.0%	15.8%	28.2%
17	16.7%	15.2%	15.5%	28.9%	17.2%	17.2%	28.7%
18	16.4%	16.9%	15.1%	29.1%	16.4%	16.0%	28.2%
19	15.2%	15.0%	15.3%	28.7%	19.4%	16.9%	28.4%
20	17.3%	16.1%	16.0%	28.8%	17.1%	17.0%	28.4%
21	15.5%	16.5%	16.6%	28.7%	18.3%	15.0%	28.9%
22	17.4%	14.6%	16.9%	29.3%	16.7%	17.4%	28.4%
23	17.9%	15.7%	15.4%	28.6%	17.0%	17.0%	28.9%
24	15.4%	17.2%	16.8%	29.1%	18.3%	15.7%	29.1%
25	16.0%	15.9%	17.5%	29.0%	16.9%	17.3%	29.5%
26	17.1%	16.9%	14.4%	29.6%	17.4%	15.3%	29.7%
27	16.8%	17.1%	14.8%	29.6%	15.9%	16.5%	29.8%
28	17.3%	15.9%	16.9%	29.6%	16.7%	15.1%	29.8%
29	16.4%	17.1%	16.3%	30.0%	17.5%	18.1%	29.5%
30	15.9%	15.9%	16.5%	29.6%	18.0%	17.2%	29.5%
31	17.2%	16.1%	16.2%	29.1%	17.9%	16.9%	29.8%
32	15.6%	15.9%	16.5%	29.6%	17.2%	16.3%	29.4%
33	17.1%	16.2%	17.5%	29.7%	17.2%	15.7%	29.2%
34	15.4%	17.4%	15.5%	29.9%	17.1%	17.3%	29.9%
35	16.6%	16.2%	16.0%	29.6%	16.4%	17.0%	30.0%
36	16.7%	16.2%	16.8%	30.1%	18.2%	17.6%	29.0%
37	15.1%	17.3%	16.3%	30.0%	18.4%	17.0%	30.8%
38	15.7%	16.1%	15.3%	30.0%	18.0%	15.2%	30.3%
39	15.7%	16.5%	17.1%	30.8%	16.3%	17.7%	30.4%
40	16.2%	17.0%	16.9%	30.5%	18.0%	17.3%	30.4%
41	16.3%	16.0%	15.3%	30.5%	17.9%	17.0%	30.7%
42	17.2%	17.3%	16.8%	30.5%	17.4%	17.1%	29.9%
43	16.1%	16.5%	15.4%	30.5%	16.9%	17.0%	29.8%
44	15.8%	15.3%	16.3%	30.9%	17.6%	17.3%	30.1%
45	17.2%	15.3%	16.5%	29.7%	17.2%	17.2%	29.4%
46	17.0%	17.5%	16.2%	30.2%	17.3%	17.5%	30.4%
47	17.2%	17.5%	17.3%	30.2%	17.6%	16.7%	31.1%
48	16.9%	14.9%	16.1%	29.7%	16.6%	15.1%	30.0%
49	16.7%	16.9%	17.2%	30.0%	17.3%	16.2%	30.1%
50	16.7%	15.8%	16.2%	30.4%	17.2%	17.2%	30.8%

Table 4-44: KNN database F PDET external position Euclidean distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	21.4%	24.0%	52.1%	84.7%	33.1%	53.7%	56.3%	60.3%	66.3%	89.3%	50.8%	54.3%	60.7%	73.6%	58.4%
2	21.1%	26.4%	56.9%	84.7%	32.0%	50.0%	50.4%	61.2%	61.4%	88.6%	47.9%	52.5%	54.9%	69.5%	54.9%
3	23.3%	25.3%	58.1%	84.3%	33.1%	47.2%	49.8%	60.0%	62.6%	89.0%	46.8%	51.7%	52.7%	68.5%	53.3%
4	22.5%	26.2%	59.0%	81.7%	33.1%	45.5%	48.1%	59.7%	61.5%	88.6%	46.1%	49.1%	50.1%	66.8%	50.8%
5	22.6%	26.4%	60.3%	80.9%	32.7%	44.2%	47.2%	59.1%	61.6%	88.3%	45.9%	47.9%	50.0%	64.9%	49.1%
6	24.2%	27.2%	60.6%	80.5%	33.9%	43.3%	45.5%	58.6%	61.0%	87.2%	45.1%	47.5%	47.9%	64.5%	48.0%
7	24.2%	28.4%	60.2%	81.0%	33.2%	43.7%	45.8%	56.3%	61.2%	86.6%	44.6%	46.3%	47.1%	64.3%	47.8%
8	24.7%	30.0%	59.9%	80.5%	33.1%	43.0%	44.6%	56.2%	61.2%	85.5%	43.7%	46.6%	46.8%	63.6%	47.7%
9	24.7%	30.0%	60.6%	79.5%	33.5%	42.8%	44.1%	55.5%	60.4%	84.2%	42.8%	45.3%	45.6%	63.0%	46.6%
10	25.0%	30.1%	59.7%	77.1%	33.3%	42.2%	43.3%	55.0%	59.7%	82.4%	41.3%	44.9%	44.8%	62.0%	46.2%
11	25.9%	29.4%	59.3%	74.6%	32.6%	41.7%	43.0%	54.9%	58.6%	79.7%	40.8%	43.7%	43.8%	62.0%	45.5%
12	25.7%	30.6%	57.7%	70.6%	33.5%	40.0%	41.7%	53.1%	58.3%	76.6%	39.9%	44.0%	44.5%	60.0%	44.9%
13	25.9%	30.7%	56.6%	67.8%	32.6%	39.8%	41.7%	52.3%	57.3%	72.8%	39.3%	42.8%	43.0%	59.3%	44.3%
14	25.2%	31.6%	56.0%	62.4%	34.3%	39.5%	41.0%	51.7%	55.7%	70.0%	39.6%	42.9%	42.2%	57.5%	43.9%
15	26.0%	32.1%	55.1%	59.2%	34.0%	39.4%	40.3%	50.9%	55.6%	67.8%	39.2%	42.5%	42.6%	56.9%	43.3%
16	26.6%	30.8%	55.1%	57.5%	33.7%	39.1%	39.8%	50.4%	54.8%	65.7%	38.9%	41.8%	41.7%	56.8%	42.6%
17	25.9%	31.0%	54.5%	54.8%	33.8%	38.2%	39.5%	49.8%	54.7%	64.5%	38.2%	40.9%	40.8%	56.2%	42.4%
18	25.9%	31.4%	54.3%	55.5%	33.6%	38.7%	40.0%	48.6%	54.2%	63.3%	39.2%	41.5%	40.4%	56.0%	42.5%
19	26.7%	31.4%	54.5%	54.5%	33.8%	37.4%	39.5%	48.6%	53.9%	62.7%	38.3%	41.9%	40.3%	55.4%	42.3%
20	26.0%	31.0%	54.3%	53.2%	34.1%	38.4%	39.8%	48.2%	53.3%	61.4%	38.5%	40.8%	40.8%	54.5%	41.5%
21	26.1%	31.4%	54.4%	53.1%	33.4%	37.8%	39.2%	48.4%	52.8%	61.4%	38.3%	40.8%	40.2%	54.3%	41.3%
22	26.2%	30.6%	54.1%	53.5%	34.1%	38.2%	38.7%	48.4%	52.2%	60.8%	38.7%	39.9%	39.9%	54.4%	40.5%
23	26.2%	31.1%	54.9%	52.8%	34.1%	37.9%	38.7%	47.6%	51.5%	61.0%	37.8%	40.1%	40.2%	53.6%	40.9%
24	26.1%	31.6%	54.7%	53.5%	33.8%	37.9%	39.2%	48.5%	51.1%	61.5%	38.5%	40.3%	39.9%	53.6%	41.3%
25	26.7%	31.1%	54.9%	53.8%	33.1%	37.3%	39.2%	48.3%	51.4%	60.3%	37.6%	40.0%	39.4%	52.7%	40.4%
26	26.9%	31.5%	55.2%	53.7%	33.2%	37.1%	39.1%	47.9%	51.2%	60.6%	37.8%	38.8%	39.8%	52.8%	40.8%
27	26.7%	31.9%	55.1%	53.6%	33.2%	36.8%	38.6%	47.3%	50.5%	60.0%	37.4%	39.2%	38.9%	52.1%	40.3%
28	27.1%	32.3%	54.6%	53.2%	33.4%	36.5%	38.0%	47.2%	49.8%	59.0%	37.6%	39.0%	38.5%	51.8%	40.2%
29	28.3%	32.7%	54.1%	52.7%	33.2%	35.9%	38.1%	47.8%	49.3%	59.1%	36.5%	38.6%	39.2%	51.2%	40.0%
30	27.8%	32.4%	54.3%	52.5%	33.3%	36.1%	37.3%	47.5%	48.3%	57.8%	36.4%	38.8%	38.9%	51.1%	38.9%

Table 4-45: KNN database F PDET all positions Euclidean distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	50.2%	53.5%	97.8%	100.0%	58.7%	82.8%	86.0%	92.6%	97.1%	100.0%	79.4%	82.7%	88.5%	98.1%	86.8%
2	44.8%	52.5%	97.4%	100.0%	53.1%	74.6%	78.4%	89.1%	94.7%	100.0%	71.8%	76.5%	80.7%	96.7%	81.2%
3	43.7%	53.6%	97.0%	100.0%	52.7%	74.0%	78.0%	90.7%	94.3%	100.0%	73.7%	77.9%	81.3%	97.0%	81.2%
4	44.1%	53.5%	96.4%	100.0%	50.6%	70.0%	73.3%	89.3%	93.3%	99.7%	68.4%	73.5%	77.3%	95.7%	77.4%
5	43.1%	51.8%	96.2%	100.0%	49.9%	69.4%	73.5%	89.0%	93.3%	99.9%	68.9%	74.4%	76.4%	95.6%	78.2%
6	41.0%	51.9%	95.6%	99.6%	47.4%	66.7%	70.8%	87.9%	92.4%	99.4%	66.3%	71.5%	74.7%	94.7%	74.2%
7	41.1%	52.0%	95.0%	99.7%	46.5%	65.6%	70.1%	87.8%	91.8%	99.6%	66.6%	71.2%	73.8%	93.9%	74.6%
8	39.4%	51.5%	93.6%	98.3%	45.5%	63.6%	68.5%	86.2%	90.1%	98.9%	64.6%	68.9%	72.6%	92.6%	72.7%
9	40.6%	50.5%	93.8%	98.0%	45.9%	62.7%	67.8%	85.6%	89.6%	97.9%	64.9%	69.7%	71.9%	92.8%	72.5%
10	38.8%	50.1%	90.6%	93.3%	44.3%	61.0%	65.9%	83.6%	87.7%	95.3%	63.9%	67.3%	69.4%	90.6%	70.8%
11	38.8%	49.4%	90.2%	91.0%	44.0%	61.5%	65.7%	82.3%	86.2%	92.4%	62.2%	66.6%	69.5%	90.0%	69.8%
12	38.6%	49.5%	85.3%	85.0%	44.0%	59.4%	63.9%	80.5%	83.5%	87.0%	60.9%	65.3%	66.8%	86.0%	67.4%
13	38.4%	49.1%	83.3%	80.6%	43.7%	58.5%	63.3%	80.0%	82.5%	84.5%	60.2%	63.5%	66.5%	85.2%	67.4%
14	37.1%	48.6%	79.9%	75.2%	43.6%	56.8%	62.0%	77.6%	80.3%	78.8%	58.6%	62.9%	64.7%	82.4%	66.2%
15	37.9%	48.6%	78.4%	72.5%	42.3%	55.9%	61.0%	76.6%	78.5%	76.3%	58.2%	61.1%	63.7%	81.3%	65.8%
16	37.6%	47.9%	76.4%	71.6%	42.2%	56.2%	60.6%	75.7%	77.4%	75.2%	56.9%	61.2%	62.2%	79.2%	63.5%
17	37.4%	47.8%	75.9%	71.1%	41.9%	55.7%	59.5%	74.8%	76.9%	74.9%	55.9%	59.4%	61.7%	78.6%	62.7%
18	37.9%	47.8%	75.0%	71.5%	43.0%	54.4%	58.4%	73.4%	76.3%	73.6%	55.9%	58.9%	61.3%	77.5%	61.6%
19	37.7%	47.5%	74.2%	72.0%	41.7%	53.7%	57.9%	72.7%	75.4%	73.5%	55.3%	58.7%	60.3%	77.2%	61.6%
20	37.3%	47.2%	73.4%	71.4%	41.2%	53.1%	57.4%	71.8%	74.7%	73.2%	54.4%	56.8%	59.2%	75.8%	60.9%
21	37.0%	47.4%	72.6%	71.1%	40.9%	52.2%	56.8%	71.0%	73.8%	73.2%	54.0%	57.2%	59.4%	75.3%	60.1%
22	36.4%	46.9%	72.7%	70.7%	39.6%	52.0%	55.5%	70.0%	72.9%	72.0%	53.3%	56.5%	58.5%	74.0%	59.2%
23	36.6%	46.7%	72.1%	70.9%	40.3%	51.8%	54.7%	70.3%	72.5%	72.2%	53.7%	56.0%	58.1%	73.4%	58.4%
24	36.3%	46.7%	71.7%	70.6%	40.1%	50.5%	54.4%	69.5%	72.1%	71.8%	53.0%	55.7%	56.8%	73.1%	57.7%
25	36.0%	47.1%	71.5%	69.9%	40.0%	50.5%	53.4%	69.4%	71.9%	71.7%	52.1%	55.1%	57.1%	72.8%	57.8%
26	35.3%	45.9%	71.3%	70.4%	39.5%	49.7%	53.2%	69.1%	71.3%	71.3%	51.4%	54.8%	55.2%	72.0%	57.3%
27	35.0%	46.2%	71.0%	69.5%	39.4%	49.5%	52.4%	68.9%	71.3%	70.8%	50.6%	54.3%	54.9%	71.5%	56.1%
28	34.6%	46.3%	70.0%	69.4%	39.0%	48.9%	52.4%	68.5%	70.6%	70.7%	50.1%	53.5%	54.3%	71.6%	55.5%
29	34.0%	46.0%	69.9%	69.2%	38.7%	48.5%	51.6%	68.1%	69.9%	69.8%	49.9%	53.0%	54.3%	70.8%	54.9%
30	34.5%	45.6%	68.9%	68.4%	38.6%	47.6%	51.0%	67.4%	69.5%	69.2%	49.1%	52.0%	54.0%	69.6%	54.4%

Table 4-46: KNN database F PDET external position Mahalanobis distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	21.4%	24.7%	52.0%	84.8%	34.3%	58.8%	56.3%	59.4%	58.9%	72.5%	49.9%	48.5%	65.1%	63.5%	58.9%
2	21.5%	25.9%	55.7%	83.9%	33.5%	55.1%	51.8%	58.0%	56.4%	67.5%	48.2%	46.2%	61.6%	60.5%	56.3%
3	23.3%	25.7%	58.1%	84.1%	33.1%	53.4%	50.9%	57.9%	56.6%	66.9%	46.3%	46.0%	61.1%	62.9%	57.4%
4	22.4%	26.5%	59.0%	81.7%	33.7%	50.5%	48.7%	56.0%	56.9%	66.1%	46.0%	45.0%	59.8%	63.2%	57.0%
5	23.6%	27.4%	60.1%	80.7%	34.6%	50.0%	49.6%	55.7%	54.9%	65.9%	45.0%	44.4%	59.3%	63.4%	56.7%
6	24.2%	27.4%	60.1%	81.1%	35.3%	48.2%	47.3%	53.9%	54.1%	65.2%	42.3%	41.5%	58.9%	62.8%	55.7%
7	24.6%	28.0%	59.5%	81.5%	33.9%	47.0%	46.9%	53.4%	52.5%	63.8%	42.7%	41.4%	60.0%	62.9%	56.9%
8	24.5%	29.3%	59.7%	80.1%	34.1%	46.4%	46.0%	52.1%	52.3%	63.4%	41.6%	40.4%	58.9%	62.5%	56.4%
9	25.0%	29.5%	59.8%	80.4%	33.5%	45.8%	45.7%	52.0%	51.9%	63.5%	40.9%	40.0%	58.3%	62.0%	54.7%
10	26.1%	30.1%	60.1%	76.4%	32.7%	45.8%	45.0%	50.9%	51.6%	61.9%	40.6%	39.7%	57.9%	61.9%	55.2%
11	26.1%	30.6%	58.9%	74.8%	32.2%	44.5%	44.4%	50.4%	50.5%	62.1%	39.8%	38.9%	57.4%	60.6%	53.7%
12	24.8%	30.6%	57.8%	71.3%	31.3%	43.5%	43.2%	50.0%	50.9%	61.4%	39.2%	38.4%	57.1%	59.7%	53.1%
13	25.9%	30.7%	56.7%	66.4%	31.0%	43.0%	42.6%	48.5%	49.4%	60.3%	38.4%	37.8%	57.5%	59.0%	53.0%
14	25.6%	30.5%	55.4%	62.8%	31.1%	42.0%	41.6%	48.5%	48.6%	59.8%	38.0%	38.3%	56.6%	59.0%	51.9%
15	26.1%	31.6%	55.3%	58.2%	30.3%	41.2%	41.3%	47.1%	49.0%	59.5%	38.3%	37.8%	55.1%	58.0%	51.8%
16	26.3%	30.8%	54.2%	57.5%	29.9%	40.3%	40.8%	47.3%	48.5%	58.6%	37.8%	37.5%	55.7%	57.4%	49.9%
17	25.7%	31.7%	54.4%	55.9%	30.6%	41.0%	40.7%	47.0%	48.1%	58.4%	37.4%	36.9%	55.4%	57.0%	49.8%
18	26.4%	30.9%	55.2%	55.3%	30.6%	40.2%	40.2%	46.6%	46.9%	57.6%	37.6%	36.9%	54.1%	56.9%	49.4%
19	26.7%	30.9%	55.1%	54.2%	30.6%	40.1%	40.1%	47.0%	46.4%	58.4%	37.2%	36.4%	54.3%	56.0%	48.4%
20	26.9%	30.8%	54.2%	53.3%	31.0%	40.6%	40.3%	46.0%	46.9%	57.9%	36.7%	36.7%	53.8%	56.3%	48.4%
21	26.4%	31.5%	54.5%	53.3%	30.9%	39.7%	40.3%	46.5%	46.1%	57.2%	37.5%	36.4%	54.5%	55.3%	47.4%
22	26.7%	30.9%	54.5%	53.4%	30.7%	40.7%	40.5%	46.9%	45.3%	57.6%	37.3%	36.6%	53.0%	55.4%	47.4%
23	26.2%	31.3%	54.9%	53.0%	31.1%	40.4%	40.0%	46.2%	45.5%	57.3%	37.6%	36.9%	54.1%	54.3%	47.7%
24	26.6%	31.6%	55.2%	53.9%	31.5%	39.8%	39.3%	46.6%	45.3%	57.1%	37.6%	36.2%	53.1%	53.9%	47.4%
25	26.3%	31.4%	54.8%	54.0%	31.0%	39.9%	39.8%	46.2%	45.1%	56.7%	37.8%	36.3%	52.2%	54.4%	47.1%
26	26.8%	31.9%	54.9%	54.1%	30.7%	40.4%	38.9%	45.8%	45.2%	56.9%	38.2%	36.1%	52.2%	53.2%	46.8%
27	27.0%	31.9%	54.6%	53.2%	30.6%	40.0%	38.6%	45.6%	45.0%	56.2%	37.6%	35.9%	52.2%	53.4%	46.4%
28	27.5%	32.0%	54.7%	54.0%	31.5%	40.2%	39.1%	45.3%	44.4%	56.3%	36.9%	36.2%	52.5%	53.2%	46.4%
29	26.9%	32.4%	54.7%	52.5%	32.1%	39.5%	37.9%	45.1%	44.8%	56.6%	38.1%	35.7%	51.2%	52.9%	46.6%
30	26.7%	33.1%	54.9%	52.5%	32.0%	39.8%	38.0%	45.3%	43.8%	56.4%	37.7%	36.0%	51.6%	52.4%	45.6%

Table 4-47: KNN database F PDET all positions Mahalanobis distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	50.9%	57.5%	97.9%	100.0%	58.1%	78.5%	78.6%	77.4%	80.7%	93.9%	63.7%	65.3%	83.6%	79.2%	71.3%
2	48.5%	56.3%	97.3%	100.0%	53.9%	72.3%	72.9%	73.4%	76.0%	90.8%	60.4%	60.6%	78.9%	75.4%	68.2%
3	49.9%	59.6%	97.2%	100.0%	54.6%	72.3%	72.6%	73.6%	76.6%	91.6%	61.5%	64.4%	80.7%	78.2%	72.4%
4	48.3%	58.5%	96.4%	100.0%	54.0%	70.2%	69.2%	72.7%	74.9%	89.5%	61.1%	62.9%	77.0%	76.3%	70.6%
5	49.4%	60.4%	96.0%	100.0%	53.8%	68.1%	68.2%	71.7%	74.4%	89.1%	61.2%	62.1%	76.0%	77.3%	71.1%
6	48.8%	59.5%	95.1%	99.8%	53.5%	66.6%	67.5%	72.0%	73.7%	87.4%	60.5%	61.5%	75.2%	75.9%	69.2%
7	48.3%	60.5%	94.6%	99.3%	53.5%	66.9%	67.6%	72.2%	73.2%	87.4%	59.7%	62.5%	74.1%	75.4%	69.2%
8	46.7%	60.1%	93.0%	98.2%	52.8%	64.9%	65.7%	70.4%	71.3%	85.4%	58.9%	60.9%	71.9%	74.2%	68.3%
9	47.1%	59.5%	92.4%	97.2%	53.3%	65.1%	65.6%	70.1%	71.1%	85.5%	58.7%	59.8%	71.7%	73.1%	67.2%
10	45.6%	59.4%	89.2%	92.5%	51.6%	63.7%	63.8%	68.7%	69.6%	81.5%	58.0%	60.2%	70.3%	72.6%	65.5%
11	46.7%	59.7%	87.3%	91.1%	52.5%	62.2%	64.1%	68.1%	69.2%	81.2%	57.5%	59.4%	68.7%	70.5%	65.3%
12	45.7%	58.6%	84.5%	81.2%	51.5%	61.2%	64.0%	67.5%	68.3%	77.1%	57.7%	59.4%	67.9%	69.6%	64.3%
13	45.8%	57.6%	82.4%	78.4%	50.5%	60.4%	62.3%	67.5%	67.6%	76.4%	56.7%	58.8%	66.2%	69.4%	62.8%
14	45.0%	57.8%	78.1%	70.8%	49.3%	59.4%	61.9%	66.6%	66.9%	73.8%	56.5%	56.8%	65.4%	68.8%	62.8%
15	44.8%	57.6%	76.7%	68.1%	49.1%	59.1%	60.8%	66.6%	66.6%	72.4%	55.0%	57.3%	64.2%	67.2%	61.9%
16	44.3%	56.3%	74.8%	65.5%	48.9%	58.3%	60.2%	65.9%	66.5%	71.3%	55.2%	56.1%	63.5%	66.1%	61.4%
17	43.8%	55.8%	74.6%	66.3%	48.9%	57.4%	60.7%	65.0%	65.9%	70.8%	54.9%	55.8%	63.6%	65.6%	60.1%
18	43.8%	55.9%	73.9%	66.6%	48.4%	57.1%	59.0%	64.6%	65.2%	69.4%	54.0%	54.8%	62.0%	64.5%	59.6%
19	43.8%	55.5%	73.0%	67.4%	47.7%	56.4%	58.6%	63.9%	65.1%	68.9%	53.0%	54.3%	62.1%	64.4%	59.0%
20	42.6%	55.8%	72.0%	66.4%	46.7%	56.0%	58.6%	63.2%	64.3%	68.0%	52.9%	53.4%	61.5%	63.2%	58.2%
21	42.8%	55.3%	71.3%	65.8%	46.7%	54.9%	57.8%	62.5%	64.0%	67.1%	51.9%	53.0%	61.0%	62.9%	57.4%
22	42.1%	55.3%	70.8%	65.0%	46.0%	54.5%	57.3%	62.8%	63.5%	66.6%	51.4%	52.2%	60.2%	62.3%	57.5%
23	42.8%	54.4%	70.3%	65.1%	45.6%	53.6%	56.7%	62.3%	63.1%	65.7%	51.6%	52.5%	59.7%	61.2%	56.3%
24	42.3%	53.9%	69.3%	64.5%	45.6%	53.4%	55.5%	61.8%	62.1%	65.2%	50.1%	51.6%	58.9%	61.2%	56.5%
25	42.0%	54.3%	69.4%	64.8%	46.1%	52.6%	54.8%	61.0%	62.1%	64.2%	50.6%	50.5%	59.1%	60.2%	55.0%
26	41.2%	54.1%	68.9%	64.3%	45.0%	52.5%	54.3%	60.9%	61.4%	63.7%	49.6%	50.0%	58.2%	60.3%	55.7%
27	40.8%	52.9%	68.4%	64.3%	45.5%	51.1%	54.2%	60.4%	60.7%	63.5%	49.2%	50.5%	58.1%	59.2%	54.9%
28	40.6%	53.3%	68.0%	63.8%	44.8%	50.7%	53.2%	59.2%	61.3%	63.2%	49.2%	49.5%	57.7%	59.5%	53.8%
29	40.9%	53.0%	67.6%	63.8%	44.3%	50.7%	53.4%	59.1%	60.1%	62.5%	49.1%	49.4%	57.3%	58.6%	53.8%
30	40.5%	53.1%	66.5%	63.0%	44.3%	50.5%	52.1%	59.3%	59.9%	62.1%	48.3%	48.8%	56.3%	57.9%	53.8%

