I OPENER on I-CATCHER

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Internship of doing Objective & Precise Evaluation and doing Narrow & Extensive Research on Intensive-Care Access to Terminology & Course of Health Exploration and Retrieval. Picture is of the ICU of the UMC of Utrecht.

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ABSTRACT

Purpose: The purpose of this document is to report on how research is done in a scientific setting. The scientific setting will be the I-Catcher project at the Medical Informatics department of the Academic Medical Center in Amsterdam. The objectives are (1) to contrast the original research proposal with the actual research activities and results and (2) to investigate how new research questions arose from this research.

Methods: To get familiar with the I-Catcher project, a literature survey has been conducted. The literature survey covers also some background information about IC departments in a general sense, methods that can be used at the IC department and the various scores that are in use at the IC departments. To get a feeling of what the algorithm of I-Catcher does, a demonstration has been given. Information of how research has been done and will be done with and on I-Cather an interview is conducted.

Results: I-Catcher – which is the cooperation between several universities and a teaching hospital – uses temporal data to discover frequently occurring patterns which can be used for creating prognostic models ultimately to support intensivists in getting insight into their patients and quality of care. As the literature survey showed, there are a lot articles about prognosis and the importance of it. Prognostic models provide insights in the process of prognosis. There are several approaches to prognostic models, commonly used techniques are simple decision rules based on the categorization of a prognostic score, Bayes' rule, logistic regression, classification trees and decision trees. Research cannot be performed without funding. The NWO funded I-Catcher because it fits in the overall mission of the NWO, which has been defined in several documents. In those days that I-Catcher was proposed there were one document and one research program, the NOAG ICT 2001-2005 document and the Token2000 program. To keep an eye on the future the NOAG-ICT 2005-2010 document is mentioned.

Conclusions: In the NOAG-ICT document several research and cooperation areas have been defined, I-Catcher still fits in certain areas of the NOAG-ICT 2005-2010 document. This means that the I-Catcher project is still relevant and prognostic models and knowledge discovery in data remains interesting in the future. Overall when the prognostic models are compared with static models they showed improvement and the prognostic models using temporal data are better in predicting the real world situation. Future research should investigate how the I-Catcher algorithm will perform with other test sets and where I-Catcher is used for the individual patient, I-Catcher+ and future research should focus on the subgroup discovery. In the research questions are slight differences between the original research proposal and the actual research, apparently this happens frequently. I-Catcher is a finished project; it has been finished in October 2007.

1. INTRODUCTION

For knowledge institutions the most important goal is to acquire knowledge. Unfortunately knowledge does not appear just like that. When an institution or a person would like to acquire knowledge it has to be accomplished by doing research.

Doing research is important to get new insights in the area of health care. Health care professionals rely on the insights acquired by research. Research can find new evidence for treatment, help a health care professional with making a diagnosis or – with the help of research – new models can be created for prognosis. These are just some examples of what research can add to the health care.

Research is done within research projects. A researcher will create a project group and they will create a proposal. Because doing research requires money, creating a proposal is important. With the proposal the research group can request money. Ultimately when the research proposal is approved, the researchers will be funded for doing their research.

The purpose of the internship is to obtain insight of how research is done. Therefore in this document I will examine this process in the context of a specific project, namely the I-Catcher project.

The research questions are:

- What is I-Catcher?
- What is the motivation for I-Catcher?
- What is the objective of I-Catcher?
- What are their research questions?
- Which people stand behind I-Catcher?
- How is it funded?
- How do new questions arise?
- Are the subjects still relevant?

These questions will be answered in this document. In section two the methods are described; how did I obtain the information I need. Section 3 deals with the results, in this section I-Catcher is introduced and explained and the organization who funded the project.

In section 4 the results and literature will be debated and critically evaluated. The research questions will be answered in the conclusion which is section 5.

2. METHODS

There are several ways how I gathered information. The project leader of I-Catcher provided me a list of relevant literature **[1-8]**, which was a starting point for obtaining knowledge about the area. I extended the literature study by visiting several websites of organizations which are somehow related to the subject **[9-18]**. All the extra literature and websites I found by using Google.

Because funding is an important aspect of doing research, I checked whether the I-Catcher project does fit in the mission of the funding organization **[12,21,22]**.

It is not possible to continuous follow fellow members of the I-Catcher project team; therefore I have conducted an interview to gain insight of the I-Catcher project.

By interviewing the project leader it is possible to acquiring knowledge about how research is done and how it is done with the I-Catcher project.

The I-Catcher team of the University of Amsterdam consists of Ameen Abu Hanna, Niels Peek, Tudor Toma, Nicolette de Keizer and Ronald Cornet. During this internship only Ameen Abu Hanna has been interviewed **[19]**.

The interview was a semi-structured interview. The reason for this structure was that I could guide the interview with some pre-defined questions and the interviewee had some guidance and yet the liberty to answer. The liberty of the interviewee can give more insight than using a structured interview. Because of the liberty an answer can lead to new questions and even more insight in the matter.

I have seen a demo of I-Catcher. Lilian Minne showed me how I-Catcher worked and the reason for the demo was that it gave me even more insight in I-Catcher.

3. RESULTS

Throughout this section the results will be reported as followed; first the results of the literature survey and the articles are described, second the NWO is described – what is NWO, what is their mission & ambition and third the Token2000 program and NOAG-ICT documents are described.

Finally the I-Cather project is described and where there are any differences with the original setup it is reported in the I-Catcher section. The original setup is the setup which is known by the NWO. It is the setup for which the I-Catcher project has received funds from the NWO.

3.1. I-CATCHER

3.1.1. WHAT IS I-CATCHER?

I-Catcher is an acronym which stands for: **I**ntensive-**C**are **A**ccess to **T**erminology & **C**ourse of **H**ealth **E**xploration and **R**etrieval **[14]**.