Table 4-48: KNN database F PDET external position Cosine distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	15.8%	14.0%	14.8%	15.0%	17.0%	24.7%	27.8%	29.5%	28.7%	28.7%	35.0%	31.9%	44.0%	40.9%	39.6%
2	16.0%	16.4%	13.4%	14.9%	17.8%	26.5%	27.6%	31.4%	30.1%	29.9%	34.5%	32.5%	44.3%	41.8%	38.1%
3	16.8%	17.5%	15.0%	17.2%	17.0%	26.9%	28.4%	31.6%	31.2%	31.1%	36.6%	33.2%	43.2%	43.7%	37.3%
4	16.9%	13.1%	15.4%	16.8%	17.0%	28.3%	29.0%	33.3%	31.2%	34.0%	36.3%	33.1%	41.9%	43.9%	38.1%
5	14.3%	15.6%	15.6%	14.9%	17.5%	28.0%	28.2%	34.2%	31.5%	33.5%	35.7%	33.4%	40.6%	43.7%	37.2%
6	16.3%	15.9%	14.8%	16.7%	17.9%	29.0%	28.2%	34.2%	33.6%	33.6%	35.1%	32.7%	40.3%	44.3%	37.0%
7	16.0%	15.8%	14.4%	16.3%	18.7%	29.7%	28.1%	35.6%	32.9%	33.4%	34.6%	32.6%	40.2%	44.5%	36.9%
8	15.4%	15.3%	14.7%	16.0%	18.9%	29.5%	28.0%	35.2%	32.6%	32.4%	34.5%	32.7%	39.6%	43.6%	35.3%
9	16.0%	17.8%	15.5%	15.4%	19.0%	30.0%	28.2%	34.7%	33.3%	32.8%	34.1%	33.1%	39.3%	43.2%	36.3%
10	15.6%	15.1%	15.4%	15.4%	19.9%	29.7%	27.6%	35.5%	33.5%	32.9%	33.6%	33.5%	38.4%	43.7%	36.7%
11	16.4%	15.1%	14.1%	16.2%	20.0%	29.9%	27.8%	35.1%	33.5%	32.6%	34.3%	32.5%	37.9%	44.5%	35.1%
12	16.0%	14.7%	15.8%	16.6%	20.0%	29.7%	27.7%	34.9%	33.3%	32.5%	33.9%	33.7%	36.9%	43.2%	34.8%
13	16.0%	15.6%	15.6%	14.7%	18.6%	30.1%	28.2%	34.3%	34.2%	32.7%	33.7%	33.3%	36.2%	42.5%	34.9%
14	14.5%	15.7%	15.4%	17.2%	18.5%	30.5%	27.7%	35.8%	34.1%	32.8%	34.0%	33.6%	35.8%	42.6%	33.7%
15	15.6%	15.9%	14.7%	16.5%	18.8%	29.8%	27.6%	33.9%	33.5%	33.3%	33.1%	33.3%	34.9%	40.7%	35.5%
16	16.9%	15.9%	15.7%	15.6%	18.4%	29.0%	28.1%	34.4%	34.1%	33.7%	33.1%	33.5%	34.6%	41.3%	34.3%
17	13.3%	15.4%	16.5%	14.7%	18.6%	28.7%	27.6%	34.0%	33.9%	33.2%	32.9%	33.3%	34.9%	40.3%	35.2%
18	16.4%	17.3%	15.7%	16.5%	18.0%	29.0%	27.3%	34.7%	34.1%	34.1%	33.0%	33.9%	33.4%	40.4%	35.8%
19	15.0%	14.4%	15.6%	17.6%	18.5%	29.5%	27.9%	34.0%	34.5%	34.2%	33.5%	33.7%	33.3%	40.8%	35.7%
20	13.0%	15.7%	16.0%	15.5%	18.1%	29.0%	28.1%	33.2%	34.6%	33.9%	33.6%	33.7%	33.7%	41.1%	34.9%
21	15.3%	16.0%	17.7%	16.4%	18.8%	29.7%	29.2%	33.5%	34.7%	33.6%	33.1%	33.6%	33.3%	40.4%	35.4%
22	15.9%	15.5%	16.7%	16.4%	18.5%	28.6%	28.2%	33.9%	34.6%	34.5%	32.7%	34.0%	33.0%	39.8%	35.8%
23	15.6%	16.7%	15.0%	16.8%	18.9%	28.4%	27.8%	34.2%	34.3%	34.3%	33.5%	33.4%	32.6%	40.2%	35.0%
24	16.1%	15.8%	17.0%	17.4%	19.2%	29.3%	27.7%	33.8%	34.9%	33.9%	33.4%	33.7%	33.3%	39.3%	35.4%
25	16.8%	15.7%	16.2%	18.3%	19.2%	29.0%	28.5%	33.8%	34.6%	34.0%	32.1%	33.9%	32.3%	40.3%	34.9%
26	15.4%	14.1%	15.5%	16.9%	19.4%	28.9%	27.5%	33.8%	35.3%	34.4%	32.9%	33.7%	31.9%	39.2%	34.5%
27	16.3%	16.3%	15.6%	15.9%	20.2%	27.8%	27.7%	33.9%	35.2%	34.3%	33.2%	34.2%	30.9%	38.4%	35.6%
28	16.1%	16.4%	17.0%	16.4%	19.0%	27.7%	28.2%	34.5%	35.0%	35.5%	32.5%	34.5%	32.1%	39.2%	33.9%
29	17.6%	14.8%	16.5%	16.2%	19.6%	28.5%	27.8%	34.7%	35.2%	34.6%	32.7%	34.0%	31.6%	38.6%	34.6%
30	16.5%	15.8%	16.9%	14.8%	20.3%	28.1%	27.5%	34.6%	35.8%	34.3%	32.9%	33.4%	31.2%	39.4%	35.3%

Table 4-49: KNN database F PDET all positions Cosine distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	36.2%	43.3%	93.8%	100.0%	53.6%	81.2%	85.1%	92.1%	96.6%	99.8%	77.7%	82.3%	88.1%	96.9%	85.3%
2	37.5%	43.6%	93.9%	100.0%	49.8%	74.0%	76.4%	88.6%	94.0%	99.6%	70.3%	76.1%	80.9%	95.6%	78.6%
3	37.0%	45.7%	93.9%	100.0%	50.6%	72.4%	77.0%	90.3%	94.4%	99.4%	73.2%	77.2%	79.6%	96.2%	80.3%
4	38.0%	45.8%	92.9%	99.9%	48.9%	69.6%	74.6%	88.6%	92.2%	98.9%	69.8%	74.5%	77.0%	94.6%	77.2%
5	38.1%	46.8%	93.1%	99.9%	48.6%	68.5%	73.8%	88.5%	92.1%	99.0%	69.7%	75.0%	76.8%	94.3%	77.0%
6	37.6%	46.8%	92.0%	99.6%	46.7%	66.7%	71.4%	88.0%	91.3%	98.3%	67.3%	72.5%	74.1%	93.2%	75.5%
7	37.5%	46.8%	92.4%	99.8%	45.7%	66.1%	72.0%	88.1%	90.7%	97.8%	66.0%	72.1%	74.9%	93.5%	75.7%
8	37.1%	46.6%	90.4%	98.2%	45.2%	64.2%	70.9%	85.7%	88.6%	96.2%	64.6%	70.5%	72.4%	91.8%	73.5%
9	36.7%	46.7%	88.9%	97.1%	44.1%	63.7%	69.5%	84.9%	88.5%	95.3%	64.6%	70.3%	71.4%	90.5%	73.1%
10	37.1%	47.2%	86.6%	94.0%	44.6%	62.6%	68.4%	83.1%	85.9%	91.8%	62.7%	69.2%	69.6%	88.1%	71.9%
11	36.9%	47.3%	85.0%	90.6%	44.4%	60.8%	67.4%	80.9%	84.1%	91.6%	61.4%	68.0%	68.5%	86.5%	70.4%
12	36.8%	46.9%	81.7%	83.1%	44.0%	59.4%	65.5%	79.7%	82.3%	86.2%	59.7%	65.9%	67.3%	84.1%	69.0%
13	36.6%	46.6%	78.4%	79.6%	43.0%	59.1%	63.7%	77.8%	79.8%	83.0%	59.4%	63.9%	67.0%	82.3%	66.8%
14	36.4%	46.0%	75.5%	74.6%	43.0%	58.1%	62.4%	76.1%	78.1%	78.6%	58.4%	62.7%	64.3%	79.2%	65.3%
15	35.9%	46.1%	72.9%	70.9%	43.1%	57.4%	61.5%	74.5%	77.1%	75.5%	57.1%	62.0%	63.1%	78.0%	63.5%
16	35.7%	46.3%	71.7%	69.7%	42.6%	56.3%	59.8%	73.4%	75.9%	74.4%	57.1%	61.1%	62.3%	76.5%	63.0%
17	35.1%	45.6%	71.1%	69.5%	42.3%	55.9%	59.2%	72.8%	74.9%	73.5%	55.8%	60.8%	61.3%	75.9%	62.7%
18	34.9%	45.2%	70.1%	70.2%	41.7%	53.5%	58.5%	72.1%	74.8%	73.9%	54.9%	59.0%	59.7%	75.3%	60.9%
19	34.8%	45.7%	70.6%	70.2%	42.1%	53.8%	57.8%	71.1%	73.5%	73.0%	55.4%	58.2%	59.3%	75.2%	60.7%
20	34.8%	45.5%	69.6%	69.5%	41.6%	53.1%	56.2%	69.8%	73.2%	72.3%	54.1%	57.7%	58.6%	74.1%	59.3%
21	35.0%	45.2%	69.0%	68.9%	41.6%	52.7%	55.4%	70.3%	72.4%	71.7%	52.9%	56.9%	58.0%	74.3%	59.0%
22	35.1%	45.4%	69.2%	69.2%	41.2%	52.1%	55.7%	68.9%	71.9%	71.5%	53.1%	56.7%	57.1%	73.4%	57.5%
23	34.5%	44.5%	68.2%	68.8%	40.6%	51.5%	54.4%	68.6%	71.3%	71.7%	52.3%	55.5%	56.7%	72.5%	57.8%
24	34.4%	44.6%	68.2%	68.5%	40.3%	51.2%	54.0%	68.7%	71.5%	70.8%	52.7%	55.0%	55.2%	72.4%	56.0%
25	33.4%	44.5%	67.9%	68.8%	40.6%	50.2%	53.3%	68.4%	70.6%	70.8%	52.5%	54.8%	54.5%	71.9%	56.6%
26	34.1%	45.1%	68.0%	67.5%	40.4%	50.1%	52.6%	67.5%	69.8%	70.4%	50.8%	53.7%	53.4%	71.4%	54.5%
27	34.4%	45.0%	67.9%	68.2%	39.4%	49.8%	52.9%	66.9%	70.4%	70.3%	51.3%	53.2%	53.5%	71.4%	54.3%
28	34.1%	44.6%	67.9%	67.4%	39.2%	49.2%	52.0%	66.9%	69.1%	69.3%	50.1%	52.8%	53.2%	70.8%	54.8%
29	34.0%	44.5%	67.5%	66.6%	39.4%	48.6%	51.9%	66.5%	68.5%	69.4%	50.3%	51.4%	52.5%	70.3%	53.3%
30	34.2%	44.8%	67.6%	65.7%	39.9%	48.1%	51.4%	65.7%	68.7%	68.3%	49.5%	52.1%	51.1%	69.4%	53.0%

Table 4-50: KNN database F SINRD external position Euclidean distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	21.6%	19.5%	29.4%	84.5%	39.7%	35.2%	35.3%	37.3%	44.3%	67.7%	48.0%	48.9%	39.1%	44.4%	51.0%
2	20.9%	20.3%	32.9%	85.0%	38.5%	33.8%	35.6%	36.1%	40.6%	65.5%	42.6%	44.2%	38.0%	42.3%	46.7%
3	20.8%	20.3%	32.7%	84.2%	39.9%	34.5%	36.1%	36.7%	39.6%	63.2%	42.8%	43.9%	39.2%	42.0%	46.9%
4	21.6%	21.0%	34.0%	82.6%	37.5%	34.5%	36.1%	35.4%	40.1%	63.2%	41.7%	43.4%	38.3%	41.8%	44.0%
5	21.9%	20.3%	35.5%	81.3%	36.3%	34.1%	36.4%	34.9%	38.6%	63.5%	39.6%	42.0%	36.9%	41.3%	42.7%
6	22.8%	20.8%	35.3%	83.0%	36.4%	33.6%	35.5%	34.8%	37.9%	62.0%	39.1%	37.8%	36.8%	39.8%	41.1%
7	23.0%	21.6%	35.9%	82.4%	35.2%	34.2%	35.5%	34.5%	38.0%	63.0%	36.3%	37.6%	37.2%	39.8%	38.9%
8	23.8%	21.6%	36.6%	81.1%	32.6%	33.2%	35.0%	34.0%	37.5%	61.3%	34.9%	36.0%	37.7%	39.0%	36.1%
9	24.2%	21.5%	36.1%	79.1%	33.8%	33.0%	34.4%	34.3%	35.8%	61.3%	33.9%	34.4%	36.9%	38.8%	36.1%
10	23.4%	21.3%	36.9%	75.7%	32.1%	32.3%	33.7%	33.1%	35.3%	60.2%	33.6%	33.9%	35.6%	37.6%	34.9%
11	24.3%	21.6%	37.2%	74.1%	31.4%	32.6%	33.2%	33.0%	35.6%	59.1%	31.1%	33.4%	36.0%	37.2%	33.2%
12	24.6%	22.1%	37.4%	69.6%	30.7%	32.5%	32.3%	31.3%	35.2%	58.2%	30.9%	32.4%	36.2%	36.8%	32.7%
13	24.1%	22.1%	37.9%	66.0%	30.6%	30.5%	32.8%	30.8%	33.8%	57.6%	31.4%	31.8%	34.5%	36.3%	33.0%
14	24.2%	22.4%	38.2%	60.4%	31.1%	31.5%	32.7%	31.3%	33.3%	56.5%	31.0%	31.5%	35.1%	34.8%	33.3%
15	25.1%	21.8%	38.0%	57.3%	31.1%	31.0%	31.8%	30.7%	33.0%	55.8%	31.1%	32.0%	35.0%	34.5%	32.5%
16	24.7%	20.4%	38.9%	54.6%	31.4%	30.6%	31.4%	29.5%	33.3%	55.7%	32.1%	31.6%	33.6%	33.3%	32.9%
17	25.0%	20.8%	38.6%	53.4%	31.0%	29.9%	31.2%	29.0%	31.3%	55.3%	30.7%	31.6%	33.5%	32.8%	32.3%
18	24.8%	20.6%	40.1%	52.8%	31.0%	30.5%	31.5%	28.6%	30.8%	55.3%	30.9%	30.4%	33.7%	32.8%	31.7%
19	24.7%	21.1%	39.4%	52.9%	29.5%	30.4%	30.3%	28.0%	31.3%	55.5%	30.1%	29.9%	32.8%	32.0%	30.5%
20	24.9%	20.7%	38.7%	52.0%	30.5%	29.8%	30.4%	26.4%	30.3%	55.2%	29.8%	28.9%	32.9%	31.2%	31.3%
21	24.3%	20.3%	38.9%	51.3%	29.9%	29.6%	30.6%	26.8%	30.3%	54.6%	30.0%	29.5%	33.1%	30.8%	30.2%
22	24.5%	20.4%	39.5%	51.2%	29.1%	29.5%	30.6%	25.5%	29.5%	55.1%	29.3%	29.1%	32.0%	30.5%	29.5%
23	24.1%	20.1%	38.6%	51.6%	29.6%	29.5%	30.1%	26.1%	29.0%	54.6%	28.0%	28.3%	33.0%	30.0%	30.1%
24	23.3%	21.4%	39.1%	51.6%	28.6%	29.9%	30.2%	25.4%	27.6%	54.5%	28.2%	28.7%	32.1%	30.1%	29.0%
25	24.0%	20.4%	39.6%	52.4%	28.2%	29.4%	30.1%	24.6%	27.0%	53.6%	29.4%	28.6%	31.8%	29.4%	28.4%
26	23.2%	20.4%	39.5%	53.1%	27.9%	28.6%	29.1%	25.5%	26.8%	53.7%	28.1%	28.6%	32.0%	28.7%	28.5%
27	23.1%	20.3%	39.5%	53.1%	27.7%	29.4%	29.7%	24.7%	26.6%	53.3%	28.7%	28.4%	32.4%	28.0%	28.6%
28	23.3%	20.5%	39.0%	52.9%	28.2%	28.8%	29.1%	25.2%	26.2%	52.7%	28.0%	27.9%	31.5%	28.6%	29.4%
29	23.0%	21.8%	39.6%	51.7%	27.4%	28.2%	30.0%	24.4%	25.9%	53.0%	27.8%	27.7%	31.3%	28.5%	28.2%
30	22.5%	20.5%	39.2%	51.6%	26.5%	28.9%	28.8%	23.8%	25.4%	52.2%	28.5%	27.2%	31.5%	27.8%	27.3%

Table 4-51: KNN database F SINRD all positions Euclidean distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	32.8%	46.7%	90.6%	100.0%	51.4%	50.5%	52.9%	62.4%	69.3%	99.3%	54.6%	56.4%	56.9%	71.1%	59.6%
2	32.2%	43.2%	86.0%	100.0%	47.5%	46.2%	49.8%	56.3%	61.1%	98.3%	50.3%	53.2%	51.9%	63.7%	56.0%
3	31.7%	42.5%	84.2%	100.0%	47.3%	45.6%	49.9%	55.4%	59.8%	97.9%	50.5%	52.8%	51.9%	62.4%	53.9%
4	32.0%	42.4%	82.0%	99.7%	44.6%	44.5%	48.6%	53.9%	56.2%	96.7%	48.4%	50.2%	50.6%	59.3%	51.3%
5	31.7%	40.7%	81.6%	99.8%	43.7%	44.3%	48.0%	52.3%	55.2%	96.2%	45.9%	48.0%	49.9%	57.4%	49.3%
6	31.2%	40.6%	81.1%	99.6%	40.8%	44.3%	47.5%	51.4%	54.5%	95.5%	44.1%	45.5%	48.6%	57.2%	45.9%
7	30.6%	39.6%	80.7%	99.5%	38.7%	43.0%	47.0%	49.7%	53.2%	95.3%	40.2%	43.4%	48.5%	54.9%	45.0%
8	30.8%	39.6%	79.6%	98.2%	37.4%	41.9%	45.3%	48.6%	51.5%	93.3%	38.9%	41.7%	48.2%	53.1%	42.3%
9	29.7%	37.8%	78.2%	97.7%	36.6%	41.5%	44.7%	46.6%	50.5%	93.2%	38.1%	39.3%	47.1%	52.0%	40.0%
10	29.7%	37.3%	77.7%	94.7%	35.3%	40.8%	44.6%	45.3%	48.8%	90.1%	36.9%	38.3%	47.1%	51.0%	39.2%
11	29.2%	36.0%	76.2%	90.2%	34.3%	40.1%	43.4%	44.1%	48.6%	87.9%	36.2%	37.4%	45.5%	49.8%	38.4%
12	30.1%	37.0%	75.6%	86.0%	34.9%	39.6%	42.3%	43.7%	47.3%	84.1%	35.7%	36.6%	45.0%	49.0%	37.7%
13	29.5%	35.8%	73.6%	79.6%	34.5%	38.7%	41.2%	43.6%	46.4%	81.2%	35.1%	36.8%	44.6%	47.9%	37.6%
14	29.7%	35.7%	72.6%	73.8%	33.6%	38.2%	41.0%	42.1%	46.1%	77.6%	34.7%	36.4%	44.5%	46.7%	36.4%
15	29.3%	35.6%	71.1%	71.2%	34.1%	37.9%	40.3%	41.3%	44.3%	75.3%	34.5%	35.3%	43.8%	46.6%	36.3%
16	28.7%	36.1%	70.7%	70.1%	33.3%	37.0%	40.0%	40.9%	45.0%	74.2%	34.4%	35.7%	43.2%	45.1%	35.4%
17	29.0%	35.4%	68.9%	70.7%	33.3%	37.0%	39.4%	39.9%	43.8%	74.0%	34.0%	35.2%	42.3%	43.9%	36.0%
18	29.5%	35.0%	68.9%	69.8%	32.0%	35.3%	38.7%	39.0%	43.3%	73.0%	33.5%	33.9%	40.7%	43.6%	34.4%
19	29.0%	34.3%	68.2%	71.0%	32.8%	35.6%	38.6%	38.7%	41.9%	73.1%	33.0%	33.7%	40.1%	42.6%	34.4%
20	28.6%	35.1%	67.4%	70.0%	31.7%	35.3%	37.7%	38.9%	41.7%	72.2%	31.7%	33.4%	39.9%	42.3%	34.0%
21	28.1%	33.7%	66.6%	69.3%	30.7%	35.0%	37.0%	37.3%	40.6%	71.3%	31.6%	33.2%	38.5%	42.1%	33.8%
22	28.5%	32.8%	65.4%	70.3%	30.8%	33.3%	37.3%	37.5%	39.8%	71.0%	31.4%	32.9%	38.7%	40.7%	32.9%
23	28.1%	33.3%	64.7%	69.1%	30.7%	33.6%	36.5%	36.7%	38.8%	70.0%	31.0%	32.2%	38.7%	39.8%	32.8%
24	28.4%	32.5%	64.7%	69.1%	30.4%	33.2%	35.8%	35.7%	38.2%	70.0%	31.4%	31.8%	38.1%	39.8%	32.1%
25	28.0%	31.5%	63.6%	69.4%	29.6%	33.1%	35.7%	35.0%	38.0%	69.4%	29.8%	31.5%	37.3%	38.5%	31.5%
26	27.3%	31.9%	63.6%	69.3%	28.9%	32.9%	35.3%	35.0%	36.8%	68.6%	29.7%	30.9%	36.8%	38.3%	31.0%
27	28.3%	30.6%	63.1%	68.5%	29.1%	32.3%	35.4%	34.9%	37.5%	68.0%	29.4%	30.4%	36.0%	38.1%	30.9%
28	27.1%	31.4%	62.7%	68.4%	28.3%	31.6%	35.4%	34.1%	36.5%	68.0%	29.0%	30.4%	35.9%	36.7%	30.1%
29	27.3%	30.2%	62.4%	67.6%	28.3%	31.4%	34.2%	33.5%	35.9%	67.2%	27.6%	29.7%	35.7%	36.6%	29.8%
30	27.4%	30.3%	61.6%	67.5%	28.5%	31.0%	34.2%	32.9%	35.9%	66.7%	28.5%	29.4%	35.5%	37.1%	29.3%

Table 4-52: KNN database F SINRD external position Mahalanobis distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	21.8%	19.2%	29.4%	84.5%	40.5%	46.0%	40.2%	45.2%	54.8%	50.3%	66.2%	56.4%	53.1%	50.2%	67.2%
2	21.7%	19.4%	33.5%	85.1%	39.0%	44.5%	41.3%	43.1%	51.9%	51.6%	60.6%	53.9%	52.9%	47.3%	65.1%
3	20.5%	20.5%	33.7%	84.0%	38.7%	44.4%	41.7%	43.6%	49.2%	50.8%	60.1%	53.6%	51.4%	46.4%	65.2%
4	21.7%	21.4%	34.2%	82.4%	41.5%	43.2%	41.4%	43.0%	49.3%	51.7%	58.3%	52.2%	52.2%	46.7%	63.3%
5	22.1%	20.7%	36.1%	81.5%	39.4%	44.1%	42.3%	43.4%	47.1%	51.5%	56.4%	50.4%	53.3%	46.6%	63.1%
6	22.8%	20.8%	34.8%	82.6%	38.1%	42.6%	41.9%	42.0%	47.6%	50.5%	53.8%	49.6%	51.3%	44.7%	60.3%
7	23.2%	21.1%	36.0%	82.3%	36.9%	43.6%	41.6%	41.2%	46.1%	51.1%	52.4%	47.2%	50.5%	44.3%	59.5%
8	23.2%	22.0%	36.3%	80.4%	35.9%	42.7%	42.3%	40.1%	46.4%	50.4%	50.6%	47.2%	49.6%	43.5%	59.1%
9	24.8%	21.2%	37.6%	79.5%	34.4%	42.1%	41.4%	40.6%	45.5%	50.8%	50.1%	45.9%	49.5%	43.0%	58.3%
10	23.8%	21.2%	36.0%	76.3%	33.7%	42.4%	40.8%	39.6%	45.3%	50.3%	48.8%	44.3%	49.3%	41.7%	57.9%
11	24.0%	21.7%	37.7%	75.2%	32.9%	41.2%	41.1%	39.9%	44.9%	49.5%	48.5%	43.9%	49.4%	41.5%	57.2%
12	24.5%	21.8%	37.7%	68.9%	32.8%	40.2%	41.6%	39.3%	43.5%	50.0%	48.9%	43.5%	48.2%	40.8%	58.0%
13	25.8%	21.2%	37.8%	65.8%	32.5%	39.9%	41.4%	39.8%	42.7%	49.8%	47.1%	42.1%	48.5%	40.8%	56.5%
14	23.9%	21.6%	38.3%	60.2%	32.7%	40.4%	41.3%	39.3%	42.7%	49.1%	47.2%	41.5%	47.9%	40.9%	55.1%
15	24.4%	21.3%	38.3%	57.4%	32.4%	40.2%	40.5%	39.1%	41.0%	49.7%	46.9%	41.5%	47.3%	40.6%	55.7%
16	24.6%	21.6%	38.7%	55.3%	32.6%	40.1%	41.1%	39.3%	41.0%	49.4%	45.9%	41.0%	47.5%	40.3%	53.8%
17	24.4%	21.0%	38.2%	54.6%	31.5%	39.6%	39.9%	38.5%	40.9%	48.3%	45.1%	41.1%	47.4%	40.4%	54.3%
18	24.7%	20.6%	38.6%	52.1%	31.6%	38.7%	40.1%	38.9%	40.7%	48.4%	44.6%	40.6%	47.8%	40.7%	53.3%
19	23.9%	20.2%	38.8%	52.7%	31.5%	38.8%	39.4%	38.7%	39.8%	48.0%	44.1%	39.0%	47.3%	40.5%	53.1%
20	24.1%	21.3%	39.2%	51.5%	30.3%	39.3%	39.0%	38.4%	39.8%	47.8%	42.8%	39.5%	46.5%	40.7%	52.9%
21	24.6%	20.7%	39.1%	51.4%	29.4%	38.4%	39.5%	38.2%	39.8%	47.7%	42.4%	38.1%	45.7%	40.2%	52.1%
22	24.6%	20.8%	39.0%	50.8%	29.6%	38.7%	38.3%	38.9%	39.3%	48.0%	42.7%	38.0%	46.4%	40.3%	51.4%
23	24.2%	20.9%	39.2%	51.1%	29.0%	38.6%	38.6%	38.9%	39.7%	46.9%	42.1%	38.2%	45.6%	39.9%	51.9%
24	23.6%	20.3%	39.1%	51.3%	29.1%	38.2%	38.1%	38.0%	39.2%	46.9%	41.5%	37.5%	45.9%	39.3%	50.8%
25	23.5%	20.7%	39.1%	51.7%	28.0%	38.2%	37.8%	38.4%	39.5%	46.4%	42.0%	37.5%	45.2%	39.4%	50.3%
26	23.5%	20.8%	39.2%	52.8%	27.7%	38.2%	38.1%	38.7%	38.8%	46.4%	41.4%	37.1%	44.5%	39.7%	50.5%
27	22.4%	20.5%	40.0%	52.8%	27.8%	38.4%	36.4%	37.4%	38.3%	45.7%	40.3%	37.0%	45.0%	38.0%	49.3%
28	23.6%	20.9%	38.7%	52.4%	28.0%	38.7%	37.0%	38.3%	37.4%	45.9%	41.0%	35.9%	43.9%	39.2%	50.1%
29	23.0%	19.9%	39.9%	52.5%	27.9%	37.8%	36.9%	37.6%	38.5%	45.7%	40.8%	36.6%	44.6%	39.1%	49.7%
30	22.7%	20.4%	38.7%	52.2%	27.0%	38.2%	36.4%	38.2%	37.8%	45.6%	40.8%	36.3%	43.6%	38.7%	49.4%

Table 4-53: KNN database F SINRD all positions Mahalanobis distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	50.7%	58.5%	98.4%	100.0%	63.3%	83.5%	82.7%	76.9%	78.5%	97.9%	71.7%	69.0%	90.3%	81.6%	77.0%
2	47.1%	53.9%	96.6%	100.0%	61.0%	77.2%	75.2%	71.0%	72.4%	95.7%	65.8%	63.6%	85.1%	76.9%	72.5%
3	48.9%	53.9%	96.5%	100.0%	61.0%	78.2%	76.3%	73.2%	73.2%	95.3%	68.0%	67.9%	86.1%	79.0%	76.2%
4	48.4%	52.2%	94.9%	99.9%	60.0%	74.0%	71.7%	71.6%	72.3%	93.1%	67.1%	66.0%	82.0%	78.3%	72.8%
5	47.6%	52.1%	94.6%	99.6%	60.1%	71.9%	69.5%	71.7%	71.5%	92.6%	65.6%	65.5%	80.9%	78.0%	73.6%
6	47.7%	52.2%	93.6%	99.7%	58.5%	70.9%	68.1%	70.2%	69.0%	91.4%	64.7%	65.1%	78.7%	75.0%	71.6%
7	48.2%	51.5%	92.5%	99.6%	57.2%	70.1%	67.5%	69.2%	69.2%	91.0%	64.3%	64.2%	78.2%	75.7%	73.0%
8	46.3%	50.5%	91.4%	98.4%	55.5%	68.0%	65.9%	67.2%	66.7%	89.0%	63.6%	63.2%	75.7%	73.6%	69.3%
9	46.0%	50.6%	89.9%	97.4%	54.7%	67.3%	64.8%	67.0%	65.2%	88.2%	62.7%	61.9%	75.4%	73.3%	68.9%
10	45.3%	49.9%	87.0%	92.8%	53.0%	65.3%	63.6%	65.5%	64.7%	86.9%	60.9%	60.7%	73.7%	71.6%	67.2%
11	45.5%	50.1%	85.6%	89.1%	52.0%	64.9%	64.1%	65.0%	64.7%	85.7%	60.8%	60.5%	72.2%	71.4%	66.7%
12	45.5%	49.0%	82.1%	82.9%	50.7%	63.4%	61.6%	64.7%	63.8%	82.9%	59.7%	59.4%	70.6%	69.1%	65.6%
13	44.5%	49.1%	80.1%	78.7%	49.8%	62.2%	59.8%	63.3%	63.3%	81.1%	59.0%	57.6%	69.8%	68.6%	64.4%
14	44.7%	48.2%	77.0%	71.7%	49.1%	60.3%	58.4%	63.2%	62.0%	79.6%	57.9%	57.1%	69.5%	68.1%	63.3%
15	44.2%	48.4%	75.7%	67.8%	48.2%	60.4%	58.1%	62.1%	61.4%	78.5%	57.0%	55.9%	67.9%	66.6%	61.6%
16	44.0%	47.7%	74.1%	67.0%	47.7%	58.7%	57.2%	60.9%	60.3%	76.9%	56.0%	54.8%	66.4%	66.0%	61.7%
17	43.2%	47.6%	73.2%	66.1%	46.2%	58.8%	56.1%	61.2%	60.0%	75.5%	55.5%	53.9%	65.6%	64.4%	59.9%
18	43.3%	46.7%	72.7%	66.9%	45.9%	57.2%	55.8%	60.0%	59.6%	75.4%	54.6%	53.9%	64.6%	64.0%	59.0%
19	42.9%	47.0%	72.3%	66.6%	46.1%	55.9%	54.9%	59.7%	59.4%	74.0%	53.4%	53.2%	63.6%	63.1%	58.0%
20	43.1%	45.5%	72.1%	66.2%	45.3%	56.1%	53.7%	58.8%	58.4%	72.8%	53.1%	51.6%	62.7%	62.3%	57.4%
21	42.6%	45.6%	71.6%	65.4%	44.8%	55.6%	53.4%	58.4%	57.2%	72.0%	52.2%	51.3%	62.0%	60.8%	56.2%
22	41.4%	45.6%	71.0%	65.3%	44.7%	54.8%	52.7%	57.2%	56.5%	71.2%	51.7%	50.4%	61.1%	60.5%	55.5%
23	41.3%	45.5%	70.8%	64.4%	44.7%	53.9%	51.7%	56.9%	56.0%	70.5%	51.2%	49.7%	59.7%	59.3%	54.9%
24	41.6%	44.4%	69.9%	64.5%	43.0%	53.8%	52.0%	56.0%	54.7%	69.8%	50.2%	49.5%	59.4%	58.4%	54.4%
25	41.1%	44.1%	69.4%	64.5%	43.3%	53.0%	50.9%	55.1%	54.8%	69.0%	49.0%	47.9%	59.2%	57.7%	52.9%
26	41.2%	44.6%	69.5%	63.9%	43.0%	52.9%	50.3%	55.0%	53.8%	68.8%	48.7%	47.8%	57.6%	57.4%	53.4%
27	40.4%	44.5%	68.9%	63.4%	41.5%	51.7%	49.2%	53.9%	52.9%	68.1%	47.5%	46.5%	56.8%	56.2%	52.5%
28	39.9%	45.1%	67.9%	63.7%	41.7%	51.3%	49.7%	53.1%	52.8%	66.8%	47.2%	46.0%	56.5%	55.3%	52.1%
29	39.4%	44.2%	67.6%	63.1%	41.7%	50.8%	48.9%	52.8%	51.9%	67.1%	47.3%	46.0%	56.0%	55.2%	50.4%
30	39.1%	43.3%	67.4%	63.0%	40.7%	49.8%	47.8%	51.6%	51.8%	66.3%	46.3%	45.2%	55.7%	54.9%	50.6%

Table 4-54: KNN database F SINRD external position Cosine distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	13.4%	13.5%	15.0%	14.4%	20.8%	23.1%	21.9%	22.5%	23.1%	25.4%	38.4%	37.0%	32.8%	26.0%	41.6%
2	14.8%	14.5%	14.9%	13.9%	20.4%	21.8%	22.0%	21.7%	21.7%	27.3%	36.7%	36.8%	34.2%	28.1%	39.5%
3	15.2%	14.0%	16.4%	15.9%	22.2%	23.2%	21.2%	22.7%	23.6%	26.0%	36.0%	35.5%	32.6%	28.4%	37.8%
4	15.7%	14.7%	14.5%	15.0%	23.2%	23.2%	19.4%	23.2%	24.6%	25.9%	35.5%	36.4%	31.6%	29.1%	38.2%
5	15.1%	16.3%	16.4%	17.1%	24.1%	23.8%	20.5%	22.9%	24.8%	25.5%	35.2%	35.9%	32.5%	28.6%	37.3%
6	16.4%	15.4%	14.7%	14.3%	24.4%	23.0%	20.8%	22.1%	24.8%	26.2%	34.8%	35.3%	32.5%	29.0%	35.9%
7	16.0%	15.6%	15.6%	15.9%	24.9%	23.0%	21.8%	22.6%	24.4%	26.3%	34.2%	34.4%	31.8%	29.7%	35.9%
8	16.2%	16.9%	16.1%	13.5%	24.8%	24.0%	22.5%	21.7%	25.6%	26.5%	33.6%	33.6%	32.1%	28.9%	34.6%
9	15.5%	16.1%	16.6%	16.4%	24.4%	23.3%	22.3%	22.0%	24.7%	27.5%	33.1%	32.2%	31.8%	28.3%	33.9%
10	16.3%	15.3%	14.1%	15.3%	24.1%	24.1%	21.8%	21.3%	25.0%	27.9%	32.2%	32.1%	32.0%	27.0%	34.0%
11	16.4%	17.0%	15.7%	16.1%	23.5%	24.5%	22.3%	22.4%	25.3%	28.1%	31.6%	32.0%	31.3%	28.1%	33.2%
12	15.4%	16.4%	16.7%	15.3%	24.4%	23.9%	22.2%	22.8%	26.4%	27.2%	31.0%	31.7%	31.2%	28.0%	33.8%
13	15.0%	15.9%	16.6%	13.2%	23.7%	23.9%	22.6%	23.2%	25.9%	28.0%	30.6%	31.7%	31.0%	28.1%	33.1%
14	16.8%	14.8%	14.2%	16.0%	23.9%	25.2%	23.3%	23.6%	26.8%	28.3%	31.8%	32.9%	30.4%	27.5%	34.3%
15	17.1%	16.5%	16.5%	15.5%	23.8%	23.7%	22.3%	23.2%	26.1%	28.8%	31.4%	31.7%	29.9%	28.1%	32.8%
16	15.8%	14.5%	16.6%	16.9%	23.7%	24.4%	22.8%	23.5%	26.5%	28.6%	30.2%	32.2%	29.6%	27.4%	33.1%
17	16.3%	14.4%	15.9%	17.6%	24.1%	24.0%	22.4%	23.4%	26.3%	28.2%	31.0%	32.6%	30.1%	28.3%	32.9%
18	13.9%	14.7%	16.7%	14.9%	24.2%	24.3%	23.3%	24.3%	26.4%	29.1%	30.2%	31.7%	29.5%	27.1%	33.3%
19	14.9%	16.5%	16.4%	15.7%	24.4%	23.4%	22.8%	23.2%	27.3%	29.2%	30.3%	32.0%	29.6%	27.6%	32.8%
20	14.7%	16.6%	16.0%	16.4%	24.8%	23.8%	23.3%	22.9%	26.9%	29.3%	30.4%	31.4%	30.1%	27.8%	32.4%
21	15.2%	14.9%	16.0%	14.6%	24.8%	23.2%	23.1%	23.7%	27.0%	28.9%	30.5%	30.8%	29.2%	27.8%	31.9%
22	14.8%	17.1%	14.3%	16.0%	24.8%	23.9%	23.5%	24.0%	26.5%	28.4%	30.6%	31.4%	29.6%	27.7%	32.3%
23	14.5%	15.3%	16.4%	17.9%	24.8%	23.4%	23.2%	24.7%	27.5%	29.8%	30.3%	31.0%	28.6%	27.3%	31.8%
24	16.0%	16.3%	15.4%	14.6%	24.9%	23.4%	23.1%	23.7%	27.2%	29.1%	29.4%	31.0%	28.9%	28.0%	31.6%
25	15.8%	14.2%	16.1%	13.9%	25.3%	23.4%	23.7%	24.2%	26.7%	28.9%	29.8%	30.5%	28.2%	27.9%	31.6%
26	16.0%	16.1%	16.7%	16.8%	25.0%	23.0%	23.7%	23.6%	26.5%	28.9%	29.1%	29.7%	29.5%	28.0%	30.5%
27	16.1%	16.6%	16.2%	14.7%	25.3%	23.2%	23.4%	24.4%	26.8%	30.2%	29.1%	29.3%	29.2%	27.7%	30.8%
28	15.9%	15.7%	14.8%	17.4%	25.7%	23.6%	23.4%	24.1%	26.6%	29.5%	28.9%	29.4%	29.0%	27.6%	30.8%
29	16.7%	15.5%	14.7%	16.3%	25.1%	23.1%	23.3%	25.0%	26.3%	29.4%	28.5%	29.6%	28.6%	28.4%	30.6%
30	15.5%	15.3%	16.1%	15.7%	24.6%	23.0%	24.0%	24.6%	26.5%	30.2%	28.9%	29.3%	28.3%	27.6%	31.1%

Table 4-55: KNN database F SINRD all positions Cosine distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	31.1%	40.4%	79.3%	100.0%	56.7%	57.3%	62.3%	71.6%	78.3%	98.9%	63.0%	64.4%	63.7%	79.1%	64.7%
2	31.6%	39.2%	77.1%	100.0%	50.3%	53.9%	58.7%	64.6%	68.9%	97.2%	56.7%	57.7%	58.7%	70.1%	60.1%
3	33.3%	40.5%	76.0%	100.0%	48.0%	53.6%	58.8%	64.2%	67.9%	97.0%	55.2%	57.8%	60.1%	69.1%	58.8%
4	33.2%	40.5%	75.5%	99.9%	47.5%	52.4%	57.5%	62.0%	64.4%	96.0%	53.6%	55.1%	57.9%	65.8%	55.8%
5	32.1%	40.5%	74.2%	99.8%	44.1%	51.7%	57.8%	61.0%	63.4%	95.3%	49.7%	52.8%	58.0%	64.8%	53.3%
6	31.3%	40.6%	73.2%	99.2%	43.0%	50.3%	55.6%	58.5%	61.7%	94.0%	48.4%	50.4%	56.4%	63.8%	49.8%
7	31.1%	39.4%	73.4%	99.0%	40.1%	50.1%	54.9%	58.0%	60.8%	93.5%	44.8%	46.5%	56.3%	62.9%	47.5%
8	30.7%	39.0%	73.1%	97.6%	36.8%	49.2%	53.9%	55.8%	58.2%	92.1%	42.8%	45.4%	55.2%	59.7%	46.3%
9	30.9%	38.2%	72.7%	96.0%	35.3%	49.1%	52.7%	55.2%	57.4%	90.0%	41.5%	43.8%	54.0%	59.7%	44.3%
10	29.6%	37.7%	70.9%	93.3%	35.0%	47.9%	51.3%	54.5%	56.3%	88.4%	41.0%	43.0%	52.9%	57.9%	43.4%
11	29.9%	36.4%	70.4%	90.6%	33.3%	47.2%	51.7%	52.6%	55.4%	86.6%	38.7%	41.9%	51.5%	57.2%	43.3%
12	29.4%	35.3%	69.9%	82.5%	33.0%	46.3%	50.0%	51.8%	54.2%	83.6%	38.1%	41.8%	50.8%	54.6%	42.1%
13	30.1%	36.0%	68.2%	79.4%	31.9%	45.6%	49.3%	50.8%	53.4%	80.2%	38.2%	40.4%	50.6%	54.7%	41.9%
14	29.4%	35.5%	67.7%	72.6%	31.5%	44.8%	48.7%	49.4%	52.2%	78.8%	37.9%	39.9%	48.9%	53.2%	41.3%
15	28.7%	35.1%	66.9%	69.9%	31.9%	44.5%	48.2%	49.0%	51.7%	75.8%	37.3%	40.1%	48.6%	52.1%	41.7%
16	29.1%	35.3%	66.3%	69.0%	31.6%	42.6%	48.0%	48.0%	51.1%	74.9%	37.8%	39.6%	48.7%	52.5%	40.6%
17	29.2%	34.6%	66.0%	68.9%	31.0%	43.1%	47.4%	47.4%	50.0%	73.5%	38.0%	39.6%	47.7%	51.8%	40.7%
18	28.6%	34.7%	65.8%	70.3%	31.4%	41.2%	46.3%	46.5%	48.6%	72.7%	36.8%	40.1%	46.7%	50.3%	40.1%
19	28.6%	34.5%	66.0%	70.1%	31.3%	42.0%	45.6%	46.2%	48.9%	72.9%	37.0%	39.8%	46.4%	49.6%	40.3%
20	27.8%	34.5%	65.0%	69.3%	31.9%	40.9%	45.4%	45.8%	48.6%	72.4%	37.4%	39.4%	45.2%	49.0%	39.9%
21	27.7%	34.0%	65.4%	69.2%	31.6%	40.1%	45.0%	45.1%	47.1%	71.7%	36.7%	38.4%	44.0%	48.0%	39.0%
22	27.9%	33.5%	65.4%	68.7%	31.6%	40.1%	43.7%	44.3%	46.9%	71.6%	35.8%	37.9%	43.8%	47.6%	38.2%
23	27.7%	33.8%	65.0%	68.7%	30.6%	39.5%	43.2%	44.3%	46.5%	71.1%	36.3%	38.4%	42.8%	46.6%	38.3%
24	27.2%	32.5%	64.8%	68.0%	30.7%	39.1%	43.0%	42.7%	45.8%	70.7%	35.6%	37.8%	43.1%	45.8%	38.6%
25	27.4%	32.5%	64.7%	67.4%	31.2%	38.7%	41.9%	43.4%	45.7%	70.1%	35.3%	37.4%	42.9%	45.8%	37.6%
26	26.4%	31.6%	64.3%	67.6%	30.9%	38.1%	41.3%	42.9%	45.4%	69.5%	35.3%	36.7%	41.9%	45.0%	37.2%
27	26.1%	31.8%	64.3%	67.6%	31.0%	37.8%	41.6%	42.5%	44.8%	69.0%	34.7%	37.0%	41.5%	44.3%	37.0%
28	25.7%	31.5%	64.0%	64.9%	30.4%	37.6%	40.3%	42.2%	43.7%	68.1%	34.5%	36.1%	40.5%	44.2%	37.0%
29	25.0%	30.6%	64.1%	65.4%	31.0%	37.2%	39.8%	41.6%	43.4%	67.9%	34.8%	36.8%	40.1%	43.4%	36.0%
30	25.6%	30.8%	64.3%	64.6%	29.8%	36.5%	39.2%	41.7%	43.1%	67.9%	34.0%	35.0%	40.6%	43.2%	35.4%

4.2.2 Databases F (distance weight: Inverse)

In this chapter the results using the inverse distance weight in KNN analysis will be shown. The difference from the Equal distance weight is that the trends of the accuracies are constant or show a slight decrease increasing the number of neighbors in each case analyzed. For each distance metric the results of the first 5 neighbors are almost equal compared to those obtained using the equal distance weight, but increasing the number of neighbors they do not suffer a drastic decrease. In most of the cases the accuracy values are almost constant up to 30 neighbors and then, in some cases, undergo a slight decrease increasing further the number of neighbors. This is due to the fact that with the inverse distance weight the point that are further from the query point have a low impact on the final classification.