The project can be divided in two parts, the first part is the *ontology mapping* and the second part is the *knowledge discovery*. This can be seen in **Figure VI**.

Ontology mapping

The ontology mapping is done by the Free University of Amsterdam. Their objective is to create a mapping between the OLVG ontology and the DICE[I] system which is in use at the IC[II] department of the Academic Medical Center of Amsterdam. For more information about DICE, the interested reader could visit the website **[15]**.

The OLVG ontology and terminology is quite a mess, it is unstructured and – even more problematic – it contains errors **[19]** and more common there is almost no – standard – diagnostic Intensive Care terminology.

The terminology has to be correct; otherwise it is difficult or even nearly impossible to characterize patients. Therefore a standard terminology is prerequisite for this. When the terminology is correct; ontology can be used for reasoning to support the health care professional **[20]**.

Knowledge discovery

Intensivists need – better – insight in how their patients are progressing and even more, how they will progress.

Data from the ICU[III] database is taken to recognize different frequent episodes. This can be done by using algorithms to find these episodes. When they are found they can be used in a model **[1,3]**.

Most likely the temporal data will improve the understanding of the process and events that occur on the ICU. Models created with the use of temporal data could better predict the mortality on the ICU than static data alone. The term temporal data is explained in Appendix A.

The ideas of I-Catcher are discussed in section 3.1.6. In that section will be elaborated on why I-Catcher is that important as it is.

[I] **DICE** = Diagnoses for Intensive Care Evaluation
[II] **IC** = Intensive Care
[III] **ICU** = Intensive Care Unit

3.1.2. THE BIRTH & MOTIVATION OF I-CATCHER

The background of Ameen Abu Hanna – nowadays project leader of I-Catcher – lies in the area of Computer Engineering and Computer Science, the research groups he is interested in are Artificial Intelligence, Terminology Systems and their application in the area of health care and medicine.

This was one of the important reasons that have led to the birth of I-Catcher. Another reason was that the IC department began with the registration of temporal data – which is embodied in the SOFA[IV] score. Questions arose very quickly whether this data could provide more information about patients and even populations.

Over time Ameen Abu Hanna has given workshops about the subject prognostic models in Artificial Intelligence and Medicine and the recording of the new temporal data encouraged to think about using prognostic models in this area.

For the next step it was important to know people. Before any research plans are created and – thorough – literature surveys are conducted, it is important to ask people whether they are interested in the subject and – when they are – if they would like to participate in the project.

One person Ameen Abu Hanna contacted was Frank van Harmelen. He was interested in the subject and these two researchers tried to create a group of people who can participate in the project.

The researchers have to find other people who – in the first place – would like to participate and – second – that they are suitable for any tasks at that moment.

When the research groups – one for the Academic Medical Center, one for the Free University and one for the OLVG – were created there has to be discussed what the project would be and what the research groups intend to do.

There were several meetings with all the group members, they discussed what to do and over time

[IV] **SOFA** = Sequential Organ Failure Assessment

the literature was studied. Before all this could take place a research plan had to be made and funds have to be applied for.

A proposal – accompanied by a general research plan – is presented to a foundation, organization or a company who might be interested in the project. For I-Catcher the proposal was presented to the NWO **[20]**.

At first the committee of the NWO rejected the proposal. Ameen Abu Hanna did not agree with the reasons why it was rejected and they challenged the decision. The NWO had to revise its former decision and the project I-Catcher received funding from the NWO. The I-Catcher project was born and definitively got off the ground.

The motivation for I-Catcher was mostly the result of the interest of Ameen Abu Hanna in using the new temporal data to create prognostic models to – eventually – help the health care to make better diagnoses and prognoses.

3.1.3. THE OBJECTIVE OF I-CATCHER

By creating the research plan and make a proposal to the NWO there were some objectives formed for the project, the – two – main objectives of I-Catcher are:

- the efficient accessibility of intensive care terminological knowledge and
- the extraction of knowledge from temporal data-bases in the intensive-care.

The first objective can be met by the ontology mapping which is implemented at the Free University of Amsterdam.

The second objective can be fulfilled by using the SOFA score for patients and use the static information already available in the ICU database which is done by the University of Amsterdam in the Academic Medical Center. This paper will focus mainly on the knowledge discovery part. The next section will cover the research questions in the knowledge discovery area.

3.1.4. RESEARCH QUESTIONS

As mentioned earlier I-Catcher has two research lines; the first one is the accessibility of terminological knowledge and the second one extraction of temporal knowledge. The main research question is *how to support intensivists in getting insight into their patients and quality of care* **[20]**.

The main research question leads to other research questions which are also important:

- What are the user needs?
- How to extract prognostic knowledge?
- How to exploit diagnostic information from the terminology server?
- How to exploit the extracted knowledge for the improvement of care?

The Academic Medical Center research team will perform and is performing research on these questions. In the next section the I-Catcher team is introduced.

3.1.5. THE I-CATCHER TEAM

The I-Catcher team consists of a couple of sub-teams, these teams are:

- The department of Medical Informatics at the University of Amsterdam at the Academic Medical Center. The team members are: Ameen Abu Hanna, Niels Peek, Tudor Toma (not longer at the department of Medical Informatics), Nicolette de Keizer and Ronald Cornet.
- The department of Artificial Intelligence – at the division of Computer Science and Mathematics – at the Free University. The team members are: Frank van Harmelen, Annette ten Teije and Michel Klein.
- The department of the Intensive Care at the OLVG at Amsterdam. The two members are: Rob Bosman and Hans van der Spoel.
- Two other team members are coming from the University of Utrecht – Arno Siebes – and the Informatics Institute of the University of Amsterdam – Stefan Slobach – respectively.