Given the similarities with the results obtained with the equal distance weight, the comments included in the previous section comparing the models using different features apply also in this chapter.

In the following pages the results for Euclidean, Mahalnobis and cosine distance metrics are reported for the cases of detectors in external positions and in all positions.

As for Equal distance weight the tables are cut at 30 neighbors for better visualization.

Table 4-56: KNN database F Fork detector diversion Euclidean distance metric.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	53.0%	52.3%	35.6%	67.2%	52.7%	52.8%	66.9%
2	52.8%	53.0%	35.3%	66.9%	53.1%	52.1%	67.8%
3	54.9%	54.0%	35.7%	68.4%	54.5%	54.2%	68.8%
4	55.7%	53.9%	35.6%	69.2%	55.8%	54.5%	68.6%
5	56.5%	55.4%	37.0%	68.1%	56.4%	55.2%	68.4%
6	56.9%	56.1%	36.2%	69.3%	56.5%	55.2%	69.2%
7	57.4%	56.3%	36.1%	69.1%	57.5%	55.8%	69.8%
8	57.7%	57.1%	36.2%	68.5%	57.5%	56.5%	69.1%
9	57.1%	56.7%	36.0%	69.4%	58.1%	56.7%	69.6%
10	57.8%	56.7%	36.6%	69.7%	58.5%	56.3%	69.1%
11	57.9%	56.5%	36.5%	69.1%	58.0%	56.1%	69.1%
12	57.0%	56.9%	36.3%	68.5%	58.4%	57.0%	69.6%
13	56.9%	57.1%	36.6%	69.2%	58.2%	57.5%	68.8%
14	58.0%	56.8%	36.1%	69.3%	57.6%	56.7%	68.6%
15	58.1%	57.7%	36.4%	68.3%	57.3%	57.2%	69.1%
16	58.0%	57.2%	36.5%	69.1%	58.1%	57.0%	68.6%
17	58.2%	57.6%	36.4%	68.0%	57.8%	57.4%	68.6%
18	58.4%	57.4%	36.5%	68.3%	57.9%	56.9%	68.5%
19	58.0%	57.5%	36.6%	68.6%	58.6%	57.2%	68.4%
20	58.5%	56.9%	36.5%	68.9%	57.7%	56.6%	67.7%
21	58.0%	57.5%	36.0%	68.4%	58.4%	57.4%	67.4%
22	58.1%	57.2%	36.1%	68.2%	58.3%	56.9%	68.1%
23	58.2%	57.0%	36.9%	68.4%	58.1%	57.4%	68.0%
24	57.6%	57.5%	36.6%	68.4%	57.7%	57.4%	68.4%
25	57.9%	57.1%	36.2%	68.4%	58.0%	57.4%	68.6%
26	57.8%	57.2%	36.0%	67.6%	57.8%	57.7%	68.0%
27	57.9%	57.2%	36.1%	67.1%	58.4%	57.7%	67.4%
28	58.3%	57.0%	36.6%	68.4%	58.0%	58.1%	67.8%
29	57.6%	57.3%	35.9%	67.7%	58.1%	57.6%	67.3%
30	58.3%	58.2%	36.2%	68.1%	58.2%	57.4%	67.1%
31	57.7%	57.9%	36.9%	67.2%	58.3%	56.9%	67.6%
32	57.5%	57.4%	36.2%	66.5%	57.9%	57.3%	67.0%
33	58.1%	57.9%	35.9%	67.2%	58.1%	57.8%	67.5%
34	58.4%	57.8%	35.8%	67.0%	58.1%	57.3%	68.0%
35	58.1%	57.3%	36.0%	67.5%	58.5%	56.8%	67.8%
36	58.2%	57.3%	37.0%	67.1%	58.5%	57.6%	67.3%
37	57.6%	57.7%	35.5%	67.4%	58.5%	57.1%	67.8%
38	58.0%	56.8%	36.0%	67.4%	58.2%	57.8%	67.4%
39	58.2%	57.7%	36.6%	66.6%	57.7%	57.4%	67.2%
40	57.8%	57.0%	35.9%	68.0%	58.0%	57.9%	66.6%
41	58.2%	57.2%	36.2%	66.7%	58.0%	57.8%	67.4%
42	57.8%	57.1%	35.9%	66.7%	58.2%	57.3%	67.1%
43	58.1%	57.1%	36.4%	66.9%	58.2%	57.1%	67.6%
44	58.1%	57.7%	36.1%	66.7%	57.2%	57.5%	67.5%
45	58.0%	57.7%	36.6%	67.5%	57.8%	57.6%	67.2%
46	58.2%	56.9%	36.5%	66.7%	57.7%	57.6%	66.8%
47	58.3%	57.2%	36.2%	66.7%	58.1%	57.4%	66.5%
48	58.0%	57.2%	36.7%	67.4%	57.8%	57.1%	67.0%
49	57.6%	57.7%	36.3%	66.8%	57.6%	58.1%	66.7%
50	58.4%	57.5%	36.8%	67.1%	58.0%	57.5%	67.2%

Table 4-57: KNN database F Fork detector diversion Mahalanobis distance metric.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	52.9%	53.3%	35.9%	59.6%	58.4%	59.0%	55.4%
2	52.5%	52.7%	35.5%	59.2%	59.1%	59.2%	54.5%
3	54.3%	53.8%	36.2%	58.5%	60.4%	59.8%	56.3%
4	55.7%	54.4%	36.0%	58.7%	60.4%	58.7%	55.8%
5	55.6%	55.2%	36.1%	57.8%	59.8%	59.2%	55.8%
6	56.6%	55.5%	36.2%	56.9%	60.5%	58.6%	55.0%
7	57.8%	56.0%	35.5%	56.8%	60.2%	59.3%	55.6%
8	57.4%	56.4%	36.5%	56.9%	60.4%	58.2%	54.7%
9	58.1%	56.8%	35.9%	56.8%	59.9%	60.2%	55.3%
10	57.6%	56.5%	36.4%	56.1%	60.5%	58.4%	53.9%
11	57.8%	56.8%	35.6%	55.4%	59.6%	59.2%	53.9%
12	58.5%	56.7%	37.2%	55.5%	58.9%	59.0%	54.1%
13	58.0%	56.2%	36.4%	54.9%	58.9%	57.7%	53.9%
14	56.7%	56.6%	35.6%	54.8%	59.6%	58.5%	52.9%
15	58.2%	56.8%	36.4%	55.3%	59.4%	58.9%	53.3%
16	58.3%	57.4%	36.8%	55.1%	58.3%	58.0%	53.3%
17	58.0%	57.4%	36.6%	54.5%	58.0%	58.1%	53.8%
18	58.4%	57.2%	37.0%	54.5%	58.5%	56.9%	53.5%
19	58.2%	57.3%	36.7%	54.7%	57.8%	56.9%	52.9%
20	58.1%	57.9%	35.9%	53.8%	58.5%	56.7%	52.9%
21	58.3%	57.0%	36.7%	53.5%	57.4%	57.1%	52.7%
22	57.6%	57.4%	36.8%	54.1%	57.9%	56.7%	53.2%
23	57.7%	57.2%	36.1%	54.1%	57.3%	56.2%	53.0%
24	58.3%	57.0%	36.0%	52.9%	57.9%	56.8%	52.5%
25	58.0%	57.1%	36.2%	53.9%	57.5%	56.8%	52.3%
26	58.0%	56.9%	36.3%	53.6%	57.2%	56.2%	52.1%
27	58.2%	57.5%	36.4%	53.5%	57.4%	56.5%	51.8%
28	58.0%	57.5%	36.0%	53.0%	57.2%	56.8%	51.6%
29	58.7%	57.3%	36.5%	51.8%	57.2%	56.3%	51.7%
30	57.9%	57.3%	36.3%	52.9%	57.1%	57.0%	51.6%
31	58.4%	56.7%	35.9%	53.4%	57.3%	56.5%	52.2%
32	58.6%	57.6%	36.0%	51.8%	57.3%	56.1%	50.8%
33	57.9%	57.2%	36.0%	52.7%	57.3%	56.0%	51.3%
34	57.8%	58.2%	36.2%	53.1%	57.3%	55.0%	52.1%
35	57.6%	57.8%	36.1%	52.4%	56.7%	56.7%	52.4%
36	57.6%	57.6%	35.9%	52.7%	57.0%	55.5%	51.0%
37	58.6%	56.4%	36.6%	52.4%	57.0%	55.5%	50.7%
38	58.2%	57.5%	36.6%	52.8%	56.8%	55.8%	50.5%
39	58.0%	57.6%	36.2%	52.5%	56.6%	55.1%	51.8%
40	58.1%	56.9%	35.9%	53.4%	56.1%	55.5%	50.1%
41	58.3%	57.5%	36.3%	51.8%	56.5%	55.9%	50.8%
42	58.4%	57.1%	35.9%	52.2%	56.5%	55.4%	50.9%
43	58.2%	57.5%	36.3%	52.5%	56.7%	55.9%	51.0%
44	58.1%	57.3%	35.7%	52.3%	57.0%	54.9%	50.7%
45	58.3%	57.7%	36.4%	51.8%	56.5%	54.5%	50.4%
46	57.5%	57.9%	36.0%	51.9%	55.7%	55.6%	50.7%
47	58.6%	57.5%	35.9%	51.9%	56.7%	55.9%	50.1%
48	58.0%	57.1%	36.7%	51.5%	56.4%	54.8%	50.1%
49	57.3%	57.0%	36.9%	51.4%	56.7%	55.3%	50.4%
50	58.3%	57.5%	36.4%	52.5%	56.1%	54.6%	50.3%

Table 4-58: KNN database F Fork detector diversion Cosine distance metric.

				N without Cd	Current	Current	N without Cd
							Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	13.3%	15.1%	15.7%	28.3%	16.0%	15.5%	29.2%
2	14.8%	14.6%	14.4%	28.7%	16.3%	15.7%	29.3%
3	15.7%	16.7%	13.9%	28.8%	17.9%	17.8%	28.7%
4	15.7%	15.2%	16.0%	29.5%	17.4%	16.6%	29.6%
5	15.8%	16.6%	14.5%	28.9%	17.3%	17.0%	30.1%
6	16.2%	16.3%	15.2%	29.9%	16.4%	15.2%	29.6%
7	14.9%	15.7%	15.3%	29.5%	16.9%	14.8%	29.3%
8	14.8%	15.5%	15.8%	29.1%	15.7%	17.0%	29.9%
9	16.3%	15.0%	15.5%	30.0%	16.6%	16.2%	29.8%
10	15.6%	16.3%	16.7%	29.4%	17.7%	16.5%	29.4%
11	16.5%	16.2%	16.0%	29.2%	18.2%	16.8%	29.6%
12	16.4%	15.7%	15.6%	29.7%	17.9%	18.5%	29.5%
13	16.4%	17.1%	14.7%	29.4%	17.3%	17.3%	29.4%
14	15.9%	14.6%	16.2%	29.4%	17.7%	17.7%	29.8%
15	15.2%	16.1%	16.1%	29.5%	18.1%	17.6%	29.5%
16	17.1%	17.1%	16.8%	30.0%	17.7%	17.9%	29.2%
17	16.7%	16.7%	14.7%	30.0%	17.4%	16.7%	29.4%
18	15.5%	15.9%	15.9%	30.2%	18.0%	16.3%	29.4%
19	16.3%	16.2%	17.0%	30.2%	16.2%	15.4%	29.8%
20	16.1%	15.1%	16.3%	30.3%	19.1%	16.7%	29.9%
21	16.7%	16.1%	16.7%	30.4%	17.0%	17.2%	30.5%
22	15.9%	15.1%	16.5%	30.1%	17.9%	18.7%	30.1%
23	16.0%	15.8%	16.2%	29.7%	16.6%	16.0%	29.8%
24	15.2%	15.9%	13.8%	30.2%	17.7%	18.1%	30.2%
25	15.1%	15.8%	16.5%	29.6%	16.8%	17.8%	29.8%
26	15.6%	15.2%	13.5%	29.6%	18.6%	18.1%	29.9%
27	15.1%	15.9%	16.0%	30.3%	18.1%	17.1%	29.9%
28	15.0%	17.1%	14.5%	29.8%	18.0%	17.4%	30.2%
29	15.7%	16.7%	16.2%	30.2%	16.6%	16.8%	30.5%
30	16.9%	16.9%	15.0%	29.5%	18.6%	16.4%	29.9%
31	15.1%	17.4%	15.8%	30.3%	18.8%	16.5%	29.7%
32	14.3%	16.9%	14.8%	30.1%	17.5%	18.6%	30.1%
33	16.3%	16.3%	17.1%	30.3%	17.8%	16.5%	29.5%
34	17.5%	15.6%	16.8%	30.3%	16.9%	17.5%	30.4%
35	16.1%	16.3%	17.4%	29.0%	19.4%	14.7%	30.8%
36	16.6%	15.7%	16.8%	29.7%	17.4%	17.8%	29.8%
37	14.6%	16.7%	16.3%	29.9%	18.7%	17.7%	29.8%
38	15.3%	16.1%	16.3%	29.9%	18.1%	18.2%	30.4%
39	15.5%	16.4%	16.9%	30.1%	18.3%	17.0%	30.0%
40	15.4%	17.1%	15.6%	30.0%	18.2%	16.6%	29.8%
41	15.7%	16.6%	15.3%	30.4%	18.4%	17.3%	29.5%
42	16.3%	15.7%	16.8%	30.3%	17.0%	17.0%	30.2%
43	16.4%	15.9%	14.9%	29.6%	17.8%	17.7%	29.8%
44	15.8%	16.3%	17.0%	30.0%	18.1%	17.5%	30.1%
45	15.4%	17.5%	17.3%	30.8%	16.5%	18.5%	29.5%
46	15.5%	16.6%	16.1%	29.7%	19.4%	17.1%	29.1%
47	17.1%	16.0%	16.4%	30.4%	18.0%	17.9%	30.5%
48	14.8%	17.7%	17.5%	30.0%	18.1%	17.3%	30.1%
49	16.6%	16.5%	16.9%	29.9%	18.7%	17.6%	29.7%
50	17.3%	15.2%	16.1%	30.4%	17.7%	16.8%	29.7%

Table 4-59: KNN database F Fork detector replacement Euclidean distance metric.

	N with Cd	N without Cd	Current	N with Cd N without Cd	N with Cd Current	N without Cd Current	N with Cd N without Cd Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	47.4%	52.3%	32.5%	60.5%	47.6%	52.9%	61.3%
2	48.2%	53.4%	32.7%	60.7%	47.6%	52.5%	61.2%
3	48.8%	54.2%	33.6%	62.8%	49.3%	54.2%	63.0%
4	49.7%	54.7%	33.6%	63.2%	50.3%	54.5%	62.6%
5	51.1%	55.2%	33.3%	63.9%	51.1%	54.9%	63.2%
6	51.6%	55.8%	34.3%	63.3%	51.5%	55.9%	63.7%
7	52.2%	56.0%	33.6%	63.8%	51.9%	56.2%	64.4%
8	52.1%	57.0%	34.1%	64.5%	51.4%	56.0%	64.4%
9	52.3%	56.7%	34.6%	64.0%	52.3%	57.2%	64.5%
10	52.2%	56.6%	34.4%	63.4%	52.1%	56.8%	64.2%
11	52.3%	56.9%	34.7%	63.6%	52.1%	56.8%	63.9%
12	52.4%	57.3%	34.5%	64.3%	52.5%	57.3%	63.8%
13	52.3%	57.3%	34.3%	63.8%	52.3%	57.1%	63.7%
14	52.4%	56.8%	34.8%	63.3%	52.1%	56.8%	63.4%
15	52.2%	56.9%	35.1%	63.6%	52.8%	57.2%	63.8%
16	52.9%	57.5%	34.8%	63.4%	52.3%	56.7%	63.6%
17	51.9%	57.2%	34.6%	63.4%	53.1%	57.3%	63.6%
18	51.9%	57.0%	34.9%	63.4%	52.6%	57.5%	63.5%
19	52.4%	56.9%	34.5%	63.4%	52.5%	57.7%	63.6%
20	52.4%	57.3%	34.8%	63.2%	52.5%	56.3%	63.8%
21	52.4%	57.5%	34.9%	63.1%	52.5%	57.3%	63.9%
22	52.6%	57.4%	35.0%	63.1%	52.8%	57.2%	63.6%
23	52.5%	56.9%	35.4%	63.7%	52.2%	57.3%	63.6%
24	52.6%	57.8%	34.5%	62.7%	52.8%	57.3%	63.1%
25	52.6%	57.0%	34.5%	63.5%	52.4%	57.5%	63.0%
26	52.8%	57.2%	34.3%	63.4%	52.1%	58.1%	63.1%
27	52.5%	57.2%	35.3%	63.3%	52.3%	57.2%	64.0%
28	53.0%	57.7%	35.0%	63.0%	52.3%	57.8%	63.1%
29	52.3%	57.2%	34.7%	63.5%	52.7%	57.1%	63.7%
30	52.4%	57.5%	35.4%	63.4%	52.7%	57.4%	63.3%
31	52.9%	57.7%	34.9%	62.9%	52.8%	57.1%	63.1%
32	52.3%	57.3%	34.9%	62.6%	52.4%	57.3%	62.9%
33	52.5%	57.1%	34.8%	63.1%	53.1%	56.9%	63.2%
34	52.2%	57.2%	34.8%	62.9%	53.0%	58.0%	63.1%
35	52.1%	56.8%	33.8%	62.7%	52.5%	57.3%	63.3%
36	52.6%	57.1%	34.1%	63.0%	52.7%	58.1%	63.2%
37	52.2%	57.5%	35.6%	63.5%	52.3%	57.6%	63.3%
38	52.5%	57.7%	34.4%	63.3%	52.1%	57.5%	62.8%
39	53.3%	56.9%	35.3%	63.6%	53.0%	57.5%	63.6%
40	53.3%	57.9%	34.8%	63.3%	52.0%	57.1%	62.8%
41	52.5%	56.9%	34.3%	63.1%	52.0%	57.3%	63.5%
42	52.0%	57.3%	34.8%	63.2%	52.8%	57.6%	63.4%
43	52.5%	56.9%	34.4%	63.5%	52.8%	57.4%	63.1%
44	52.8%	57.0%	34.8%	63.0%	52.5%	57.3%	63.3%
45	52.8%	57.4%	35.1%	63.2%	52.1%	57.1%	63.2%
46	52.0%	57.3%	34.7%	62.8%	52.6%	57.2%	62.8%
47	52.2%	57.1%	34.2%	63.3%	52.6%	56.7%	62.9%
48	52.3%	57.8%	35.1%	63.6%	52.2%	57.3%	62.3%
49	52.6%	57.9%	34.9%	62.6%	52.1%	57.6%	63.3%
50	52.7%	57.0%	35.0%	63.0%	53.2%	57.0%	63.0%

Table 4-60: KNN database F Fork detector replacement Mahalanobis distance metric.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	47.8%	52.4%	32.3%	50.5%	54.9%	55.0%	53.3%
2	47.4%	52.8%	32.6%	49.5%	55.1%	55.1%	52.0%
3	49.5%	54.4%	32.8%	51.9%	55.2%	55.6%	53.1%
4	50.1%	54.6%	33.3%	51.1%	55.1%	55.5%	53.3%
5	50.5%	55.5%	32.7%	50.5%	55.5%	56.5%	51.9%
6	51.0%	55.6%	33.7%	50.4%	54.9%	56.0%	51.8%
7	51.4%	55.9%	34.3%	50.3%	55.2%	55.7%	52.6%
8	52.1%	56.4%	34.8%	49.7%	54.7%	56.1%	52.2%
9	52.1%	56.3%	34.1%	49.2%	54.9%	56.0%	51.1%
10	52.9%	56.9%	34.9%	48.9%	54.9%	55.3%	50.9%
11	51.8%	56.6%	34.4%	48.5%	54.7%	54.9%	49.8%
12	52.2%	56.8%	34.0%	48.0%	54.7%	55.7%	50.7%
13	52.8%	57.2%	35.0%	48.2%	55.2%	54.6%	50.0%
14	52.3%	56.7%	34.9%	47.8%	54.3%	56.0%	50.1%
15	52.6%	57.0%	33.6%	47.5%	53.9%	54.3%	49.5%
16	52.7%	57.5%	34.5%	47.1%	54.0%	55.0%	49.1%
17	52.4%	57.2%	34.2%	47.7%	54.0%	53.7%	49.1%
18	52.7%	57.4%	34.6%	47.7%	54.5%	54.4%	48.9%
19	52.8%	56.9%	35.0%	47.6%	53.9%	54.9%	49.5%
20	52.4%	57.0%	34.6%	47.5%	53.5%	54.3%	48.3%
21	52.9%	57.5%	34.4%	47.8%	53.5%	53.6%	49.1%
22	52.6%	57.8%	34.2%	46.8%	53.0%	53.3%	48.7%
23	52.8%	57.8%	34.5%	46.7%	53.7%	53.5%	48.1%
24	52.5%	57.3%	34.6%	46.7%	53.9%	53.5%	49.0%
25	52.4%	58.0%	35.1%	45.5%	53.6%	54.1%	49.0%
26	52.4%	57.8%	35.1%	46.3%	53.7%	53.8%	48.5%
27	52.5%	57.3%	34.7%	46.8%	53.3%	53.6%	48.3%
28	52.1%	57.4%	34.6%	46.8%	53.5%	53.8%	48.3%
29	52.1%	58.2%	35.3%	45.5%	53.0%	53.3%	48.0%
30	52.3%	57.6%	35.2%	46.3%	52.7%	53.7%	47.6%
31	53.1%	57.0%	35.0%	46.0%	53.3%	53.9%	48.4%
32	52.7%	57.3%	34.6%	46.5%	52.6%	53.9%	47.7%
33	53.1%	57.5%	34.6%	46.1%	52.6%	53.6%	48.3%
34	52.5%	56.8%	35.1%	46.4%	52.3%	52.8%	47.7%
35	52.9%	56.9%	34.3%	45.4%	52.1%	53.7%	47.1%
36	52.5%	57.6%	34.7%	45.8%	52.9%	53.0%	48.1%
37	52.2%	57.7%	34.1%	46.3%	53.3%	52.0%	48.0%
38	52.8%	57.2%	34.9%	46.2%	52.5%	52.5%	47.7%
39	52.1%	57.5%	35.1%	45.8%	52.8%	53.0%	46.8%
40	52.0%	57.5%	34.8%	46.4%	51.6%	53.1%	48.0%
41	53.6%	57.4%	35.3%	46.0%	51.9%	53.0%	46.8%
42	52.8%	57.0%	34.5%	45.6%	52.1%	53.4%	47.4%
43	52.7%	57.6%	34.4%	45.1%	51.4%	53.2%	46.6%
44	52.5%	57.4%	35.3%	45.8%	53.1%	52.8%	46.7%
45	52.2%	56.9%	34.9%	45.6%	52.2%	52.8%	46.7%
46	52.4%	57.3%	34.5%	46.0%	52.2%	52.9%	46.7%
47	52.2%	57.2%	34.9%	45.9%	51.8%	51.7%	47.2%
48	53.1%	57.4%	34.1%	46.0%	52.3%	52.4%	47.7%
49	52.2%	57.5%	35.4%	46.6%	51.7%	52.1%	47.5%
50	52.3%	57.1%	35.4%	45.7%	51.2%	52.2%	47.1%

Table 4-61: KNN database F Fork detector replacement Cosine distance metric.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
#NEIGHBORS	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
1	15.2%	14.7%	14.1%	23.8%	14.2%	16.8%	23.9%
2	15.3%	15.7%	16.8%	23.1%	16.4%	16.9%	22.6%
3	17.0%	15.4%	16.3%	23.0%	16.8%	16.2%	22.7%
4	14.2%	16.3%	15.8%	23.3%	17.8%	17.3%	23.4%
5	15.7%	17.6%	15.2%	23.6%	16.8%	16.3%	22.3%
6	15.6%	16.3%	16.2%	23.5%	18.1%	15.6%	23.6%
7	15.4%	14.9%	16.9%	23.4%	17.5%	16.8%	23.2%
8	16.7%	14.9%	16.2%	23.9%	16.9%	15.9%	24.0%
9	16.1%	16.5%	14.6%	23.3%	18.3%	16.8%	23.9%
10	15.8%	15.5%	16.4%	22.9%	17.1%	16.7%	23.7%
11	14.6%	15.0%	15.8%	23.8%	17.8%	15.5%	23.8%
12	16.8%	15.0%	16.7%	23.8%	17.5%	17.6%	22.8%
13	17.2%	15.4%	14.7%	23.9%	16.8%	15.9%	23.7%
14	16.4%	13.9%	14.9%	23.7%	16.6%	15.7%	23.1%
15	14.1%	18.0%	17.1%	23.6%	17.1%	17.0%	23.7%
16	16.5%	16.6%	15.5%	23.4%	17.1%	17.4%	23.8%
17	16.9%	16.4%	16.1%	22.9%	16.7%	17.0%	23.5%
18	15.8%	15.8%	16.8%	23.5%	18.1%	16.3%	23.3%
19	14.8%	16.9%	15.5%	24.1%	18.8%	16.7%	23.8%
20	15.7%	16.3%	15.0%	23.2%	17.8%	15.3%	23.0%
21	15.8%	16.7%	16.0%	23.9%	17.8%	18.3%	23.9%
22	15.4%	14.6%	14.9%	23.9%	19.0%	17.1%	23.6%
23	15.3%	16.0%	16.2%	23.6%	17.4%	16.9%	23.7%
24	17.7%	15.0%	14.5%	24.2%	17.8%	15.9%	23.7%
25	15.9%	15.9%	17.0%	23.9%	18.1%	18.0%	23.6%
26	15.6%	16.8%	17.0%	23.7%	17.1%	16.8%	23.6%
27	15.8%	15.4%	15.7%	23.4%	20.0%	15.7%	23.0%
28	15.6%	17.1%	16.0%	22.9%	18.5%	16.9%	23.6%
29	14.4%	17.3%	17.1%	23.9%	17.7%	15.4%	23.9%
30	15.1%	14.6%	17.4%	23.7%	18.2%	18.2%	23.6%
31	16.9%	16.9%	16.3%	22.8%	16.9%	16.4%	23.7%
32	15.3%	14.0%	14.7%	23.7%	18.6%	15.8%	24.2%
33	16.3%	16.6%	15.8%	23.2%	16.2%	16.7%	23.4%
34	15.6%	16.8%	14.3%	23.4%	18.4%	17.5%	24.2%
35	17.3%	15.6%	17.3%	23.8%	17.6%	16.9%	23.4%
36	16.8%	17.0%	15.3%	23.6%	17.8%	17.9%	24.0%
37	16.0%	16.0%	13.8%	23.0%	18.4%	16.6%	23.9%
38	14.8%	17.3%	16.8%	24.1%	18.4%	17.4%	23.9%
39	15.9%	17.3%	17.1%	23.7%	19.0%	18.3%	23.5%
40	16.6%	16.3%	17.7%	24.1%	17.5%	16.9%	23.7%
41	15.8%	14.8%	15.6%	23.3%	18.3%	17.2%	23.5%
42	17.2%	16.9%	14.6%	22.9%	18.4%	16.0%	23.5%
43	17.4%	16.7%	16.2%	23.8%	18.6%	16.5%	23.7%
44	16.2%	16.8%	16.5%	23.7%	17.6%	17.2%	23.9%
45	16.6%	16.5%	14.6%	22.8%	17.3%	16.4%	24.0%
46	17.1%	15.4%	16.3%	24.1%	17.2%	17.0%	23.9%
47	17.1%	16.9%	17.5%	23.9%	19.0%	16.1%	24.0%
48	16.1%	16.5%	16.8%	23.2%	18.6%	17.2%	23.5%
49	17.5%	16.6%	15.9%	23.6%	17.9%	17.6%	23.9%
50	16.8%	17.1%	16.8%	23.5%	18.6%	17.7%	23.3%

Table 4-62: KNN database F PDET external position Euclidean distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	21.4%	24.7%	52.0%	84.8%	32.2%	53.3%	56.0%	61.6%	66.4%	89.2%	50.9%	54.9%	61.2%	73.5%	57.2%
2	21.5%	24.7%	52.3%	84.1%	32.0%	53.5%	55.7%	61.2%	66.6%	89.1%	50.5%	54.4%	61.5%	74.2%	57.7%
3	22.7%	24.4%	53.3%	84.5%	33.5%	53.8%	55.3%	61.6%	66.8%	89.4%	50.2%	53.4%	60.3%	72.6%	56.1%
4	22.7%	24.3%	54.5%	83.4%	34.8%	53.6%	54.4%	61.7%	66.1%	89.8%	48.5%	52.7%	59.1%	72.6%	54.8%
5	22.8%	24.7%	54.8%	84.5%	34.1%	52.4%	54.4%	60.7%	67.0%	89.5%	49.2%	52.3%	58.6%	71.9%	54.0%
6	22.6%	24.8%	55.8%	84.1%	34.6%	52.8%	55.0%	61.3%	66.1%	89.3%	48.5%	52.1%	58.0%	71.0%	53.9%
7	22.2%	24.8%	55.9%	84.2%	34.4%	52.4%	54.1%	60.7%	66.6%	89.5%	49.0%	52.7%	58.1%	70.6%	53.2%
8	22.4%	25.1%	55.5%	84.3%	34.7%	52.0%	54.3%	61.3%	66.4%	89.3%	48.8%	51.1%	57.8%	70.8%	53.2%
9	22.9%	25.0%	56.5%	84.8%	34.6%	51.4%	53.9%	60.7%	66.3%	88.8%	48.5%	51.3%	57.2%	70.6%	53.1%
10	22.7%	24.9%	56.3%	84.6%	34.1%	51.3%	53.3%	61.4%	66.2%	89.0%	48.4%	52.0%	56.9%	69.7%	53.2%
11	23.3%	25.2%	56.4%	84.1%	35.0%	50.7%	52.9%	60.6%	65.9%	88.7%	47.2%	50.7%	57.5%	69.3%	52.4%
12	22.6%	26.1%	56.3%	84.8%	34.9%	50.6%	52.7%	60.9%	65.7%	88.4%	46.8%	50.2%	57.0%	69.3%	52.0%
13	22.6%	25.7%	56.3%	84.5%	34.4%	50.1%	53.4%	60.9%	66.7%	88.1%	47.6%	51.1%	56.6%	69.4%	52.1%
14	23.0%	25.6%	56.9%	84.7%	35.0%	50.0%	51.9%	60.5%	65.8%	88.4%	47.7%	50.8%	56.9%	69.6%	52.2%
15	22.7%	25.7%	57.0%	84.6%	35.4%	51.0%	52.1%	59.7%	64.9%	88.0%	48.2%	50.6%	56.1%	69.5%	52.1%
16	23.7%	25.9%	56.6%	84.4%	35.7%	50.5%	51.9%	60.9%	65.1%	87.6%	47.2%	50.1%	55.1%	68.7%	52.5%
17	22.8%	25.7%	56.3%	84.7%	35.1%	50.1%	52.0%	60.6%	65.5%	88.4%	46.6%	50.4%	55.8%	68.5%	51.6%
18	23.3%	26.4%	57.2%	85.0%	35.2%	50.1%	52.0%	60.8%	65.7%	87.9%	46.3%	49.6%	55.8%	68.1%	51.1%
19	23.2%	24.6%	57.0%	85.1%	36.2%	49.0%	52.0%	60.3%	65.6%	88.1%	46.2%	49.3%	55.0%	68.2%	50.1%
20	23.4%	25.8%	57.5%	85.0%	35.1%	49.1%	51.4%	60.4%	65.1%	87.7%	46.4%	49.1%	55.7%	68.5%	51.6%
21	23.2%	26.7%	57.1%	84.6%	35.5%	48.9%	51.9%	60.2%	65.1%	87.6%	47.0%	49.9%	55.7%	67.8%	51.1%
22	23.3%	26.0%	56.8%	84.5%	35.8%	49.5%	51.6%	60.0%	64.8%	87.2%	46.5%	49.4%	54.9%	67.8%	51.4%
23	23.0%	25.8%	57.3%	85.0%	35.4%	49.2%	51.1%	60.3%	64.9%	87.2%	46.0%	49.2%	54.5%	67.9%	50.9%
24	23.5%	26.4%	57.1%	85.1%	35.6%	49.4%	51.1%	59.7%	64.5%	87.1%	47.4%	48.9%	53.5%	67.4%	50.8%
25	23.7%	26.1%	57.2%	84.2%	36.1%	49.0%	51.0%	59.8%	63.7%	86.9%	46.4%	49.3%	54.2%	67.1%	50.7%
26	22.8%	26.1%	56.9%	85.2%	35.9%	49.7%	51.6%	59.3%	64.4%	86.8%	45.9%	48.6%	53.9%	67.3%	50.3%
27	23.5%	26.3%	57.2%	84.2%	35.9%	49.3%	51.0%	60.1%	64.9%	86.5%	46.5%	48.7%	55.1%	67.6%	50.2%
28	23.8%	26.2%	56.6%	84.4%	35.9%	48.9%	51.8%	59.5%	64.0%	86.8%	45.9%	48.4%	53.8%	67.4%	50.3%
29	23.3%	26.2%	57.3%	84.2%	35.8%	49.4%	50.4%	59.1%	64.0%	87.0%	45.2%	47.7%	54.5%	67.6%	49.4%
30	23.8%	26.1%	57.7%	84.4%	36.1%	48.6%	50.8%	59.9%	64.2%	86.7%	46.3%	49.1%	53.5%	66.4%	49.6%

Table 4-63: KNN database F PDET all positions Euclidean distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	50.8%	53.5%	97.8%	100.0%	58.6%	83.1%	86.3%	92.4%	97.1%	100.0%	79.0%	82.8%	88.3%	98.0%	86.8%
2	50.0%	53.5%	97.7%	100.0%	59.3%	83.1%	85.7%	92.2%	96.9%	100.0%	78.9%	83.0%	88.7%	98.0%	86.6%
3	49.0%	55.4%	97.0%	100.0%	56.5%	79.4%	83.0%	91.8%	95.9%	100.0%	75.5%	79.5%	86.3%	97.4%	83.1%
4	47.3%	56.0%	97.3%	100.0%	55.2%	79.2%	82.4%	92.1%	95.9%	100.0%	76.1%	80.4%	85.4%	97.4%	84.3%
5	48.0%	53.6%	96.6%	100.0%	54.2%	78.3%	81.8%	90.7%	95.1%	100.0%	74.7%	79.2%	85.1%	96.5%	82.3%
6	48.0%	54.7%	96.3%	100.0%	53.9%	77.2%	81.5%	90.9%	95.2%	100.0%	74.1%	79.1%	85.2%	96.6%	82.5%
7	47.1%	54.4%	96.3%	100.0%	52.7%	77.0%	80.0%	90.0%	94.7%	99.9%	74.1%	77.6%	84.7%	96.4%	81.7%
8	46.9%	54.8%	96.4%	100.0%	52.2%	76.5%	80.2%	90.1%	94.8%	99.9%	73.4%	77.2%	84.0%	96.0%	81.6%
9	47.4%	53.7%	96.3%	100.0%	51.6%	75.3%	80.2%	89.7%	94.1%	99.9%	72.7%	76.5%	83.1%	95.5%	80.0%
10	46.3%	54.2%	96.4%	100.0%	51.2%	74.5%	78.9%	89.8%	94.2%	99.8%	72.9%	76.1%	82.6%	95.9%	79.5%
11	46.3%	54.3%	96.0%	100.0%	51.0%	74.6%	78.2%	89.7%	93.6%	99.7%	71.5%	75.7%	81.7%	95.6%	78.8%
12	45.9%	53.1%	96.2%	100.0%	50.4%	73.9%	78.3%	88.9%	93.1%	99.6%	71.2%	74.1%	81.0%	94.9%	78.4%
13	45.6%	53.3%	96.0%	99.9%	50.1%	72.3%	77.4%	88.3%	92.5%	99.7%	70.5%	73.4%	80.7%	94.6%	77.0%
14	45.5%	53.5%	96.1%	100.0%	50.3%	72.1%	77.2%	87.5%	93.0%	99.6%	69.9%	72.0%	79.9%	94.6%	76.8%
15	45.0%	53.4%	95.8%	99.9%	50.5%	71.5%	75.7%	87.7%	92.1%	99.6%	69.6%	72.4%	78.8%	93.9%	76.2%
16	45.1%	53.0%	96.2%	100.0%	48.7%	71.4%	76.0%	87.2%	91.8%	99.5%	68.2%	71.6%	78.6%	93.9%	75.4%
17	45.2%	53.1%	96.0%	100.0%	49.2%	71.0%	74.9%	86.8%	92.0%	99.2%	67.7%	71.7%	78.4%	93.3%	75.5%
18	44.4%	53.2%	95.5%	100.0%	48.7%	70.6%	74.3%	86.2%	91.3%	99.1%	67.1%	70.6%	76.9%	93.5%	74.4%
19	44.8%	52.9%	95.4%	100.0%	49.8%	69.9%	74.4%	86.2%	91.1%	99.0%	66.6%	70.9%	76.5%	92.8%	74.0%
20	43.9%	52.0%	95.8%	100.0%	48.4%	69.8%	73.8%	85.5%	91.4%	98.9%	66.3%	70.4%	75.6%	92.8%	73.9%
21	44.3%	52.0%	95.6%	100.0%	47.6%	69.7%	72.6%	85.0%	90.1%	98.8%	66.3%	70.4%	75.7%	92.8%	72.9%
22	43.8%	52.5%	95.5%	100.0%	47.1%	69.1%	73.0%	84.7%	89.7%	98.7%	66.2%	69.5%	75.5%	91.6%	73.2%
23	43.7%	52.4%	95.2%	100.0%	48.2%	69.0%	72.5%	84.1%	90.2%	98.7%	66.2%	69.1%	75.7%	91.3%	73.1%
24	43.0%	51.8%	95.3%	100.0%	46.5%	68.2%	72.5%	83.7%	89.3%	98.4%	65.0%	68.6%	74.9%	91.1%	72.2%
25	43.8%	52.0%	95.3%	100.0%	47.0%	68.0%	71.7%	83.8%	88.9%	98.5%	64.3%	68.4%	74.8%	91.2%	71.4%
26	43.1%	51.6%	95.2%	100.0%	47.2%	67.5%	71.4%	82.4%	88.8%	98.2%	63.3%	68.6%	75.0%	90.1%	71.7%
27	42.6%	51.7%	94.9%	99.9%	46.3%	67.2%	71.7%	82.7%	88.8%	98.1%	64.3%	68.5%	74.3%	90.6%	70.9%
28	43.2%	51.8%	94.7%	100.0%	45.8%	66.9%	71.3%	82.3%	87.7%	98.1%	63.3%	66.7%	73.8%	89.9%	69.7%
29	42.3%	51.2%	94.8%	99.9%	45.9%	66.3%	70.7%	82.0%	87.5%	97.9%	63.3%	67.6%	74.3%	89.4%	70.4%
30	42.0%	52.0%	94.4%	99.9%	45.5%	66.0%	70.6%	81.6%	87.3%	97.8%	62.6%	67.2%	72.7%	89.6%	70.4%

Table 4-64: KNN database F PDET external position Mahalanobis distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	21.4%	24.7%	52.0%	84.8%	34.8%	58.5%	57.5%	58.7%	59.4%	72.7%	49.9%	48.5%	65.1%	63.5%	59.8%
2	21.5%	24.7%	52.3%	84.1%	34.4%	59.2%	56.9%	58.4%	59.0%	72.2%	49.8%	47.9%	65.6%	62.5%	59.0%
3	22.7%	24.4%	53.3%	84.5%	34.3%	57.6%	56.2%	58.6%	59.4%	71.5%	48.9%	48.9%	64.7%	63.6%	59.0%
4	22.7%	24.3%	54.5%	83.4%	33.7%	57.3%	56.3%	59.2%	60.5%	70.8%	49.0%	49.1%	64.3%	65.2%	59.6%
5	22.8%	24.7%	54.8%	84.5%	34.4%	56.3%	55.9%	58.9%	59.4%	71.4%	47.8%	47.7%	63.5%	65.0%	59.6%
6	22.6%	24.8%	55.8%	84.1%	34.6%	56.8%	56.2%	58.7%	59.2%	71.8%	47.1%	46.8%	63.8%	65.0%	59.8%
7	22.2%	24.8%	55.9%	84.2%	35.1%	56.3%	55.7%	58.7%	58.9%	71.3%	47.9%	46.9%	64.3%	64.5%	59.5%
8	22.4%	25.1%	55.5%	84.3%	35.5%	56.3%	54.5%	58.3%	58.5%	71.1%	46.6%	46.6%	64.7%	65.1%	60.0%
9	22.9%	25.0%	56.5%	84.8%	35.1%	55.5%	54.2%	58.0%	58.3%	70.8%	47.2%	45.4%	63.9%	65.0%	59.2%
10	22.7%	24.9%	56.3%	84.6%	35.2%	55.1%	54.3%	57.8%	58.9%	71.2%	48.0%	45.9%	63.3%	65.0%	58.8%
11	23.3%	25.2%	56.4%	84.1%	35.6%	55.9%	53.6%	57.7%	58.4%	71.1%	48.0%	46.8%	63.5%	65.1%	58.4%
12	22.6%	26.1%	56.3%	84.8%	36.1%	55.3%	53.4%	58.5%	59.2%	70.1%	47.3%	46.2%	63.3%	63.7%	58.9%
13	22.6%	25.7%	56.3%	84.5%	34.2%	55.6%	53.5%	57.1%	58.8%	70.8%	47.0%	45.7%	63.5%	63.3%	58.7%
14	23.0%	25.6%	56.9%	84.7%	35.1%	56.2%	53.9%	57.9%	57.7%	69.4%	46.9%	46.1%	63.1%	64.5%	58.3%
15	22.7%	25.7%	57.0%	84.6%	34.7%	55.3%	54.6%	57.7%	58.0%	70.3%	47.2%	46.1%	62.7%	63.4%	58.1%
16	23.7%	25.9%	56.6%	84.4%	35.3%	55.4%	53.9%	57.7%	57.9%	69.1%	47.7%	46.0%	62.5%	63.5%	58.0%
17	22.8%	25.7%	56.3%	84.7%	34.9%	55.0%	53.8%	57.9%	57.7%	69.3%	47.9%	45.6%	62.8%	63.3%	57.7%
18	23.3%	26.4%	57.2%	85.0%	35.2%	54.6%	53.7%	57.9%	58.2%	68.8%	47.5%	45.9%	62.3%	63.7%	58.0%
19	23.2%	24.6%	57.0%	85.1%	34.6%	54.3%	52.0%	57.0%	57.5%	68.9%	46.8%	46.4%	61.9%	62.8%	57.0%
20	23.4%	25.8%	57.5%	85.0%	34.8%	53.9%	52.9%	57.7%	57.3%	68.2%	46.7%	46.3%	62.3%	63.0%	56.5%
21	23.2%	26.7%	57.1%	84.6%	35.4%	54.5%	52.4%	57.3%	57.5%	69.0%	46.9%	45.5%	62.1%	62.9%	56.5%
22	23.3%	26.0%	56.8%	84.5%	34.5%	54.5%	52.9%	58.4%	57.7%	68.0%	47.3%	45.8%	62.1%	62.8%	57.2%
23	23.0%	25.8%	57.3%	85.0%	34.7%	54.8%	52.7%	57.2%	57.6%	68.1%	47.2%	45.9%	61.7%	62.3%	56.8%
24	23.5%	26.4%	57.1%	85.1%	34.8%	53.6%	52.4%	57.1%	56.8%	68.0%	47.4%	45.7%	61.7%	61.9%	56.1%
25	23.7%	26.1%	57.2%	84.2%	35.4%	52.8%	52.0%	57.2%	57.2%	67.9%	47.6%	45.8%	61.8%	62.6%	56.2%
26	22.8%	26.1%	56.9%	85.2%	35.9%	53.9%	52.4%	57.6%	57.0%	68.5%	47.4%	45.6%	61.1%	61.7%	56.5%
27	23.5%	26.3%	57.2%	84.2%	35.3%	53.1%	52.5%	56.6%	57.2%	67.8%	46.9%	45.4%	61.0%	61.9%	56.2%
28	23.8%	26.2%	56.6%	84.4%	35.5%	52.1%	51.9%	57.6%	56.7%	67.8%	46.5%	46.2%	61.6%	61.7%	55.7%
29	23.3%	26.2%	57.3%	84.2%	36.2%	53.1%	52.6%	57.6%	57.0%	67.6%	47.9%	45.2%	60.7%	61.9%	56.2%
30	23.8%	26.1%	57.7%	84.4%	35.3%	52.6%	51.2%	57.6%	57.1%	67.9%	47.1%	45.7%	61.0%	61.7%	55.5%