The first three teams that are summed here are the most important ones in the I-Catcher project; the other team members are partially involved. The team members of the Academic Medical Center have specific roles and they are not full-time available for I-Catcher. Their roles are:

- Ameen Abu Hanna is project leader and leader of the theme 'Extraction of temporal knowledge'.
- Niels Peek is a Postdoc on the theme 'Extraction of temporal knowledge'.
- Tudor Toma is a PhD student on the theme 'Extraction of temporal knowledge'.
- Ronald Cornet is a researcher of the theme 'Accessibility of terminological knowledge'.
- Nicolette de Keizer is only involved in the theme 'Accessibility of terminological knowledge' as an advisor and can be contacted when her expertise is required on the subject.

3.1.6. IDEAS OF I-CATCHER

The whole idea of I-Catcher is that it can support the health care. The first way by accessing the terminological knowledge it can be used to search, navigate and register the diagnostic terms in a clearly defined way. This is what the Free University of Amsterdam is trying to accomplish.

Secondly I-Catcher tries to help intensivists to get insight of their patients and the quality of care by analyzing the temporal data of the patient.

It should be the case that a health care professional can access the EPR [v] and see predictions for the patient. While a health care professional is accessing the EPR a DES[vi] can read the temporal data from the EPR and characterize the temporal data from the patient into patterns. By doing that the DES can provide predictions over time, produce an alarm when necessary and give advice about the treatment **[20]**. More information about DES can be found in Appendix A.

Before the DES could work the terminological knowledge part of the Free University of Amsterdam has to be integrated with the extraction of temporal knowledge part of the Academic Medical Center. The DES uses the terminology server to cluster the disease terms. These clusters are used in the discovery process, to eventually help the health care professional as mentioned earlier.

3.1.7 DEMO

The demonstration of the algorithm described in the SOFA score papers **[1,3]** could be demonstrated with the I-Cather program.

The program will search for common episodes or patterns in for each day at the IC department. When the algorithm is finished the user gets a list with the episodes which appear in the – different – patients admitted to the IC department and have appearance above a certain threshold (for example five percent).

Different episodes can be shown, it is possible to see the overall – SOFA – episodes and see the episodes that occur frequently for the six different organ systems.

The user is able to do some modifications to the list by adding episodes, changing episodes or deleting episodes.

When the list of episodes is complete and no more modifications are needed, than the user can save the list of frequent episodes. The results of the algorithm can be used as input for research to find interesting subgroups in the IC population.

3.1.8. THE SPONSOR

The proposal of the project has been submitted to the NWO which funded the project via the Token2000 program. Before the NWO would fund the project a research plan has been submitted.

[v] **EPR** = Electronic Patient Record
[vi] **DES** = Discovery and Extraction Server

Time passed by and eventually the NWO decided to fund the project. The money of the NWO is transferred to the AMR[VII].

The I-Catcher team has to request the money that has been funded by the NWO from the AMR. The AMR checks whether the request is legitimate. When the request is legitimate than the money is transferred to the I-Catcher team. For more information about the AMR the interested reader can visit this website **[16]**.

3.1.9. HOW DO NEW QUESTIONS ARISE FROM I-CATCHER?

New questions can arise on numerous ways. The ways new questions arose from I-Catcher were:

- Unanswered research questions, these questions were known from the beginning but there was no time to answer them (yet).
- Questions that arise during the project which were an immediate cause of the results of the current project.

I-Catcher has a wide scope with respect to the research areas. There are numerous research questions that have to be answered and sometimes there is not enough time to answer them all. This can result in a new project which intends to answer the unanswered questions.

During the I-Catcher project there arose some new questions which are quite interesting. This has led to the birth of the I-Catcher+ project. The – main – difference between these two projects is that I-Catcher focus mainly on the individual patient and I-Catcher+ focus on subgroup discovery.

Subgroup discovery is important to distinguish between patient populations. When different subgroups are found, more specific models can be created which are dedicated to a subgroup. This can result in a better prognostic value and therefore better support the patient care and the health care professional with the decision making process.

I-Catcher+ use also temporal data and use it also in a multivariate way, which has not been done yet with the I-Catcher Project.

In a general way new questions can arise is that the outcome of a project can lead to new insights which can be very interesting for future research. When the future research will be done, new research questions arise.

At the other hand also unanswered questions and the interest of the research group can lead to new questions. When the research group would like to research the new questions; a new project may be born.

3.2. NWO

3.2.1. WHAT IS NWO?

The task of NWO[VIII] is mainly the allocation of funds to researchers and universities. The NWO falls under the jurisdiction of the ministry of OCW[IX] and the financial means of the NWO are mainly coming from the budget of the ministry of OCW – see **Figure I**.

Because of the jurisdiction of the ministry of OCW the minister of this department has several rights, these rights lay outside the scope of this article and the interested reader is directed to this website **[10]**.

There are eight different science-areas which are funded by the NWO. A science-area has its own budget and board of directors. The eight areas are:

- Earth and Life Sciences
- Chemical Sciences
- Exact Sciences
- Humanity Sciences
- Social and Behavioral Sciences
- Medical Sciences (in this area the I-Catcher project does fit)
- Physics
- Technical Sciences

[VII] **AMR** = AMC Medical Research

[VIII] **NWO** = Dutch organization for Scientific Research

[IX] **OCW** = Education Culture and Science

ZonMw [X] **[11]** is responsible for the Medical Sciences area. ZonMw falls under the jurisdiction of NWO and the ministry of VWS[XI].

The I-Catcher project team is funded by the NWO via Token2000 program – see **Figure I** for more details about the policy structure. They have applied for the funding by NWO and therefore they have to fit in the missions and ambitions the NWO has.

For research projects the guidance can be found in the NOAG-ICT documents and the Token2000 program. These documents and program makes the mission and ambition of the NWO more clear and touchable. In sections 3.2.3., 3.2.4. and 3.2.5. the fitting of the I-Catcher project will be discussed.