Table 4-65: KNN database F PDET all positions Mahalanobis distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	51.0%	57.4%	97.8%	100.0%	58.8%	78.4%	79.0%	77.0%	81.7%	93.8%	64.6%	64.8%	84.1%	78.4%	72.4%
2	51.6%	57.7%	97.9%	100.0%	58.4%	78.0%	78.8%	77.0%	81.8%	93.9%	64.7%	65.5%	84.1%	79.4%	72.5%
3	51.8%	59.0%	97.2%	100.0%	57.8%	75.8%	76.3%	75.5%	78.8%	92.4%	64.4%	65.1%	82.1%	79.5%	74.6%
4	51.7%	59.8%	97.2%	100.0%	57.4%	75.0%	75.6%	75.8%	78.9%	93.1%	63.9%	66.2%	83.0%	80.9%	74.5%
5	51.2%	60.5%	96.8%	100.0%	56.5%	73.6%	75.2%	75.3%	77.7%	92.0%	63.3%	65.3%	80.9%	79.1%	73.3%
6	50.7%	60.8%	96.5%	100.0%	57.4%	73.5%	74.3%	75.2%	77.6%	92.1%	63.9%	66.3%	81.2%	80.1%	73.6%
7	51.4%	60.9%	96.4%	100.0%	56.8%	72.4%	72.9%	74.8%	77.3%	91.4%	62.7%	63.9%	80.2%	79.2%	72.2%
8	51.1%	60.7%	96.0%	100.0%	57.1%	71.7%	72.4%	75.0%	77.4%	90.9%	62.4%	64.0%	79.1%	77.9%	71.8%
9	50.8%	61.2%	96.0%	100.0%	56.8%	71.2%	71.9%	73.9%	75.8%	90.1%	63.0%	62.6%	78.8%	77.7%	71.0%
10	50.8%	60.9%	95.8%	100.0%	55.8%	70.5%	71.3%	73.8%	75.9%	88.9%	62.0%	63.0%	78.7%	76.4%	70.9%
11	50.6%	61.0%	95.9%	100.0%	56.5%	69.7%	71.0%	72.3%	75.3%	88.9%	61.5%	62.8%	77.6%	76.3%	70.6%
12	49.7%	60.3%	95.6%	100.0%	55.5%	69.2%	70.6%	73.2%	74.7%	89.0%	61.5%	63.0%	77.5%	76.1%	69.7%
13	50.0%	60.4%	95.6%	100.0%	55.0%	68.3%	69.6%	72.1%	74.2%	87.7%	61.4%	61.3%	76.6%	74.8%	69.3%
14	49.8%	60.3%	95.5%	100.0%	54.8%	67.8%	70.1%	72.7%	74.4%	88.2%	61.3%	61.5%	75.6%	74.6%	69.0%
15	49.4%	60.2%	95.8%	100.0%	54.3%	67.7%	69.1%	71.0%	73.1%	87.4%	61.3%	60.8%	74.9%	73.6%	67.6%
16	49.5%	60.1%	95.5%	100.0%	54.3%	66.5%	68.1%	71.3%	73.2%	87.3%	61.3%	60.7%	75.2%	73.5%	66.7%
17	49.9%	60.3%	95.1%	100.0%	53.9%	66.6%	67.7%	70.7%	72.1%	86.7%	59.9%	60.6%	72.9%	73.0%	66.5%
18	48.4%	59.9%	95.2%	100.0%	54.0%	66.3%	67.8%	70.3%	72.5%	86.2%	60.3%	59.9%	73.5%	72.9%	66.0%
19	48.8%	59.7%	95.0%	100.0%	53.3%	65.6%	67.0%	69.9%	71.7%	85.7%	60.0%	59.6%	72.2%	72.2%	65.3%
20	48.6%	58.8%	94.8%	100.0%	52.7%	64.4%	66.7%	69.5%	71.3%	85.1%	59.3%	58.4%	71.2%	71.5%	64.2%
21	48.0%	59.3%	94.9%	100.0%	52.8%	64.2%	65.9%	70.1%	70.8%	85.3%	58.4%	59.1%	71.0%	71.5%	64.8%
22	48.5%	59.5%	94.4%	99.9%	51.3%	63.9%	65.8%	69.6%	70.1%	84.9%	57.7%	59.1%	70.9%	70.0%	63.7%
23	48.3%	58.8%	94.5%	100.0%	51.7%	63.6%	64.4%	69.1%	70.7%	85.2%	57.7%	58.3%	70.1%	70.4%	63.6%
24	48.0%	58.9%	94.1%	100.0%	51.0%	63.8%	63.9%	69.1%	70.1%	84.5%	57.3%	57.7%	70.0%	70.0%	62.4%
25	48.4%	58.7%	93.8%	99.9%	50.2%	63.4%	64.4%	67.7%	69.4%	83.8%	56.3%	57.6%	69.3%	69.7%	62.6%
26	47.9%	58.6%	93.8%	99.9%	51.1%	62.6%	63.8%	68.9%	69.5%	83.6%	56.4%	56.4%	69.0%	69.3%	61.9%
27	46.8%	57.7%	94.0%	100.0%	50.3%	62.6%	64.1%	68.4%	69.0%	82.8%	55.9%	56.1%	67.8%	68.9%	62.1%
28	47.4%	57.7%	93.7%	100.0%	50.0%	61.9%	63.0%	68.0%	68.5%	83.0%	55.3%	55.7%	67.9%	69.2%	61.7%
29	47.0%	57.7%	93.3%	100.0%	49.4%	61.4%	63.0%	67.8%	68.4%	82.3%	55.2%	55.8%	68.4%	68.7%	61.3%
30	46.1%	57.7%	93.1%	100.0%	49.5%	61.4%	62.8%	66.7%	68.4%	82.0%	54.7%	54.9%	67.5%	68.4%	60.8%

Table 4-66: KNN database F PDET external position Cosine distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	13.9%	15.5%	14.8%	15.1%	17.7%	24.3%	27.7%	30.2%	28.5%	28.5%	35.1%	32.9%	45.2%	40.8%	40.1%
2	15.9%	16.1%	14.9%	16.4%	17.6%	24.0%	27.3%	30.1%	28.5%	28.4%	35.2%	32.2%	45.5%	40.5%	39.3%
3	15.1%	15.9%	16.2%	15.9%	17.7%	23.8%	27.8%	30.5%	28.6%	29.5%	35.7%	32.6%	45.6%	40.7%	39.8%
4	15.8%	15.7%	16.6%	14.6%	17.4%	24.1%	27.8%	31.1%	29.7%	28.6%	35.9%	32.5%	45.8%	42.4%	39.8%
5	15.4%	15.8%	14.6%	16.0%	17.5%	24.1%	27.1%	30.3%	28.6%	29.1%	36.2%	33.2%	45.6%	41.8%	40.7%
6	15.4%	15.9%	16.2%	15.9%	17.4%	24.0%	27.1%	30.1%	29.9%	28.8%	35.9%	33.1%	46.1%	42.1%	40.7%
7	13.8%	14.0%	16.7%	16.4%	17.3%	23.4%	27.5%	31.1%	29.2%	29.1%	36.4%	33.7%	47.2%	41.8%	40.2%
8	15.4%	15.2%	15.8%	16.6%	17.3%	24.6%	28.1%	30.5%	28.6%	28.9%	36.0%	33.5%	46.4%	41.6%	40.2%
9	16.3%	15.6%	13.5%	16.5%	17.6%	24.1%	26.9%	30.6%	29.1%	28.9%	36.3%	33.0%	46.9%	42.5%	39.5%
10	15.6%	15.7%	16.3%	15.5%	18.0%	24.0%	28.1%	31.3%	29.1%	28.8%	36.3%	33.9%	46.2%	42.1%	40.3%
11	15.3%	14.1%	14.9%	15.8%	17.8%	24.5%	26.9%	30.8%	28.9%	29.1%	36.0%	33.3%	45.6%	42.0%	40.1%
12	16.2%	14.8%	15.4%	15.7%	17.4%	24.0%	26.7%	31.1%	29.6%	29.1%	36.6%	33.1%	46.6%	42.4%	40.9%
13	15.4%	16.1%	15.7%	16.0%	17.4%	24.0%	27.1%	29.9%	29.7%	28.9%	35.7%	32.6%	46.4%	41.9%	40.4%
14	17.3%	14.5%	17.1%	17.0%	17.6%	24.4%	27.5%	30.8%	29.3%	28.6%	36.4%	32.8%	45.9%	42.1%	39.7%
15	16.8%	16.8%	15.6%	15.9%	17.8%	24.1%	27.6%	30.9%	28.9%	29.4%	36.8%	33.6%	46.2%	41.9%	39.6%
16	16.7%	14.7%	15.4%	17.3%	18.2%	24.7%	27.2%	30.7%	29.5%	29.0%	36.2%	33.4%	45.3%	42.6%	39.7%
17	16.2%	16.3%	16.0%	15.8%	17.6%	23.5%	27.5%	30.6%	29.2%	29.9%	36.3%	32.9%	45.3%	43.1%	40.8%
18	15.4%	15.6%	15.2%	17.5%	17.7%	24.8%	26.9%	31.4%	29.2%	29.0%	37.6%	33.1%	45.5%	42.9%	39.7%
19	15.4%	15.6%	16.3%	15.2%	17.9%	24.4%	27.3%	31.2%	28.9%	29.0%	36.8%	32.9%	45.8%	42.3%	40.1%
20	15.6%	16.2%	17.2%	15.3%	18.1%	24.1%	27.3%	31.1%	29.0%	29.2%	36.0%	33.8%	45.3%	42.3%	40.3%
21	14.4%	15.5%	16.8%	16.0%	17.8%	24.5%	26.9%	30.8%	29.5%	29.3%	36.4%	33.5%	45.1%	42.0%	39.9%
22	16.2%	16.2%	15.4%	15.7%	17.4%	23.7%	27.5%	31.5%	29.8%	29.1%	36.7%	33.3%	45.7%	42.4%	39.8%
23	16.3%	15.4%	17.3%	15.3%	17.5%	24.3%	27.1%	30.4%	29.6%	28.8%	36.9%	33.1%	45.3%	42.3%	39.8%
24	14.3%	16.1%	15.0%	15.2%	18.1%	24.7%	26.6%	31.0%	29.5%	29.5%	36.3%	33.1%	44.5%	42.3%	39.9%
25	17.1%	14.3%	15.9%	16.3%	17.4%	23.9%	27.1%	30.3%	29.0%	29.0%	36.3%	33.7%	45.6%	43.1%	40.3%
26	15.9%	16.2%	15.1%	15.6%	17.8%	23.4%	27.6%	31.3%	29.0%	29.0%	37.4%	33.0%	45.3%	42.5%	39.5%
27	15.4%	16.6%	16.4%	17.8%	18.0%	24.1%	27.5%	30.4%	29.3%	29.1%	37.3%	32.9%	45.4%	42.4%	40.1%
28	16.2%	16.5%	15.7%	16.5%	18.1%	24.0%	27.5%	31.3%	29.3%	29.2%	37.2%	33.6%	44.7%	41.9%	40.3%
29	16.5%	16.7%	16.5%	16.0%	18.4%	24.8%	27.9%	31.0%	28.9%	28.6%	36.4%	33.1%	45.0%	42.2%	40.4%
30	17.2%	17.7%	15.8%	17.3%	17.6%	24.5%	27.7%	30.9%	29.0%	29.3%	36.5%	32.8%	44.6%	42.6%	39.5%

Table 4-67: KNN database F PDET all positions Cosine distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	35.8%	42.8%	94.0%	100.0%	52.6%	81.3%	85.6%	91.9%	96.6%	99.8%	77.9%	82.2%	87.5%	96.9%	85.6%
2	36.0%	43.8%	93.8%	100.0%	53.1%	82.0%	84.9%	92.0%	96.5%	99.8%	78.3%	82.4%	87.3%	97.2%	85.7%
3	35.4%	43.9%	94.0%	100.0%	52.5%	80.8%	84.4%	91.5%	96.0%	99.6%	77.6%	81.3%	87.2%	96.8%	85.1%
4	36.7%	44.2%	94.0%	100.0%	52.4%	81.0%	83.6%	92.0%	96.0%	99.6%	76.7%	81.2%	87.3%	97.1%	84.9%
5	37.4%	44.8%	94.1%	100.0%	52.1%	80.5%	84.6%	92.0%	95.6%	99.6%	77.3%	81.7%	87.2%	96.9%	84.7%
6	37.0%	45.1%	94.1%	100.0%	51.8%	80.1%	84.2%	91.8%	95.4%	99.4%	77.4%	81.2%	87.1%	96.7%	84.6%
7	36.9%	44.5%	94.1%	99.9%	52.2%	80.4%	83.9%	91.5%	95.1%	99.4%	77.1%	81.7%	86.2%	96.4%	84.1%
8	36.6%	45.1%	94.5%	100.0%	51.9%	79.6%	84.3%	91.2%	95.2%	99.4%	76.7%	81.3%	86.8%	95.9%	83.9%
9	37.0%	44.1%	94.4%	100.0%	52.0%	80.1%	84.5%	91.0%	95.0%	99.2%	76.4%	80.9%	86.5%	96.2%	84.1%
10	37.0%	45.0%	94.2%	100.0%	52.3%	80.0%	84.1%	90.9%	94.9%	99.3%	75.5%	79.9%	85.8%	96.0%	84.0%
11	37.5%	44.6%	94.2%	100.0%	52.4%	80.6%	83.3%	90.5%	94.8%	99.3%	74.9%	80.1%	85.4%	95.9%	83.7%
12	37.6%	44.9%	94.2%	100.0%	51.8%	79.4%	82.9%	90.5%	94.5%	99.3%	75.5%	80.1%	86.1%	95.7%	83.3%
13	37.1%	45.0%	94.1%	100.0%	50.8%	79.4%	83.7%	90.2%	94.1%	99.2%	74.6%	79.8%	85.8%	95.4%	82.6%
14	37.6%	45.2%	94.1%	100.0%	51.4%	80.2%	83.3%	90.4%	94.5%	99.0%	74.5%	79.4%	85.8%	95.0%	82.8%
15	37.5%	45.5%	94.2%	99.9%	51.8%	79.1%	82.7%	90.2%	94.3%	99.0%	74.4%	78.9%	84.8%	95.4%	82.1%
16	37.9%	44.4%	94.4%	100.0%	52.2%	79.4%	82.6%	90.3%	94.0%	99.0%	73.8%	79.1%	85.9%	95.1%	81.4%
17	37.3%	44.4%	94.3%	100.0%	51.4%	78.9%	82.5%	89.9%	93.7%	99.0%	73.1%	77.9%	85.3%	94.8%	81.2%
18	37.5%	44.5%	94.2%	100.0%	51.5%	78.7%	82.0%	89.8%	93.7%	99.0%	74.5%	78.4%	84.8%	95.1%	81.1%
19	38.0%	44.6%	94.0%	100.0%	51.5%	78.1%	82.2%	89.3%	93.8%	98.9%	73.9%	77.6%	85.2%	95.0%	81.3%
20	37.8%	45.0%	94.1%	100.0%	51.4%	78.9%	83.2%	89.6%	93.4%	98.9%	73.1%	78.1%	85.1%	95.1%	80.7%
21	36.6%	44.4%	94.0%	100.0%	51.9%	77.9%	81.9%	89.6%	93.7%	99.0%	73.0%	77.7%	84.2%	94.7%	80.3%
22	36.8%	44.9%	94.0%	99.9%	51.4%	78.0%	81.2%	89.4%	93.5%	99.0%	73.3%	77.5%	85.2%	94.9%	81.0%
23	36.9%	44.7%	93.9%	100.0%	50.9%	78.3%	81.3%	89.2%	93.1%	98.8%	72.7%	77.3%	84.0%	94.7%	79.7%
24	37.3%	45.5%	94.4%	100.0%	51.4%	78.2%	81.3%	89.3%	93.4%	98.9%	72.0%	76.5%	83.9%	94.4%	79.3%
25	37.8%	44.9%	93.9%	99.9%	50.5%	78.2%	80.8%	89.7%	93.2%	98.9%	73.0%	76.3%	83.9%	94.7%	79.8%
26	36.5%	45.0%	94.3%	100.0%	51.1%	78.3%	81.0%	88.9%	93.0%	98.9%	72.7%	76.4%	83.6%	94.3%	79.9%
27	37.7%	44.9%	94.1%	100.0%	50.8%	77.4%	81.2%	89.2%	92.9%	98.9%	72.2%	76.6%	83.7%	94.4%	79.1%
28	36.8%	44.8%	94.2%	100.0%	51.1%	77.8%	80.1%	88.9%	93.0%	98.9%	71.5%	76.2%	83.6%	94.5%	79.2%
29	37.1%	44.8%	94.1%	100.0%	51.1%	77.4%	80.2%	88.8%	93.0%	98.9%	72.1%	75.8%	83.1%	94.3%	78.8%
30	37.4%	44.6%	94.2%	100.0%	50.4%	77.3%	81.2%	88.7%	92.9%	98.9%	71.8%	75.7%	83.4%	94.5%	78.9%

Table 4-68: KNN database F SINRD external position Euclidean distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	21.4%	19.6%	29.3%	84.7%	39.7%	35.2%	35.3%	37.3%	44.3%	67.7%	48.0%	49.4%	38.8%	44.7%	51.9%
2	21.5%	19.1%	30.2%	84.7%	39.3%	35.2%	35.3%	38.1%	44.7%	67.6%	48.2%	50.1%	38.7%	44.8%	50.5%
3	22.3%	19.9%	29.8%	84.1%	41.5%	36.5%	36.5%	38.0%	44.1%	65.3%	48.0%	48.7%	40.7%	44.2%	50.3%
4	22.1%	19.8%	31.2%	84.0%	39.9%	37.3%	36.8%	38.2%	44.4%	65.9%	46.0%	48.0%	40.2%	45.2%	50.0%
5	22.6%	20.2%	30.4%	84.7%	39.2%	37.0%	37.2%	37.9%	44.0%	65.1%	45.9%	46.9%	40.3%	43.8%	48.0%
6	22.2%	20.3%	31.1%	84.6%	40.2%	36.9%	37.5%	37.9%	43.1%	64.8%	46.7%	46.7%	40.4%	44.2%	48.1%
7	22.9%	20.6%	31.4%	84.5%	39.7%	37.8%	37.2%	38.5%	44.2%	65.6%	45.5%	46.3%	40.0%	44.0%	47.6%
8	23.3%	20.6%	31.6%	84.6%	38.9%	37.5%	37.3%	38.3%	43.7%	65.1%	44.5%	45.5%	40.0%	44.2%	46.9%
9	23.1%	20.4%	31.8%	84.4%	39.8%	37.0%	37.5%	39.1%	43.1%	65.8%	45.2%	45.4%	41.1%	44.5%	47.1%
10	23.0%	21.1%	32.1%	84.5%	39.7%	37.3%	37.0%	37.7%	42.7%	65.5%	45.0%	45.7%	40.4%	43.2%	46.2%
11	23.1%	20.1%	32.0%	84.5%	39.5%	37.1%	36.8%	37.8%	42.6%	65.5%	43.9%	45.3%	40.0%	43.1%	46.9%
12	23.3%	20.7%	32.2%	84.6%	39.4%	37.1%	36.5%	37.8%	43.0%	65.7%	43.8%	45.2%	39.9%	43.3%	46.6%
13	22.9%	20.5%	32.1%	84.7%	38.9%	36.0%	37.1%	37.4%	41.9%	66.5%	43.7%	45.0%	40.5%	43.1%	46.5%
14	21.9%	20.4%	33.3%	85.0%	39.9%	37.0%	36.8%	37.8%	42.1%	66.6%	44.1%	44.6%	40.1%	43.2%	46.5%
15	22.8%	21.3%	33.0%	84.6%	39.7%	36.6%	36.7%	38.1%	42.3%	66.2%	43.6%	44.2%	40.0%	42.8%	45.3%
16	23.4%	20.9%	33.2%	84.8%	39.7%	36.0%	35.9%	37.0%	42.1%	65.7%	43.5%	43.2%	38.7%	42.3%	44.6%
17	23.4%	20.7%	33.5%	84.8%	40.0%	36.2%	36.3%	37.1%	41.3%	65.7%	44.3%	44.0%	39.4%	42.0%	45.7%
18	22.9%	20.8%	32.8%	84.8%	40.3%	36.5%	35.7%	37.2%	41.3%	66.1%	44.1%	44.9%	39.0%	41.6%	45.1%
19	22.7%	20.5%	33.4%	85.2%	39.1%	36.5%	35.9%	36.2%	41.9%	65.8%	43.3%	44.7%	38.9%	41.1%	44.4%
20	22.9%	20.1%	33.3%	85.1%	39.9%	35.8%	35.6%	36.0%	41.9%	66.2%	43.5%	43.6%	38.8%	41.2%	44.5%
21	23.5%	20.8%	33.3%	84.7%	39.1%	36.0%	36.3%	36.2%	42.0%	65.1%	42.9%	43.5%	39.2%	41.7%	44.9%
22	23.1%	21.1%	33.5%	84.8%	38.8%	36.1%	35.9%	36.2%	41.4%	66.1%	42.7%	43.0%	38.7%	40.6%	44.9%
23	23.0%	21.0%	33.4%	85.0%	38.6%	36.7%	36.1%	36.4%	41.1%	65.6%	42.7%	42.4%	38.8%	40.8%	44.6%
24	23.8%	20.5%	33.8%	84.4%	38.6%	36.5%	35.9%	36.2%	40.5%	65.5%	42.9%	44.1%	39.0%	41.4%	43.7%
25	22.8%	20.8%	33.5%	84.4%	38.2%	36.0%	37.0%	36.3%	40.6%	65.2%	41.8%	42.8%	39.2%	41.4%	44.5%
26	22.6%	20.6%	34.1%	84.6%	38.5%	36.4%	36.0%	35.9%	40.6%	64.8%	42.2%	43.1%	38.8%	41.1%	43.6%
27	23.6%	20.7%	33.2%	84.6%	38.4%	36.7%	36.3%	36.8%	40.8%	65.2%	42.7%	43.5%	38.7%	40.7%	44.8%
28	23.0%	20.9%	33.6%	84.9%	39.3%	36.2%	37.0%	36.3%	40.5%	65.7%	43.2%	43.5%	39.6%	41.0%	44.8%
29	23.4%	20.7%	33.9%	85.0%	38.5%	36.7%	36.3%	35.4%	39.9%	65.1%	42.1%	41.9%	39.1%	40.1%	43.6%
30	23.0%	21.6%	33.5%	84.8%	38.5%	36.5%	36.3%	35.9%	40.7%	65.1%	41.8%	42.8%	38.9%	39.9%	44.6%