3.2.2. WHAT IS THEIR MISSION AND AMBITION?

The NWO has a mission that has been secured by the law of the Dutch Government. Their mission goals are as follows **[9]**:

- Its task is to promote and encourage scientific research and the same time initialize and stimulate new development in the area of scientific research.
- Accomplish its task – especially – by assigning resources.
- To fulfill the needs of the society, the NWO stimulates the transfer of knowledge of the results of the research that has been done which have been initiated or stimulated by the NWO.
- The NWO aims mainly at the research that is conducted at the universities to reach their goal, namely accomplish their main task.

The ambition of the NWO is that the Dutch science remains at the top of global science and even tries to strengthen this position by coordination and encouragement.

Even so the results of the scientific research have to be used more in the context of society. This will accomplish that scientific research will contribute more to the prosperity and welfare.

3.2.3. TOKEN2000

Token2000 is a NWO inter-disciplinary research program. Its aim is to cope with fundamental problems which are present in the current interaction between the human user and the knowledge system.

There are five areas defined by Token2000, these areas are:

- Navigation, adaption and learning
- Language technology
- Knowledge discovery
- Delivery and presentation
- Control

The NWO program Token2000 is concerned with the accessibility and extraction of knowledge in Medical systems centered on the EPR. It has the explicit aim of the *development of methods and techniques for advanced information systems in other to make them correspond with the perception of their users* **[20]**.

The statement is coming from the I-Catcher research proposal. It is clearly a refinement of the intention of the Token2000 program. According to my research I-Catcher fits the third area. As stated on the Token2000 website **[12]** knowledge discovery is all about the possibilities to let the computer discover – hidden – connections in fragments of information. I-Catcher tries the same; it tries to find information in the ICU data to support – eventually – the prognosis.

3.2.4. NOAG-ICT 2001 – 2005

Besides the Token2000 program the NWO defines every five years a policy document, which is called NOAG-ICT[XII]. It is formulated by IPN[XIII] and the ACI[XIV] the latter is a part of the NWO.

[X] **ZonMw** = Healthcare Research in the Netherlands Medical Sciences

[XI] **VWS** = Public Health Welfare and Sports

[XII] **NOAG-ICT** = Domestic Research Program – Information and Communication Technology

The NOAG-ICT 2001-2005 **[21]** defines five types of research, these types are:

- Curiosity driven
- Society driven
- Problem driven
- Problem solving
- Implementation

As explained in the 'Birth & motivation of I-Catcher' section the reason why I-Catcher was proposed was the curiosity of the project leader. I-Catcher fits the curiosity driven research.

The document also defines seven themes of interest, these themes are:

- Parallel and distributed computing
- Embedded systems
- Software engineering
- Multimedia
- Modeling, simulation and visualization
- Intelligent systems
- Algorithms and formal methods

The I-Catcher project fits the last theme. As mentioned earlier I-Catcher uses a heuristic algorithm to find patterns in the ICU data. Therefore I-Catcher fits the last theme, and it fits the last theme because of the use of computational models and machine learning techniques. The algorithm of I-Catcher has been trained with a training set and tested with a test set.

The next section will explain whether I-Catcher fits the NOAG-ICT 2005 – 2010 program. In section 4 it will be discussed whether the I-Catcher is interesting enough for future research.

3.2.5. NOAG-ICT 2005 – 2010

The reason why NOAG-ICT 2005-2010 **[22]** is included in this section of this document is to give an explanation whether I-Catcher fits the future mission goals and ambition of the NWO. In the conclusion I will elaborate on the results presented here.

The NOAG-ICT document speaks of nine interesting research areas for – at least – the period of 2005 until 2010. In this section will be explained which categories apply for I-Catcher and why these categories apply for I-Catcher.

First of all I-Catcher is a part of the informatics in the healthcare. The project is a part of the Token2000 program which is financed by the OCW through the NWO, which can be seen in **Figure I**. The other two categories – besides health – are out of the scope of this paper, the interested reader is directed to the website **[9,12]**.

Research Themes

Figure II shows the nine research themes. The themes that are marked yellow are the themes where I-Catcher does fit. There are two themes in which I-Catcher does fit, namely the theme of *data explosion* and *intelligent systems*.

The theme of *data explosion* is confined to – at one side – general techniques and aids, at the other side to information processing of data in digitalized form.

In case of I-Catcher the information processing of data is mainly directed at pattern recognition, creating models and compares those models with the expert opinion. These phases of information processes are in concordance with the NOAG-ICT document.

In this theme there are some ICT disciplines of interest, these are:

- Algorithms and Computation Theory
- Computer-Human Interaction
- Computer Graphics
- Hypermedia, Hypertext and Web
- Information Retrieval
- Knowledge Discovery in Data
- Management of Data
- Simulation and Modeling

I-Catcher suits in the sixth discipline, namely the knowledge discovery in data. The I-Catcher project tries – with temporal data – to discern patterns in patient populations. This has been explained in section 3.1. about I-Catcher.

[XIII] **IPN** = Dutch Informatics Research Platform
[XIV] **ACI** = Advice Committee Informatics

The last discipline is somehow related to I-Catcher too, because with I-Catcher there are predictions made and models are created. Needless to say is that these are the reasons why I-Catcher fits the theme of *data explosion*.

The second theme is *intelligent systems*. The I-Catcher system is interesting in this context, because the system itself is not by definition an intelligent system.

The reason why I-Catcher fits in this theme is because of its algorithm for pattern recognition. For pattern recognition heuristic search methods are required to find common patterns in the data of the elderly patients of the NICE [xv] **[13]** registration.

In the theme of *intelligent systems* there are some ICT disciplines, which are:

- Algorithms and Computation Theory
- Artificial Intelligence
- Information Theory
- Knowledge Discovery in Data
- Programming Languages
- Robotics and Automation
- Security, Audit and Control

As mentioned earlier I-Catcher suits the fourth discipline and as explained a few paragraphs ago the first discipline applies for I-Catcher.