Table 4-69: KNN database F SINRD all positions Euclidean distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	32.7%	46.5%	91.2%	100.0%	51.2%	50.1%	53.4%	62.9%	69.2%	99.3%	55.0%	57.1%	56.5%	70.4%	58.7%
2	32.6%	46.5%	90.5%	100.0%	50.8%	50.9%	53.8%	62.6%	69.2%	99.4%	55.3%	57.4%	56.1%	70.4%	59.2%
3	32.4%	46.3%	87.5%	100.0%	51.1%	50.0%	53.5%	60.8%	65.8%	98.5%	55.1%	57.2%	56.7%	68.6%	58.8%
4	32.8%	45.9%	87.3%	100.0%	50.2%	49.2%	53.0%	59.3%	65.7%	98.7%	53.6%	55.1%	55.5%	67.2%	57.1%
5	34.4%	46.2%	86.9%	100.0%	48.4%	49.3%	52.7%	58.2%	63.1%	98.3%	52.7%	55.0%	54.8%	65.1%	55.5%
6	33.1%	45.3%	86.6%	100.0%	48.8%	48.5%	52.2%	58.9%	61.9%	98.2%	51.9%	53.2%	54.3%	64.3%	54.5%
7	33.4%	45.0%	86.1%	100.0%	47.9%	48.7%	51.8%	57.2%	61.7%	97.8%	49.9%	52.4%	54.0%	63.8%	52.8%
8	33.8%	44.8%	85.7%	100.0%	47.5%	47.3%	51.3%	57.5%	60.5%	97.4%	49.7%	51.8%	53.7%	63.0%	52.7%
9	34.0%	44.6%	85.1%	100.0%	47.4%	47.3%	51.7%	56.1%	60.3%	97.5%	49.7%	51.0%	53.8%	61.8%	52.1%
10	33.5%	44.6%	84.9%	100.0%	47.0%	47.5%	50.0%	56.0%	60.4%	97.0%	49.3%	49.6%	53.7%	61.9%	51.9%
11	33.6%	44.3%	84.8%	100.0%	46.8%	46.7%	50.6%	55.2%	59.9%	96.9%	49.1%	48.8%	53.6%	60.5%	51.2%
12	34.6%	44.2%	85.1%	100.0%	46.1%	46.0%	49.6%	55.7%	59.3%	96.5%	48.9%	50.4%	53.1%	60.6%	51.4%
13	33.9%	43.3%	84.5%	100.0%	46.6%	46.5%	49.7%	54.1%	58.3%	96.5%	48.4%	49.9%	52.2%	59.5%	50.0%
14	33.4%	44.4%	85.0%	100.0%	45.9%	45.8%	49.5%	54.0%	57.9%	96.6%	48.5%	49.2%	51.6%	59.1%	49.9%
15	33.8%	44.0%	84.6%	100.0%	47.0%	45.7%	48.5%	53.8%	57.6%	96.4%	48.0%	49.4%	51.9%	58.8%	50.2%
16	33.0%	44.0%	84.2%	99.9%	46.2%	44.7%	48.6%	53.2%	56.3%	96.3%	48.4%	49.0%	51.5%	57.5%	50.2%
17	33.8%	43.4%	83.8%	99.9%	46.3%	44.9%	48.6%	52.6%	56.7%	95.6%	48.1%	49.6%	50.7%	57.2%	50.2%
18	33.0%	43.5%	84.1%	99.9%	45.7%	45.0%	47.8%	51.8%	56.5%	95.2%	47.4%	48.5%	50.1%	56.1%	49.7%
19	33.2%	43.5%	83.2%	100.0%	45.6%	44.9%	47.1%	51.3%	56.0%	95.4%	48.5%	49.0%	49.3%	56.3%	49.4%
20	33.5%	42.2%	82.9%	99.9%	45.1%	45.0%	47.0%	51.2%	54.9%	94.7%	47.2%	47.8%	49.2%	55.7%	49.0%
21	33.0%	43.0%	82.9%	100.0%	43.8%	44.7%	46.8%	50.8%	54.8%	95.1%	47.5%	47.4%	49.4%	55.3%	49.6%
22	33.1%	42.3%	82.0%	99.9%	45.1%	44.1%	46.6%	50.6%	54.0%	94.8%	46.5%	48.0%	48.6%	54.9%	49.4%
23	32.6%	42.4%	82.4%	99.9%	44.7%	43.4%	45.7%	50.4%	53.8%	93.9%	46.3%	47.9%	48.6%	54.6%	49.5%
24	33.3%	42.1%	81.7%	99.9%	44.2%	44.1%	45.3%	50.9%	52.8%	94.1%	46.7%	47.6%	48.2%	54.5%	48.8%
25	32.6%	42.0%	81.6%	99.9%	44.1%	43.2%	46.1%	49.6%	53.7%	93.9%	46.2%	48.4%	48.0%	54.3%	48.9%
26	32.5%	42.2%	81.2%	100.0%	44.1%	41.9%	45.1%	49.7%	52.3%	94.0%	46.4%	47.9%	48.5%	53.8%	48.8%
27	32.9%	41.8%	80.8%	99.9%	43.7%	42.8%	45.3%	49.2%	52.6%	94.1%	46.2%	46.8%	47.3%	53.6%	47.2%
28	33.1%	41.3%	80.3%	99.9%	43.8%	42.3%	44.8%	49.3%	52.3%	93.6%	46.3%	47.0%	47.4%	53.8%	47.7%
29	33.4%	41.5%	80.6%	100.0%	44.4%	42.4%	45.0%	48.8%	51.6%	93.5%	46.5%	47.4%	47.0%	52.3%	47.5%
30	33.1%	41.4%	80.1%	99.9%	44.2%	42.6%	44.6%	49.0%	51.0%	93.1%	46.6%	46.8%	46.8%	53.1%	47.4%

Table 4-70: KNN database F SINRD external position Mahalanobis distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	21.7%	19.6%	29.6%	84.5%	40.4%	47.0%	39.8%	45.1%	55.0%	50.3%	65.0%	56.8%	52.7%	50.0%	68.4%
2	21.7%	19.7%	29.9%	85.0%	40.8%	45.9%	39.6%	44.6%	54.3%	50.6%	65.2%	57.3%	52.5%	49.2%	68.0%
3	22.1%	20.0%	30.5%	84.7%	41.1%	46.0%	41.1%	45.3%	53.9%	50.3%	64.0%	57.2%	52.8%	50.6%	66.9%
4	21.9%	20.3%	31.0%	84.8%	42.9%	45.7%	41.5%	45.7%	53.8%	51.2%	63.4%	57.2%	53.0%	49.3%	66.8%
5	21.4%	19.6%	30.8%	84.3%	41.7%	44.6%	40.9%	45.0%	52.4%	51.7%	62.3%	55.7%	53.8%	49.3%	66.6%
6	22.7%	19.6%	31.5%	84.6%	42.1%	45.7%	40.9%	45.1%	52.7%	51.2%	61.7%	55.7%	53.6%	48.7%	66.3%
7	22.3%	19.9%	31.0%	84.6%	41.6%	46.2%	41.3%	44.8%	53.0%	51.2%	61.8%	54.8%	52.9%	47.9%	65.0%
8	22.4%	20.9%	31.4%	84.4%	41.2%	45.7%	41.7%	44.6%	53.0%	51.0%	61.6%	54.8%	52.8%	47.9%	65.7%
9	22.8%	20.2%	31.6%	84.9%	41.0%	45.9%	41.3%	45.2%	51.5%	50.9%	61.7%	54.5%	52.4%	48.1%	64.5%
10	23.0%	20.7%	32.3%	84.9%	40.7%	46.0%	40.5%	45.4%	53.0%	51.6%	60.4%	54.7%	52.8%	47.1%	65.5%
11	22.2%	20.1%	32.4%	84.2%	40.7%	45.5%	41.0%	45.7%	52.8%	51.8%	60.7%	53.9%	52.9%	47.3%	65.6%
12	22.5%	20.8%	33.5%	84.6%	41.2%	45.8%	41.7%	44.4%	51.6%	50.8%	61.0%	53.7%	53.0%	47.4%	63.9%
13	22.3%	21.0%	31.9%	84.1%	40.8%	44.4%	40.7%	45.0%	52.4%	51.1%	59.4%	53.2%	52.1%	47.2%	63.6%
14	22.5%	20.3%	33.0%	84.7%	41.4%	44.2%	41.9%	44.5%	51.5%	51.1%	59.3%	53.5%	52.2%	47.0%	63.3%
15	23.3%	21.0%	32.8%	84.7%	40.5%	44.8%	40.7%	43.3%	51.5%	51.5%	59.9%	53.7%	52.7%	46.8%	63.7%
16	23.3%	20.7%	32.8%	84.3%	41.6%	45.3%	40.7%	44.1%	51.2%	51.4%	59.6%	53.1%	52.4%	46.6%	62.2%
17	23.2%	20.9%	33.3%	84.2%	40.8%	45.5%	41.5%	44.0%	51.3%	51.1%	58.9%	53.9%	53.2%	46.8%	63.2%
18	23.4%	20.3%	34.0%	84.6%	40.2%	45.2%	40.4%	44.4%	50.3%	50.8%	57.4%	52.7%	52.3%	46.6%	62.7%
19	23.1%	20.3%	33.3%	84.3%	40.8%	45.1%	40.3%	44.3%	50.4%	50.4%	58.2%	53.1%	52.7%	46.0%	63.1%
20	23.2%	20.8%	33.6%	84.5%	40.5%	46.0%	40.4%	43.7%	51.0%	50.4%	58.8%	52.0%	52.7%	46.5%	62.6%
21	22.5%	20.8%	33.5%	84.7%	40.9%	45.5%	40.1%	44.6%	50.3%	51.1%	58.9%	51.9%	52.2%	46.1%	62.5%
22	22.8%	20.4%	33.8%	84.6%	40.2%	45.2%	40.8%	43.7%	51.1%	50.5%	58.8%	52.5%	51.7%	46.1%	62.5%
23	22.6%	20.6%	33.4%	85.0%	40.0%	45.3%	40.8%	44.8%	50.6%	49.9%	57.6%	52.2%	51.9%	46.4%	62.3%
24	23.1%	20.6%	33.6%	84.3%	39.5%	46.1%	39.8%	43.8%	50.6%	49.7%	57.8%	51.5%	52.1%	45.9%	62.8%
25	23.1%	20.6%	33.3%	84.4%	40.0%	44.8%	40.5%	44.1%	50.3%	49.5%	57.9%	51.6%	51.9%	46.0%	62.5%
26	23.1%	21.0%	33.7%	84.5%	39.6%	45.3%	39.9%	44.1%	49.9%	49.8%	58.2%	50.6%	51.7%	45.6%	61.9%
27	23.2%	21.2%	34.8%	84.4%	40.0%	45.0%	40.1%	44.0%	50.2%	49.8%	58.0%	51.4%	52.0%	45.6%	62.2%
28	23.4%	21.4%	34.4%	84.7%	40.3%	45.3%	39.6%	44.1%	50.4%	49.4%	58.2%	51.6%	51.4%	45.3%	61.3%
29	22.7%	20.8%	33.8%	84.5%	40.7%	45.0%	39.8%	44.4%	49.7%	49.2%	56.2%	51.4%	51.4%	45.1%	61.1%
30	22.9%	20.9%	33.8%	84.3%	39.7%	45.5%	39.9%	43.5%	48.9%	50.2%	57.9%	51.5%	51.2%	45.5%	61.1%

Table 4-71: KNN database F SINRD all positions Mahalanobis distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	50.2%	57.7%	98.0%	100.0%	63.9%	82.9%	82.2%	76.9%	79.1%	97.7%	70.5%	68.5%	90.0%	81.8%	77.0%
2	49.6%	59.1%	98.1%	100.0%	63.6%	83.0%	82.7%	77.0%	78.7%	97.7%	70.9%	68.6%	89.9%	82.2%	77.3%
3	51.4%	57.6%	97.0%	100.0%	64.6%	81.8%	80.2%	76.5%	78.1%	96.5%	70.8%	69.5%	88.3%	80.8%	77.0%
4	52.0%	57.7%	97.0%	100.0%	64.0%	80.8%	79.8%	76.6%	78.6%	96.4%	70.9%	69.2%	88.6%	81.5%	77.4%
5	51.9%	57.5%	96.6%	100.0%	63.1%	80.1%	78.7%	76.4%	77.2%	95.1%	69.8%	69.1%	87.2%	80.6%	75.8%
6	51.9%	57.0%	96.5%	100.0%	62.8%	79.5%	77.6%	75.6%	77.2%	95.4%	69.1%	68.6%	86.4%	80.4%	76.3%
7	52.2%	57.0%	96.4%	100.0%	62.2%	78.2%	77.2%	74.0%	75.9%	94.8%	68.7%	68.4%	85.3%	80.3%	75.7%
8	51.8%	56.7%	96.0%	100.0%	62.0%	77.9%	76.3%	73.7%	75.5%	94.8%	67.6%	67.5%	84.4%	79.5%	74.8%
9	51.0%	56.3%	95.9%	100.0%	60.9%	76.7%	75.0%	73.3%	74.6%	93.8%	67.6%	66.5%	84.4%	79.3%	73.2%
10	51.1%	57.0%	95.9%	100.0%	60.8%	75.7%	74.3%	72.8%	74.2%	94.1%	66.8%	65.9%	82.6%	77.5%	73.4%
11	51.1%	56.8%	95.5%	100.0%	60.2%	75.4%	73.4%	72.3%	72.9%	94.0%	65.6%	65.1%	82.3%	76.2%	72.5%
12	49.9%	55.9%	95.7%	100.0%	59.7%	74.5%	72.6%	72.0%	72.7%	93.4%	65.4%	64.8%	81.7%	76.4%	71.0%
13	50.3%	54.9%	95.3%	100.0%	58.9%	73.2%	72.2%	70.6%	72.3%	92.9%	64.9%	64.1%	80.1%	75.4%	71.0%
14	50.0%	55.9%	94.8%	100.0%	58.4%	73.7%	71.3%	70.3%	71.9%	93.1%	63.6%	63.2%	80.3%	75.1%	70.2%
15	48.9%	55.3%	95.3%	100.0%	57.2%	72.7%	69.6%	69.8%	71.4%	92.6%	62.5%	62.2%	79.7%	73.9%	69.2%
16	49.3%	55.0%	94.7%	100.0%	57.7%	71.9%	69.6%	69.2%	70.7%	92.0%	62.3%	62.2%	78.5%	73.2%	68.6%
17	49.3%	55.5%	94.5%	100.0%	56.6%	71.3%	68.2%	68.8%	70.3%	92.1%	62.1%	61.2%	77.5%	72.8%	67.7%
18	49.1%	54.9%	93.8%	100.0%	56.1%	70.7%	68.3%	67.5%	69.4%	91.4%	61.0%	61.3%	76.7%	72.3%	66.7%
19	48.6%	55.9%	94.1%	99.9%	55.8%	69.5%	67.4%	68.3%	68.7%	91.4%	60.8%	60.0%	76.7%	71.3%	66.0%
20	49.1%	54.2%	93.8%	100.0%	55.5%	69.2%	66.6%	67.2%	68.4%	91.1%	60.5%	59.7%	75.6%	71.4%	65.7%
21	48.3%	54.3%	94.1%	100.0%	54.6%	68.9%	66.3%	66.7%	68.2%	90.9%	59.9%	59.4%	75.6%	70.5%	64.9%
22	47.6%	54.3%	93.8%	100.0%	54.4%	67.7%	65.6%	66.2%	67.9%	90.0%	59.2%	58.4%	74.9%	69.6%	64.4%
23	48.1%	55.0%	93.4%	100.0%	53.9%	67.9%	65.3%	65.8%	66.7%	89.9%	58.3%	58.2%	74.2%	68.6%	63.8%
24	48.1%	53.9%	93.4%	100.0%	53.4%	67.0%	64.9%	65.3%	66.6%	89.9%	57.6%	56.8%	74.2%	68.2%	63.4%
25	47.8%	53.8%	93.5%	100.0%	53.1%	65.9%	64.3%	65.6%	65.8%	89.8%	58.0%	56.8%	72.8%	67.5%	62.2%
26	47.3%	53.3%	93.1%	100.0%	52.6%	66.2%	63.8%	64.5%	65.2%	89.5%	57.2%	56.7%	72.1%	68.0%	62.9%
27	47.5%	52.3%	93.4%	100.0%	51.5%	65.3%	62.8%	64.2%	65.1%	88.7%	56.9%	55.7%	71.7%	66.9%	62.1%
28	47.3%	52.9%	92.8%	99.9%	52.0%	64.6%	63.1%	63.5%	64.9%	89.0%	56.0%	55.1%	71.4%	66.6%	61.6%
29	46.6%	52.6%	93.2%	100.0%	51.4%	64.6%	62.5%	62.5%	64.1%	88.6%	55.7%	54.3%	70.7%	65.1%	61.6%
30	46.7%	51.9%	92.5%	100.0%	50.8%	63.9%	62.1%	62.9%	64.2%	88.6%	54.4%	53.9%	70.8%	65.2%	60.9%

Table 4-72: KNN database F SINRD external position Cosine distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	15.0%	13.5%	16.4%	13.4%	20.4%	23.4%	22.2%	21.8%	22.5%	25.3%	38.4%	37.0%	32.8%	26.0%	41.3%
2	15.8%	15.3%	15.8%	13.9%	20.9%	22.8%	22.7%	22.3%	22.7%	24.6%	39.1%	37.1%	32.8%	25.7%	41.3%
3	15.5%	15.5%	15.0%	17.3%	20.7%	22.6%	22.3%	23.0%	22.5%	25.0%	38.5%	36.9%	32.6%	25.7%	40.4%
4	14.3%	15.9%	16.4%	14.7%	21.9%	22.8%	22.0%	23.2%	22.8%	24.6%	38.4%	37.1%	32.6%	26.6%	40.7%
5	15.9%	14.4%	15.3%	14.6%	22.0%	22.6%	22.4%	22.5%	23.4%	24.5%	37.7%	38.1%	33.1%	26.7%	41.0%
6	16.9%	16.1%	15.2%	16.6%	21.4%	23.5%	22.6%	23.0%	22.7%	24.5%	38.5%	37.5%	33.3%	26.3%	41.1%
7	16.2%	17.2%	15.8%	16.8%	21.2%	23.4%	22.0%	22.8%	22.3%	24.0%	38.7%	37.9%	33.2%	26.5%	41.2%
8	15.1%	17.5%	16.0%	14.3%	21.3%	23.6%	22.0%	23.0%	22.7%	24.5%	38.0%	37.3%	33.5%	26.9%	41.5%
9	15.4%	16.5%	15.7%	16.3%	21.3%	23.5%	22.2%	22.5%	22.9%	24.7%	38.5%	37.0%	32.7%	26.8%	42.0%
10	13.9%	14.0%	16.5%	15.3%	20.4%	23.1%	22.3%	21.8%	22.1%	24.6%	38.7%	37.4%	33.0%	26.6%	41.8%
11	16.7%	16.1%	14.4%	17.2%	21.0%	23.2%	22.4%	22.6%	22.9%	24.5%	38.4%	37.7%	33.0%	27.3%	42.7%
12	17.5%	14.5%	15.7%	16.0%	21.6%	23.1%	21.5%	22.7%	22.4%	24.6%	38.9%	36.9%	33.4%	27.1%	42.0%
13	15.4%	16.1%	16.4%	16.6%	21.7%	23.5%	21.8%	22.8%	22.6%	24.6%	38.4%	36.9%	32.6%	26.5%	42.0%
14	14.3%	15.9%	15.3%	16.5%	20.8%	22.4%	22.2%	22.5%	23.0%	24.4%	39.3%	38.3%	33.0%	26.9%	42.2%
15	16.3%	14.6%	14.4%	14.0%	21.4%	23.1%	22.3%	22.6%	22.7%	24.5%	39.1%	38.2%	32.5%	26.9%	41.3%
16	14.5%	14.3%	16.5%	16.2%	21.4%	23.1%	21.7%	22.9%	23.5%	24.6%	38.1%	37.1%	32.8%	27.0%	40.6%
17	15.3%	15.3%	15.5%	16.5%	21.4%	23.4%	22.6%	22.9%	22.8%	24.2%	38.6%	38.5%	32.7%	26.6%	42.1%
18	16.8%	15.7%	16.1%	15.6%	21.3%	22.3%	21.7%	22.7%	23.0%	25.0%	38.6%	38.0%	33.0%	26.9%	41.2%
19	15.1%	17.4%	17.0%	15.2%	21.3%	23.0%	22.5%	22.8%	23.0%	24.8%	38.7%	38.0%	33.3%	27.3%	41.0%
20	14.5%	16.5%	14.8%	14.6%	21.4%	22.8%	22.8%	23.1%	23.0%	24.4%	39.0%	38.3%	32.9%	27.4%	41.3%
21	15.6%	16.5%	16.6%	15.3%	21.7%	22.8%	21.8%	22.8%	22.8%	24.1%	39.6%	37.9%	32.6%	26.9%	42.2%
22	15.7%	15.7%	15.4%	15.5%	21.6%	22.9%	22.7%	23.3%	22.8%	24.5%	39.2%	38.2%	32.8%	26.6%	41.7%
23	13.9%	16.4%	16.4%	16.3%	21.3%	23.2%	22.3%	22.5%	22.8%	24.5%	39.3%	38.4%	32.8%	27.7%	41.6%
24	15.8%	16.7%	14.8%	16.7%	21.1%	22.8%	23.1%	22.6%	22.3%	24.8%	39.3%	37.7%	32.8%	26.6%	41.4%
25	14.4%	15.5%	16.8%	16.1%	21.0%	22.8%	22.0%	23.2%	23.0%	24.9%	38.4%	37.2%	32.6%	26.1%	41.7%
26	16.1%	15.4%	14.7%	17.2%	21.4%	23.1%	22.0%	22.9%	22.7%	24.8%	39.2%	38.3%	33.1%	27.1%	42.0%
27	15.8%	16.2%	14.9%	15.7%	21.5%	23.7%	22.0%	22.3%	22.8%	24.6%	38.9%	38.1%	33.3%	27.0%	41.9%
28	15.9%	16.0%	16.6%	15.0%	21.3%	23.0%	22.5%	22.7%	23.2%	24.2%	39.9%	38.0%	31.7%	26.6%	41.7%
29	16.0%	16.9%	15.3%	16.0%	21.9%	23.0%	21.7%	22.5%	22.5%	24.9%	38.8%	38.6%	32.6%	26.7%	42.1%
30	17.0%	17.4%	15.9%	16.7%	21.8%	22.9%	22.5%	22.5%	22.5%	24.6%	39.7%	38.2%	32.3%	27.0%	42.1%

Table 4-73: KNN database F SINRD all positions Cosine distance metric.

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
# NEIGHBORS	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
1	31.4%	40.6%	79.4%	100.0%	56.0%	57.0%	63.0%	70.9%	78.3%	98.6%	62.6%	63.9%	64.8%	78.5%	65.0%
2	30.7%	41.1%	79.2%	100.0%	55.2%	57.6%	62.7%	71.6%	78.9%	98.7%	62.3%	63.6%	64.9%	78.3%	65.4%
3	32.6%	40.9%	78.1%	100.0%	55.3%	57.7%	62.8%	70.4%	77.5%	98.1%	61.9%	62.4%	63.5%	77.5%	63.7%
4	31.5%	41.6%	78.2%	100.0%	55.0%	56.7%	62.1%	70.9%	76.4%	98.2%	61.8%	61.1%	63.9%	76.9%	63.9%
5	32.3%	41.8%	78.2%	99.9%	54.0%	56.9%	62.5%	69.2%	75.7%	97.7%	60.9%	61.3%	62.9%	76.4%	62.9%
6	32.2%	41.7%	78.0%	100.0%	53.2%	55.8%	62.7%	70.0%	75.8%	98.0%	59.8%	61.6%	63.0%	76.1%	62.4%
7	32.4%	42.6%	77.7%	100.0%	53.8%	56.2%	62.0%	69.9%	75.0%	98.0%	60.6%	60.9%	62.4%	75.2%	62.1%
8	32.0%	41.6%	77.8%	100.0%	53.5%	56.5%	60.4%	69.3%	75.2%	97.9%	59.5%	60.2%	62.2%	74.8%	61.4%
9	32.4%	42.2%	78.1%	99.9%	52.1%	55.3%	61.3%	68.1%	74.0%	97.7%	59.0%	60.7%	62.4%	75.1%	61.4%
10	32.2%	41.4%	78.2%	100.0%	52.9%	56.2%	61.2%	69.1%	74.1%	97.6%	59.7%	60.3%	61.9%	74.7%	61.3%
11	31.8%	42.6%	77.7%	100.0%	52.4%	55.0%	60.3%	67.7%	73.9%	97.8%	58.9%	59.9%	61.8%	73.3%	61.1%
12	32.3%	42.1%	77.9%	99.9%	52.4%	55.4%	60.9%	68.3%	73.7%	97.9%	58.7%	59.6%	61.8%	73.4%	60.5%
13	31.6%	42.1%	77.4%	100.0%	52.5%	55.5%	60.9%	68.2%	73.5%	97.5%	59.1%	60.4%	61.7%	72.9%	61.1%
14	32.2%	42.4%	78.1%	100.0%	53.0%	55.5%	60.2%	67.7%	73.5%	97.4%	58.3%	59.4%	61.4%	72.8%	60.7%
15	32.0%	42.0%	77.9%	100.0%	53.1%	55.2%	60.2%	67.6%	72.8%	97.5%	58.4%	59.9%	60.9%	72.7%	60.1%
16	31.9%	41.8%	77.8%	100.0%	52.1%	54.5%	59.3%	66.6%	73.5%	97.0%	58.4%	58.4%	59.9%	71.7%	60.5%
17	31.0%	41.8%	77.1%	100.0%	52.9%	53.8%	59.6%	67.0%	72.4%	97.2%	58.9%	58.9%	60.4%	72.6%	60.1%
18	31.9%	42.7%	77.6%	100.0%	52.3%	54.6%	60.0%	67.0%	73.0%	97.2%	58.5%	59.2%	59.9%	71.8%	60.2%
19	31.4%	42.0%	76.9%	99.9%	52.1%	54.5%	59.0%	66.2%	72.6%	97.2%	58.0%	59.2%	60.1%	71.8%	59.4%
20	31.9%	41.8%	77.0%	99.9%	52.6%	53.7%	59.0%	66.5%	73.2%	97.3%	58.6%	58.9%	60.2%	71.5%	60.1%
21	31.4%	41.7%	77.4%	99.9%	52.5%	53.4%	58.9%	66.1%	72.8%	96.9%	58.2%	57.6%	59.9%	71.2%	59.7%
22	31.1%	41.9%	77.2%	100.0%	52.2%	53.8%	59.1%	65.7%	72.6%	96.8%	58.6%	57.9%	59.7%	70.8%	59.4%
23	31.6%	42.6%	77.0%	99.9%	52.6%	53.5%	58.3%	66.1%	71.8%	97.0%	56.9%	58.4%	59.2%	70.4%	59.4%
24	31.4%	42.4%	77.2%	100.0%	51.5%	53.6%	59.0%	66.0%	71.7%	96.6%	57.7%	58.4%	58.3%	70.0%	59.3%
25	31.3%	42.5%	77.2%	100.0%	51.5%	53.0%	58.1%	65.7%	71.8%	96.9%	58.0%	57.9%	57.9%	70.5%	58.6%
26	32.0%	42.1%	77.2%	100.0%	51.8%	52.8%	57.8%	65.2%	71.7%	96.8%	57.9%	57.6%	58.7%	71.1%	59.6%
27	32.1%	42.1%	77.3%	100.0%	51.9%	52.6%	57.9%	65.3%	71.7%	96.6%	58.3%	57.6%	58.5%	70.2%	59.5%
28	32.2%	41.5%	76.9%	100.0%	52.4%	51.8%	58.4%	64.9%	71.0%	96.7%	58.2%	57.9%	58.5%	70.2%	59.5%
29	31.0%	42.5%	77.2%	100.0%	51.6%	52.8%	57.4%	64.7%	71.2%	96.4%	58.1%	57.6%	58.1%	70.4%	59.0%
30	31.5%	42.1%	76.9%	99.9%	51.4%	52.6%	57.7%	65.2%	71.4%	96.5%	57.8%	57.1%	58.6%	69.8%	58.8%

4.3 Discriminant analysis

4.3.1 Databases F

The tables of this chapter show the accuracies calculated using the discriminant analysis method for databases F for each type of detectors. In this case an accuracy values are obtained for each combination of type of covariance matrix structure and the type of discriminant analysis adopted.

4.3.1.1 Fork detector

Tables 4-74 and 4-75 show the results obtained using the Fork detector for diversion and replacement. From the first table it is possible to observe a relevant decrease in the accuracies compared to the previous methods; all the accuracies are included between 15% and 27%. The linear discriminant with the full covariance matrix shows slightly higher results compared to the diagonal structure, in particular for the combination of the fast neutrons and the total number of neutrons (NwithCd-NwithoutCd) which reaches an accuracy value of 24%. The quadratic discriminant analysis shows the best results reaching an accuracy value of 27.3% using all features. Also in this case the full covariance structure shows slightly higher results compared to the diagonal structure.

The same considerations can be applied to the results for the replacement database, although a global decrease in the accuracies is observed. The maximum accuracy value in this case is 25% using all features with the quadratic discriminant analysis and full covariance matrix.

The standard deviations associated to these results are included between 2% and 3% both for diversion and replacement.

4.3.1.2 PDET

The tables from 4-76 to 4-79 show the results for the PDET detector. The results in this case depend also on the detectors positions used as input features. As for the Fork detector, considering the linear discriminant analysis the best results are obtained using a full covariance matrix, reaching values up to 55% using all detectors positions. Unlike the previous machine learning algorithms, this method shows higher result for thermal neutrons (TH) and resonance neutrons (RES) compared to fast neutrons (FA) and gamma-rays (P) considering the results for one single feature. For the linear discriminant analysis, the combination of more features shows increasing results reaching the maximum value using all features and positions. The combinations of more positions show higher results compared to the values obtained for single features, except for the combination central peripheral that shows accuracies more similar to those obtained with a single detector position. The use of diagonal structure for the covariance matrix causes a decrease in the values of accuracies, and similar accuracy values were obtained independent from the detectors positions or input features selected.

The same considerations could be extended to the quadratic discriminant analysis with a global increase in the accuracies both for full and diagonal structure of the covariance matrix reaching values up to 75% for full diagonal using all detectors positions and all features.

The standard deviations associated to these results are included between 2% and 4% both for diversion and replacement.

4.3.1.3 SINRD

The tables from 4-80 to 4-83 show the results for the SINRD detector. The results are similar to those obtained for the PDET with a slight increase of the accuracies reaching a maximum value of 77% using the quadratic discriminant analysis with a full covariance matrix taking all detectors positions and all features. The only difference from the PDET is that in this case the combination central peripheral does not show lower accuracies compared to the other combinations of positions but shows a similar trend.

The standard deviations associated to these results are included between 2% and 4% both for diversion and replacement.

Table 4-74: Discriminant analysis database F Fork detector diversion case.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
Linear/Full	19.4%	19.1%	18.0%	24.0%	15.5%	15.7%	19.6%
Linear/Diagonal	19.3%	19.2%	17.3%	19.1%	18.4%	16.9%	18.5%
Quadratic/Full	20.3%	19.5%	18.7%	27.1%	16.4%	16.5%	27.3%
Quadratic/Diagonal	20.3%	20.1%	18.4%	16.8%	17.1%	16.0%	16.8%

Table 4-75: Discriminant analysis database F Fork detector replacement case.

	N with Cd	N without Cd	Current	N with Cd	N with Cd	N without Cd	N with Cd
				N without Cd	Current	Current	N without Cd
							Current
	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy	accuracy
Linear/Full	19.2%	19.7%	16.4%	22.1%	15.9%	16.3%	19.0%
Linear/Diagonal	19.5%	19.5%	17.0%	19.2%	17.4%	17.8%	17.1%
Quadratic/Full	17.7%	19.6%	17.6%	23.9%	16.9%	18.1%	25.0%
Quadratic/Diagonal	18.4%	19.6%	17.3%	15.0%	16.9%	16.4%	16.9%

Table 4-76: Discriminant analysis database F PDET (Linear/Full).

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
POSITION	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Central	21.3%	22.7%	19.1%	19.4%	23.3%	23.3%	24.1%	24.8%	25.2%	24.0%	25.7%	25.5%	24.4%	27.2%	27.4%
Peripheral	22.1%	22.9%	20.3%	20.0%	24.1%	24.9%	24.5%	25.4%	24.4%	21.0%	25.6%	25.7%	24.3%	25.9%	27.2%
External	26.2%	31.2%	20.6%	19.7%	30.0%	27.9%	28.6%	31.5%	32.3%	28.5%	31.2%	32.2%	33.5%	38.6%	37.4%
Cen/Per	17.6%	18.1%	22.2%	23.1%	20.9%	24.1%	23.6%	28.4%	26.3%	23.9%	29.6%	28.0%	27.5%	31.1%	32.3%
Cen/Ext	29.4%	36.6%	25.6%	24.8%	35.1%	31.6%	32.3%	39.5%	39.7%	35.8%	39.6%	39.1%	36.5%	44.6%	44.8%
Per/Ext	28.9%	36.8%	22.8%	23.1%	34.1%	28.9%	29.5%	39.7%	38.9%	40.4%	38.6%	38.5%	40.5%	48.0%	52.2%
Cen/Per/Ext	28.7%	36.7%	22.7%	20.6%	35.1%	32.5%	32.8%	40.7%	41.3%	39.4%	40.0%	40.2%	45.3%	50.2%	54.8%

Table 4-77: Discriminant analysis database F PDET (Linear/Diagonal).

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
POSITION	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Central	21.2%	22.7%	19.2%	19.3%	23.8%	21.4%	21.6%	23.1%	24.4%	19.6%	24.6%	24.9%	21.8%	22.6%	25.4%
Peripheral	22.2%	21.8%	19.9%	20.3%	22.1%	23.6%	23.4%	24.4%	24.2%	20.4%	23.2%	23.5%	23.2%	24.8%	23.9%
External	26.4%	31.1%	20.5%	20.8%	29.1%	28.9%	29.4%	33.2%	33.5%	21.8%	30.0%	31.2%	28.1%	33.1%	31.1%
Cen/Per	23.0%	24.4%	20.1%	20.6%	26.4%	23.9%	23.5%	26.4%	26.8%	20.1%	27.6%	28.1%	23.6%	25.7%	28.8%
Cen/Ext	28.9%	36.5%	21.4%	21.1%	33.4%	30.4%	30.8%	37.3%	38.5%	21.0%	34.2%	35.0%	31.0%	38.2%	35.1%
Per/Ext	27.3%	34.3%	21.1%	20.4%	30.2%	28.9%	29.3%	36.5%	37.0%	19.7%	31.9%	31.8%	30.1%	36.3%	32.8%
Cen/Per/Ext	28.5%	36.8%	20.1%	19.5%	33.0%	29.7%	29.8%	37.5%	38.2%	19.7%	34.4%	34.9%	30.6%	37.5%	35.4%

Table 4-78: Discriminant analysis database F PDET (Quadratic/Full).

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
POSITION	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Central	31.2%	28.5%	35.4%	36.8%	30.5%	36.7%	40.8%	40.8%	41.4%	45.1%	38.9%	39.5%	44.2%	44.7%	43.4%
Peripheral	32.3%	33.9%	38.7%	40.5%	35.5%	43.8%	43.3%	43.8%	43.3%	43.8%	43.4%	43.4%	46.8%	50.5%	49.6%
External	26.2%	33.1%	43.0%	42.0%	32.1%	42.3%	41.5%	44.0%	43.9%	47.6%	44.7%	43.2%	48.4%	52.0%	52.8%
Cen/Per	31.2%	36.6%	39.1%	41.2%	37.5%	44.9%	45.0%	51.1%	50.6%	56.4%	49.5%	48.9%	58.8%	62.1%	63.1%
Cen/Ext	36.9%	42.4%	46.7%	45.0%	42.0%	46.3%	47.1%	53.0%	54.8%	57.8%	51.7%	52.8%	58.0%	61.7%	61.1%
Per/Ext	37.4%	44.6%	46.6%	48.3%	47.7%	52.6%	54.5%	57.0%	58.1%	65.6%	56.7%	57.4%	66.9%	67.5%	70.7%
Cen/Per/Ext	40.3%	50.8%	52.7%	56.0%	50.5%	53.9%	56.0%	59.5%	62.2%	70.2%	59.1%	60.7%	70.8%	71.8%	74.9%

Table 4-79: Discriminant analysis database F PDET (Quadratic/Diagonal).

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
POSITION	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Central	30.6%	28.4%	35.8%	37.1%	31.1%	35.3%	37.4%	36.2%	38.1%	37.8%	36.5%	38.6%	38.2%	37.7%	38.3%
Peripheral	32.3%	34.0%	38.7%	40.3%	34.3%	41.1%	41.8%	40.8%	41.6%	40.3%	40.8%	40.8%	41.9%	42.3%	41.8%
External	26.5%	33.0%	42.6%	41.9%	31.5%	41.3%	41.8%	45.5%	45.0%	41.6%	43.8%	45.0%	41.2%	45.1%	44.3%
Cen/Per	33.3%	33.0%	37.9%	38.7%	33.1%	39.8%	40.2%	40.1%	40.3%	38.5%	40.1%	40.0%	39.2%	39.6%	40.3%
Cen/Ext	36.9%	38.4%	42.5%	41.8%	39.7%	43.7%	43.8%	47.0%	46.8%	42.7%	47.0%	46.8%	43.6%	46.6%	46.5%
Per/Ext	35.2%	41.9%	43.2%	44.2%	40.5%	45.5%	45.5%	48.4%	48.3%	44.0%	46.3%	46.5%	45.2%	48.2%	47.7%
Cen/Per/Ext	34.9%	39.8%	41.6%	41.8%	39.3%	44.1%	44.1%	47.0%	46.7%	42.1%	45.8%	45.9%	43.3%	46.5%	46.3%

Table 4-80: Discriminant analysis database F SINRD (Linear/Full).

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
POSITION	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Central	18.5%	19.3%	19.2%	19.3%	22.1%	20.1%	20.3%	20.9%	23.5%	32.1%	22.7%	23.3%	34.4%	29.3%	32.9%
Peripheral	16.1%	18.5%	18.9%	20.3%	20.4%	20.0%	20.6%	19.8%	21.3%	27.3%	23.2%	23.4%	29.8%	25.9%	34.3%
External	16.7%	20.0%	19.9%	21.6%	19.9%	18.6%	20.1%	20.7%	22.1%	27.4%	20.2%	21.3%	29.4%	29.2%	37.2%
Cen/Per	18.5%	21.1%	23.8%	24.0%	24.2%	22.7%	23.5%	26.4%	27.5%	32.2%	27.7%	27.6%	35.0%	34.0%	42.0%
Cen/Ext	18.0%	21.3%	25.1%	24.9%	24.1%	27.4%	24.5%	33.3%	31.5%	33.5%	32.0%	30.7%	37.9%	39.6%	45.1%
Per/Ext	18.7%	24.1%	22.7%	23.2%	27.6%	33.3%	28.2%	38.7%	35.3%	38.4%	39.1%	36.1%	46.6%	50.6%	55.3%
Cen/Per/Ext	18.8%	25.7%	22.3%	22.6%	29.4%	33.7%	28.0%	38.9%	35.6%	40.0%	40.0%	37.9%	47.3%	52.1%	57.7%

Table 4-81: Discriminant analysis database F SINRD (Linear/Diagonal).

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
POSITION	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Central	17.9%	20.4%	19.4%	19.5%	20.4%	20.4%	20.3%	20.2%	20.1%	21.6%	21.6%	21.5%	22.1%	21.6%	22.3%
Peripheral	17.1%	18.4%	19.5%	20.2%	19.3%	20.8%	20.3%	20.2%	21.2%	20.9%	20.9%	22.4%	22.6%	22.5%	23.5%
External	16.6%	19.1%	19.6%	21.3%	19.1%	18.8%	20.1%	20.4%	20.6%	22.8%	21.9%	20.6%	21.8%	22.1%	23.0%
Cen/Per	16.8%	19.2%	19.9%	20.3%	20.7%	20.9%	21.3%	21.2%	22.5%	22.5%	21.6%	22.3%	23.6%	24.2%	23.1%
Cen/Ext	16.8%	20.2%	22.0%	21.2%	22.8%	22.1%	20.9%	23.2%	22.6%	24.3%	26.3%	24.7%	25.5%	25.3%	26.9%
Per/Ext	16.8%	19.9%	24.6%	20.5%	21.2%	22.0%	20.2%	23.0%	21.6%	24.3%	24.5%	23.1%	23.7%	22.3%	26.8%
Cen/Per/Ext	17.3%	21.2%	23.3%	19.9%	23.0%	22.3%	21.7%	23.9%	23.2%	24.6%	25.1%	24.1%	24.6%	25.0%	26.5%

Table 4-82: Discriminant analysis database F SINRD (Quadratic/Full).

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
POSITION	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Central	18.3%	24.2%	35.4%	38.3%	29.6%	38.0%	39.2%	37.7%	39.3%	45.5%	38.4%	38.5%	48.4%	45.0%	49.8%
Peripheral	16.8%	23.3%	38.5%	39.7%	27.3%	38.8%	38.7%	36.8%	39.0%	41.8%	41.1%	39.3%	43.2%	41.2%	50.9%
External	16.1%	19.2%	36.1%	42.1%	20.8%	39.2%	41.2%	34.8%	40.3%	43.7%	42.2%	40.4%	46.7%	41.5%	53.8%
Cen/Per	27.1%	29.0%	41.3%	42.6%	36.4%	42.5%	42.9%	42.8%	44.0%	51.6%	47.9%	45.4%	54.3%	52.2%	60.8%
Cen/Ext	28.5%	29.4%	47.7%	45.0%	37.9%	47.1%	44.9%	51.9%	49.6%	53.1%	51.5%	48.9%	58.1%	55.9%	66.4%
Per/Ext	28.3%	33.2%	50.2%	50.7%	42.8%	54.4%	53.8%	55.6%	55.2%	59.7%	58.1%	56.2%	64.6%	65.5%	68.7%
Cen/Per/Ext	32.7%	38.0%	55.1%	57.4%	48.5%	58.8%	58.1%	61.2%	59.6%	70.3%	61.8%	60.3%	72.0%	72.3%	77.0%

Table 4-83: Discriminant analysis database F SINRD (Quadratic/Diagonal)

Detector response 1	TH	RES	FA	P	TH	TH	TH	RES	RES	FA	TH	TH	TH	RES	TH
Detector response 2					RES	FA	P	FA	P	P	RES	RES	FA	FA	RES
Detector response 3											FA	P	P	P	FA
Detector response 4															P
POSITION	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Central	18.1%	23.6%	35.4%	38.2%	22.9%	35.7%	38.4%	36.0%	38.3%	38.9%	35.7%	37.9%	38.9%	38.9%	38.8%
Peripheral	16.5%	23.6%	38.3%	39.4%	22.2%	38.4%	39.5%	37.9%	38.6%	41.3%	37.4%	39.4%	41.2%	40.3%	40.2%
External	17.0%	19.0%	36.2%	42.1%	19.9%	35.6%	41.6%	36.3%	42.4%	40.4%	35.9%	42.2%	40.7%	42.1%	41.8%
Cen/Per	17.0%	25.1%	38.4%	39.0%	24.6%	37.9%	39.5%	38.2%	38.7%	39.9%	37.3%	39.0%	40.2%	39.4%	39.8%
Cen/Ext	17.9%	26.4%	42.2%	43.1%	25.8%	41.6%	43.3%	42.2%	42.3%	44.2%	41.5%	42.4%	44.7%	43.8%	44.1%
Per/Ext	16.5%	23.2%	41.3%	44.2%	24.8%	41.1%	44.9%	40.7%	43.5%	44.0%	41.4%	44.1%	44.1%	44.1%	44.3%
Cen/Per/Ext	16.7%	26.5%	42.3%	42.9%	26.3%	42.1%	42.9%	41.8%	41.8%	43.1%	41.6%	42.5%	44.0%	42.6%	43.2%

5 Conclusions

This study aimed at investigating some methods to detect and to classify fuel pins diversions from spent nuclear fuel using machine learning algorithms. Different types of detector were tested inside the different algorithms to improve the accuracies of the final classification of the spent fuel assembly.

Several databases were created for this study, gathering the results from Monte Carlo simulations of PWR 17x17 fuel assemblies. Both complete fuel assemblies with different initial enrichment, burnup, and cooling times were included in the database, as well as more than 100 scenarios with fuel assemblies with dummy pins made of stainless steel. The detector responses simulating the NDA measurements with the Fork detector, the SINRD, and the PDET techniques were included in the database and used as input features in the machine learning models. Each observation in the database was associated to an output class, which was related to the percentage of fuel pins replaced by stainless steel dummies.

The machine learning models considered in this study were the decision trees, the K-nearest neighbors, and the discriminant analysis. The decision tree models were tested with databases of increasing difficulty, since the first database (database A) included only complete fuel assemblies and assemblies with more than 50% of dummies, whereas the last database (database F) included also assemblies with less than 10% dummies. The KNN and discriminant analysis models were tested only against the database F for comparison. All models developed in this work were compared in terms of accuracy, which was defined as the percentage of correct classifications.

The first observation that can be done looking at the results of the decision tree models is that going from database A to database F for each type of detector the accuracies decrease due to the increasing number of classes and consequently the complexity of the databases. For this reason the KNN and discriminant analysis algorithms were tested only with databases F to analyze and classify the most complex databases which provide a more refined classification of the assemblies.

Using the decision tree algorithm with the database of the Fork detector for database A it was observed that the split criterion used by the decision tree did not influence the final accuracies in a relevant way. For this reason in the following cases the Gini's index was adopted as cost function to determine the splits of the tree. The accuracies of the models start to increase with the number of splits, becoming almost constant around 10 spits. To avoid the problem of the overfitting it is recommended to choose a maximum number of splits between 8 and 12, because in each case analyzed there is no relevant increase in the accuracies increasing further the total number of splits.

Considering the three types of NDA techniques included in this thesis, the results showed similar accuracies for the SINRD and PDET analysis, while for the Fork detector the accuracies decrease between 30-35% comparing the same database for each type of algorithm used. This is due to the different detector types, to the number of detectors, and to their positions within or around the assembly. The results suggest that PDET and SINRD are more sensitive than the Fork detector to the diversion of fuel pins. The similarity between the accuracies obtained for PDET and SINRD shows that there are no relevant differences between measurements performed in air or in water.

From the results section it is also possible to observe that the combination of more detector responses most of the times gives similar accuracies, in particular for the cases in which for PDET and SINRD the response of the gamma-ray detector is involved. This feature gives the best values of accuracy also without the combination with other detector responses. In fact most of the complete correct classifications were found for the single P feature for one or multiple detectors positions. From these considerations it is possible to assert that the gamma-ray detectors are the most sensitive to the diversion of the fuel pins. Therefore the combinations of the position of the detectors, in most of the cases, lead to an increase in the accuracies considering the same combination of detector responses. For the Fork detector the best single feature is the current and the higher values of accuracies are obtained from a combination of the current with one of the other two features or taking the combination of all the three features. There are no relevant differences in the accuracy using replacement or diversion databases.

Comparing the results of the databases F for the three different type of machine learning algorithms it is immediate to observe that the KNN algorithm give the best accuracies. It is the only algorithm able to classify with 100% accuracies the spent nuclear fuel for PDET and SINRD, while for the Fork detector reach values between 60-70%. For comparison, considering PDET and SINRD the maximum accuracy values are between 70-75% for the decision tree and 77% for the discriminant analysis, while the Fork detector is able to reach maximum values between 25-30% for the decision tree and between 20-25% for the discriminant analysis.

Analyzing the results of the KNN algorithm for each type NDA technique considered in this study it is possible to observe a decreasing trend for the accuracies with the increasing number of neighbors in case the equal distance weight is chosen. The best choice of number of neighbors is between 8 and 10 to avoid decreases in the accuracies and the risk of overfitting. In case the inverse distance weight is selected, the accuracy values start from similar values compared to those of the equal distance weight, but they keep constant or slightly decreasing with the number of neighbors. The different distance metrics used in this study gave similar results except for the Mahalanobis and Cosine that gave the worse values of accuracies. In particular the cosine distance metric using a single detector position gave accuracy values lower than 50% for each combination of features.

In the case of the discriminant analysis the best results were obtained using quadratic functions, which are able to generate borders capable to better separate the classes compared to the linear functions. The accuracy values obtained using the full covariance matrix are in general higher than the corresponding values obtained using only the diagonal of the matrix. This is probably due to the loss of information caused by using only one part of the matrix.

In conclusion the machine learning models considered in this study proved to be very promising for the detection of fuel pins diversions. Overall the highest accuracies obtained in this study to classify the spent nuclear fuel were obtained with the KNN algorithm. The results using this algorithm were not influenced in a relevant way from the distance metric used, provided that the choice is made between Euclidean, Cubic, Chebychev or City Block. It is suggested to select the inverse distance weight to obtain accuracies that are largely independent from the number of neighbors chosen. However, it is recommended to limit the number of neighbors to 15 to prevent overfitting of the training database. Comparing the NDA techniques considered in this study, PDET and SINRD gave similar accuracy values, especially when the gamma-ray detector response is used as input feature in the machine learning model.

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