Cooperation with other scientific areas

Figure III shows the cooperation areas. For the I-Catcher project the area of interest is one of the areas where the cooperation still has to be developed; the area of *healthcare and ICT*.

The area of *healthcare and ICT* consist of three challenges according to the NWO, these are:

- Knowledge and information for the professional
- Diagnostics with images and image driven treatment
- Healthcare logistics

I-Catcher suits the first challenge, the challenge of I-Catcher is to find common episodes and create models to estimate the mortality of patients. This results into new *knowledge and information for the professional*.

This knowledge and information would help the professional to plan the treatment of a patient on the ICU and even may decide to stop the treatment because I-Catcher showed that a substantial part of the patients with the same score – and episode pattern – died.

[xv] **NICE** = National Intensive Care Evaluation

4. Discussion

The discussion will be divided in three parts; at first I will reflect on the internship and reflect on the objectives, secondly the literature and results are assessed and last the relevance for the patient care and knowledge on this area are discussed.

Reflection

The two objectives were (1) to contrast the original research proposal with the actual research activities and results and (2) to investigate how new research questions arose from this research.

The original research proposal the research questions are a little bit different than the research questions later shown in the summary of I-Catcher on the I-Catcher website. The original research proposal had questions that were more detailed. This is just a minor difference.

The original research proposal showed the – envisioned – architecture of I-Catcher is not fully constructed; therefore I cannot say whether the actual architecture is fully compliant to the original architecture that has been proposed.

I have the impression that it is difficult to stick with the original plan, partially because of the dynamic environment and working with human beings can cause changes. Teams can change over time – in the I-Catcher project that has happened – thereby changing the overall expertise of the team. A new team member has to be found and be fitted in the project. These changes can cause differences between the original proposal and the actual research activities.

New research questions can arise in numerous ways, which have been discussed in this paper. It looks like a visual circle; research has been done and on the way there are questions that cannot be answered due to time or funds constrictions. Later on a new research proposal is made, with the unanswered questions and – again – research has been done, that research project raised new questions and the whole cycle starts over again.

There was enough time to fulfill the objectives and it may be a good idea to shorten the period of the first internship and create a longer period for the second internship in which a research has to be conducted.

Critical Assessment of literature and results

Many of the results rely on the information provided on the website, this was the case for the NWO. It might be the case that this information is outdated and not perfectly correct anymore. Secondly the NOAG-ICT document was used for this paper and I may be the case that policy change within a few years and that some of the remarks made in this paper are no longer valid by then. The I-Catcher website provided a lot of information, but some parts were missing and I doubt whether the website has been updated periodically.

For my results on I-Catcher I rely – to a large extent – on the expertise of the project supervisor and the website. May be when Tudor Toma was available some results could be different.

Another way that the results can be different is because of the possibility that the models based on the SOFA score is not that better than the models based on the static data. May be I-Catcher will perform worse on other training sets, the data that has been used to train the data may also be favoring the good results which have been reached so far.

The literature supported me to understand the problem and the reason why I-Catcher is needed. It gave me a good insight in the problems that are present on the ICU and which methods and scores could be used to say something useful about the patients on the ICU.

The articles **[1,3]** were about the use of temporal – measured – data which can be used to discover patterns in the dataset **[1]** and use these patterns to create predictive – prognostic – models and compare them with the static data models to test whether the models based on temporal data are better than the static ones. However the articles made it clear that additional research is required. As the authors mentioned themselves, the prognostic models that are created could give worse results with other training data. Prognostic models are introduced in another article where the possibilities of these models are described **[4]**. The results mentioned in these papers were used in I-Catcher. I-Catcher uses also the individual organ failure scores which are mentioned in **[3]**.

The enhanced value of I-Catcher is that it uses a data intensive method, which means that scores like SOFA are used extensively; like the authors **[1,3]**, I-Catcher does not take the mean of the score, but just the score itself.

There are other methods to distinguish between patients or entire populations. These methods have not been used in the I-Catcher project, but they are nevertheless relevant for the patient care. Thus an important thing to do on the ICU is discovering subgroups in the very elderly patients admitted to the ICU. There are different methods to create subgroups; one of the articles is using the PRIM this method tries to make a distinction between possible groups **[5]**.

The PRIM [XVI] method has some promises for identifying subgroups; but PRIM is not exhaustive in it search and more important mortality was used for subgroup discovery, however in the data there was no record whether dead was caused by stopping the treatment or due to severe illness. This could influence the subgroup discovery very much. Nevertheless PRIM shows better results than the 'old-fashioned' SAPS II[XVII] Score. The PRIM method is explained in Appendix A.

PRIM has the advantage of a high quality research result **[18]**. However it requires more computational power which can be a problem in

[XVI] **PRIM** = Patient Rule Induction Method
[XVII] **SAPS II** = Simplified Acute Physiology Score II

high n-dimensional spaces. Its discretization has its limitations; by choosing a wrong *alpha* the results could be completely different and useless.

Classification trees are easy to understand and they give a clear view of the subgroups which have been created. In the article it was a highly specified classification tree – very elderly patients only in the Netherlands – therefore results can differ among other populations; domestic and abroad. Another item of critique expressed by the authors is the use of prognostic models for triage decisions; I agree that such developments have to be prevented. However the classification tree showed promise and identified subgroups with a mortality rate over the 75 percent. In comparison with the SAPS II and APACHE [xviii] score, the classification trees performed better **[2]**.

In another article the classification tree is used to create subgroups and use these subgroups to create local prognostic models. Their method is based on machine learning and statistical ideas and they want to exploit the information that underlies the scoring variable **[6]**. The hybrid model performed better than the SAPS and the traditional logistic regression model; the creation of subgroups can provide more information. The authors also recommend researching the temporal data – the SOFA score – that can be used. That is exactly what has been done in the I-Catcher project.

A problem that still remains with classification trees can be *overfitting* or *underfitting* the results found in these articles could be sub-optimal. Because classification trees are not used in I-Catcher, the project does not suffer from the disadvantages of the classification tree method.

Risk factors are important to discover, because they can influence the short-term and/or long-term mortality in a bad way. The authors have found some independent risk factors **[7]**. However in the paper describing the discovery of the risk factors, the authors created models which used many variables; this can lead to *overfitting*. This has been mentioned by the authors themselves.

[xviii] **APACHE** = Acute Physiology and Chronic Health Evaluation

The article about Bayesian networks gave a good description what the possibilities are for this kind of networks when they are used in biomedicine and health care. The Bayesian networks can reason with uncertainty which is all time present in the health care. Bayesian networks are not only suitable for diagnosis, but also for prognosis and they are easily interpreted. However most datasets are too small to create a – valid – Bayesian network and in respect to prognosis there is not much proof that Bayesian networks could contribute much **[8]**.

What is the medical relevance for patient care? Or better, what is the relevance for knowledge on this area?

The relevance for knowledge on this area is that I-Catcher uses a data intensive method. The temporal scores that have been used have not been altered. This can provide more insight in the ICU population and their data. It is easier to detect patterns because of using the original scores and not the altered ones like the weighted SOFA or the mean SOFA. I-Catcher is one of the first projects which showed the benefits of, and even use a data intensive method.

When certain patterns are discovered in a patient, could be possible to compare the pattern with the patterns in the ICU database and see what the outcome of the patients were with the pattern that has also presented itself in the new patient. The health care professional can use that information to his/hers advantage to come to a more informed decision. Eventually the quality of care could be improved by these new developments. That is – namely – the relevance for the patient care.

5. CONCLUSIONS

I-Catcher is a program that can discover knowledge in the ICU data and the discovered data can be used for models which are used for mortality predictions. The project showed some promising results. It seems that the temporal data has a better predictive value than the static data alone. Furthermore I-Catcher is one of the first projects

that use a data intensive method. The advantage of a data intensive method is that data does not have to be altered and no information is lost.

Some other studies used a derivative of the temporal data score, like weighted SOFA. The information you lose is the information about how SOFA has changed over time. Therefore a data intensive method is preferable.

The motivation for I-Catcher was mostly the result of the interest of Ameen Abu Hanna in using the new temporal data to create prognostic models to – eventually – help the health care to make better diagnoses and prognoses.

The funding has been received from the NWO, because I-Catcher does fit in the mission and ambition of the NWO. The I-Catcher project is in concordance with the Token2000 program and the NOAG-ICT 2001-2005 document. Even the future looks bright for the I-Catcher project; there are several areas where I-Catcher does fit according to the NOAG-ICT 2005-2010 document. After going into the I-Catcher project; there is no reason to change the areas where I-Catcher does fit in.

The team may not fully comply with the original research proposal, but still I-Catcher embraces knowledge discovery in the data; it tries to discover patterns in the patient data and use these patterns to create models. Knowledge discovery is a part of the data explosion area of the NWO. Even so I-Catcher is a part of the intelligent systems area, because it uses a heuristic algorithm to find the patterns. When I-Catcher is fully operational it holds knowledge and information for the health care professional.

The project is finished in October 2007, however not all research questions have been answered and not all the components of the I-Catcher are implemented yet. The Free University of Amsterdam is still working on the ontology part and momentarily there is no – good working – bridge between the work of the Free University of Amsterdam and the work of the Academic Medical Center of Amsterdam.

When the bridge is ready it can be tested or researched whether the whole I-Catcher project can support the health care professional when it has been fully integrated in the EPR.

I-Catcher is aimed at the individual patient, future research should be – and will be – the discovery of subgroups in the ICU data. When these subgroups are discovered, they can be used to create prognostic models dedicated to a specific subgroup, which can lead to better predictions and better evaluation of the – quality of – care. Then new – future – research is required to test whether these prognostic models based on subgroups are better than prognostic models for the entire population.

The ICU is a very dynamic and rapidly changing environment, therefore there is always a need for new insights and new prognostic models to support the health care and even better the health care. Projects like I-Catcher will always raise new – research – questions; for now the most important future research is that I-Catcher will be thoroughly tested and that I-Catcher+ should be used to discover subgroups, which may improve the prognostic models. Some participants of I-Catcher will continue their participation in the I-Catcher+ project.

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APPENDIX A - TERMS

DES – Discovery and Extraction Server

The Discovery and Extraction Server consists of three parts. These parts are:

- Diagnostic clustering (individual)
- Prognostic clustering (population)
- Care evaluation (population)

The first part is at the individual level and the latter two are at the population level. DES is responsible for the knowledge extraction. A health care professional could access the EPR and thereby the DES.

Diagnostic clustering is about the clustering of disease terms in the EPR according to the knowledge in the terminology server.

DES will read the specific patient information from the EPR which has been accessed by the health care professional. The information will be characterized in a pattern, like the SOFA scores of several days.

DES will provide some predictions over time about the patient and produces alarms when necessary. It can even provide some advice for treatment.

At the population level the DES can be used to create prognostic models. These prognostic models can be used for patient clustering and health care evaluation. All these actions can provide better predictions for a specific patient or even populations.

Temporal data

Static and temporal data differ from each other. Static data in this context – like SAPS II and APACHE – means that it is only recorded at the admission to the ICU. The SAPS II and APACHE score do not change over the patients stay at the ICU.

However temporal data – like the SOFA score – is recorded every day resulting in an integer ranging from 0 (which is the best score) to 24 (the most worse score).

The SOFA score is constructed of six individual organ systems. Each of these systems can have a value of 0 (which is the best score) to a score of 4 (which is the worse score). Adding the scores of the six individual organ systems will result in the overall SOFA score.

The SOFA scores of more days – of the same patient – can form a pattern. The pattern of 9-12-13-15-17 shows a certain decay of the organ systems. The algorithm of I-Catcher categorizes the numbers in Low, Medium and High. Low is a score of 0 up to and including 6, Medium is a score of 7 or 8 and High is a score of 9 up to and including 24. The pattern that has been described earlier in this paragraph will be: H-H-H-H-H **[1]**.

These patterns can be used to create models. A model that has been created by the authors of this article **[1]** for day 5 looks like this:

$$\frac{e^{-2,7+0,02*SAPS+1,1*M+1,3*H}}{1-e^{-2,7+0,02*SAPS+1,1*M+1,3*H}}$$

After filling in the values, the probability of dying for this patient is known. The models change over time and are not the same for another day. As can been seen in this model, the static data is also used. The static data is represented by the SAPS II score.

More information can be derived when the IOF[XIX] scores are included **[3]**. As the SOFA score can either positively or negatively influence the mortality even so the IOF scores can. The IOF shows which organ systems fail and may cause the dead of a patient. This cannot be seen when only the overall SOFA score is used.

PRIM

PRIM – Patient Rule Induction Method – is a way to discover subgroups in a population. It does not matter what kind of population that may be. Imagine a box – that represents the population – and two variables, variable 1 and 2. These variables can be continuous or categorical. See **Figure IV** for visualization.

[XIX] **IOF** = individual organ failure

What PRIM does is removing observations. In a two dimensional space there are four ways to remove observations; up, right, bottom and left. PRIM uses a heuristic algorithm to check which removal will be the best.

Figure IV shows that in the first few steps it does not matter which removal operation is performed. Later on the algorithm has to choose which operation cost the least red dots. When the algorithm has calculated which operation meets the requirement, that operation is executed.

The influence of the operations differ, the impact of an operation is defined as *alpha*. *Alpha* is a percentage of the whole box. Most common is five percent. When *alpha* is too big – for example 40 percent – there is a risk that a significant box is missed. When *alpha* is small the PRIM algorithm is more patient and will eventually arrive at an answer **[5]**.

When a subgroup – a small box – is found the PRIM algorithm can expand this box as long the overall characteristics of the subgroup do not significantly change. In case of the completion of a subgroup discovery the result is and its associated box and observations are removed.

When the first box and its associated observations are removed, the algorithm can start all over again. This way the second subgroup can be discovered as showed in **Figure V**. These results are also removed and ultimately there are no additional subgroups discovered **[5,17,18]**.

APPENDIX B - FIGURES

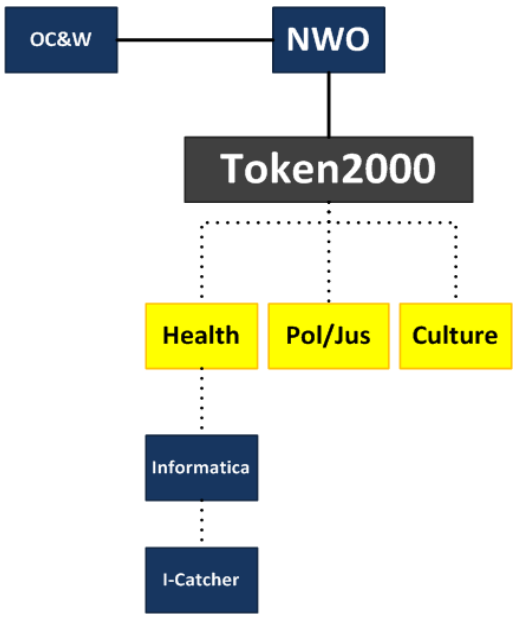
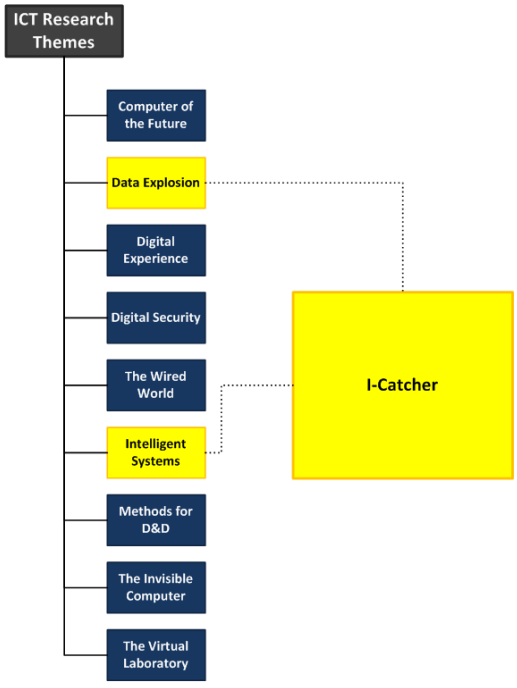


Figure I – The main view of how all the organizations, areas and projects are interleaved with each other



D&D = Design & Development

Figure II – The nine ICT research themes as defined by NOAG-ICT 2005 – 2010

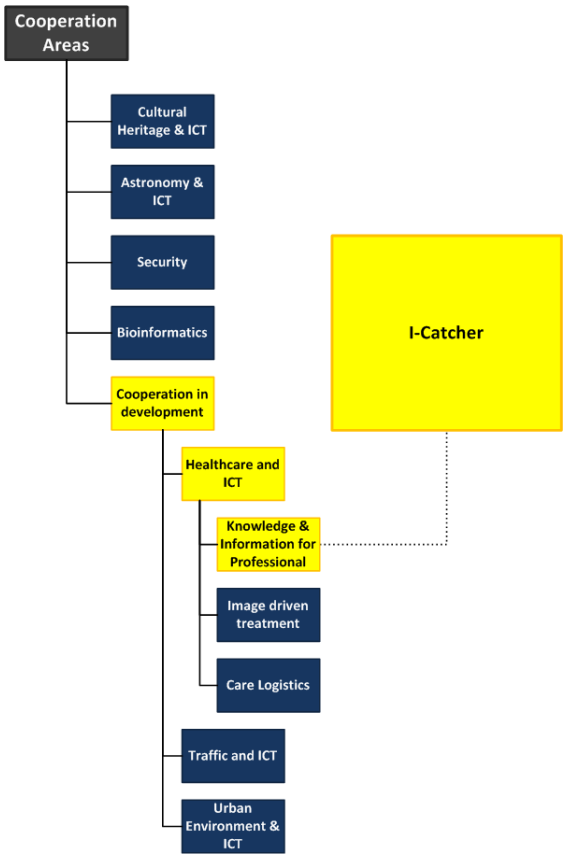


Figure III – The cooperation areas as defined by the NOAG-ICT 2005 – 2010

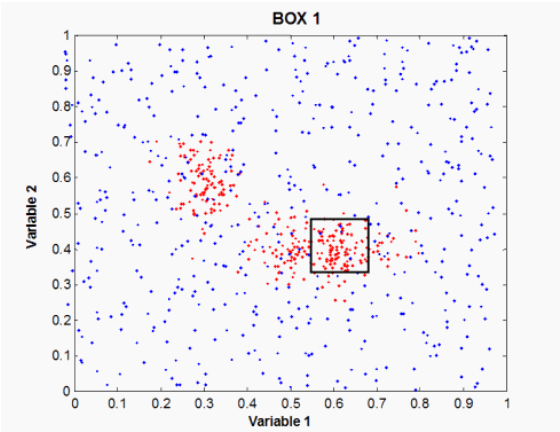


Figure IV – The PRIM Method explained, the first box is found **[17]**.

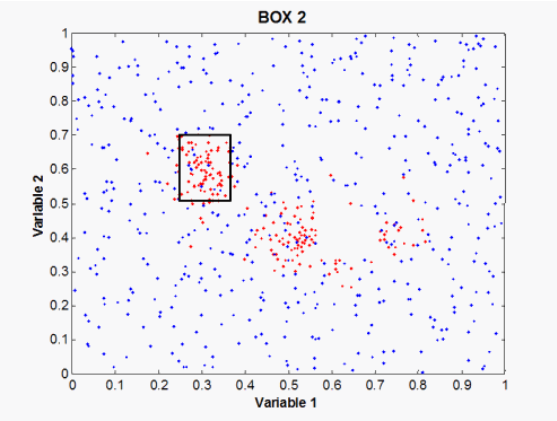


Figure V – The PRIM Method explained, the second box is found **[17]**.

APPENDIX C - SCHEMA OF I-CATCHER

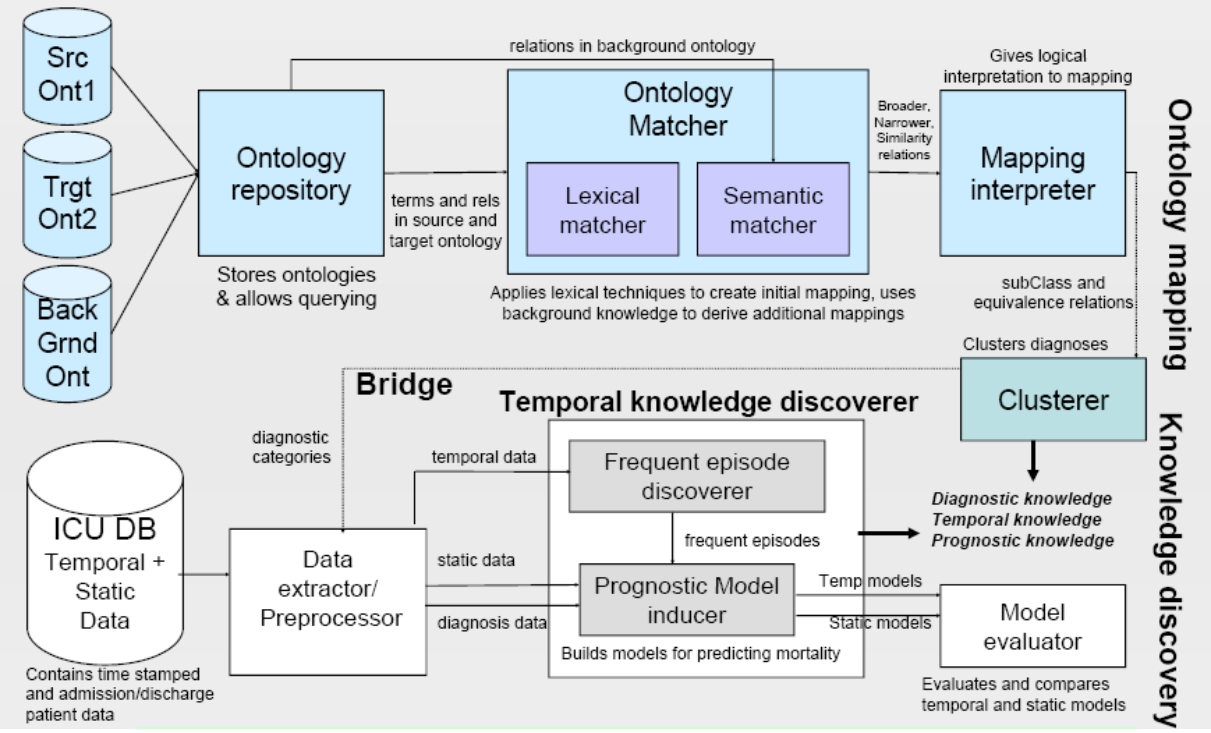


Figure VI – The schema of I-Catcher. The ontology mapping is done at the Free University of Amsterdam and the knowledge discovery part is done at the University of Amsterdam. Schema extracted from the I-Catcher website **[14]**