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# Inhaltsverzeichnis

# Abbildungsverzeichnis

# Tabellenverzeichnis

# Abstract

# Überblick

# Acknowledgements

Thank you!

# Conventions

Throughout this thesis we use the following conventions.

*Text conventions*

Definitions of technical terms or short excursus are set off in coloured boxes.

**EXCURSUS:**
Excursus are detailed discussions of a particular point in a book, usually in an appendix, or digressions in a written text.

Definition: *Excursus*

Source code and implementation symbols are written in typewriter-style text.

`myClass`

The whole thesis is written in Canadian English.

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# Kapitel 1

# Introduction

> Michael öffnet nach einem längeren Arbeitstag zuhause seine Wohnungstüre. Er hat keinen Schlüssel. Kameras an verschiedenen Positionen im Flur haben seinen Bewegungsablauf und seine Haltung registiert. Nach der Eingabe seiner Pin auf einer Konsole wurde die DNA sowie die Retina über eine weitere Kamera gescannt. Ein intelligentes System hat Michael bereits erkannt. Als er die Küche betritt erkennt sein intelligentes Apartment, dass Michael heute müde ist. Das Licht wird verdunkelt, die Jalousien werden heruntergefahren. Michaels Verhalten signalisiert dem System, dass er in der nächsten Stunde nicht gestört werden möchte. Die Telefone und Haustürklingel werden auf stumm geschalten.
>
> Als Michael nach einer Stunde wieder aufwacht, ist er erholt. Die Jalousien öffnen sich wieder etwas. Michael muss jetzt noch etwas für die Arbeit tun, da er oftmals besser von zuhause arbeiten kann. Er geht an seinen Rechner und öffnet die ersten Arbeitsdokumente. Das System ist gekoppelt mit dem Arbeitssystem seiner Arbeitsstelle. Es erkennt Michaels aktuellen und sich schnell ändernden Arbeitsprozess. Alle relevanten weiteren benötigten Informationen werden Michael unauffällig zur Vergügung gestellt. Michael beginnt sich seiner Arbeit zu widmen.

Das obige Zukunftsszenario skizziert eine Arbeitsumgebung und Privatumgebung, die auf einem vernetzten intelligenten System basiert. Assistenz- und ortssensitive Informationssysteme halten zunehmend Einzug in den Alltag. Diese Entwicklung kann vom persönlichen Standpunkt aus gut oder schlecht geheißen werden. Tatsache ist, dass die Entwicklung intelligenter Systeme zu einem sprunghaften Fortschritt ansetzt. Bekannte Wissenschaftler im Bereich der Artificial Intelligence wie Ray Kurzweil, Rodney Brooks und Jeff Hawkins sind der Meinung, dass die Zukunft dieser Entwicklung im Bereich der sog. „biologischen intelligenten Systeme“ angesiedelt sein wird. Diese ergänzen die auf der Inferenzstatistik beruhenden bisherigen Lernmodelle maschineller Intelligenz um zusammen neuartige intelligente System zu bilden. The Intelligent systems that are mentioned in the example above rely on certain architecture: lots of data (so-called "Big Data") is collected via a sensoric layer. For example sensors collecting information about engergy consumption within a building or sensors that recognizes the surroundings of a building in order to detect moving persons. The accumlated raw data then has to be transferred to information and fed into a machine learning algorithm that condenses the information and is able to predict future events and deduce patterns in the flow of information. In the above example this means that that the actual energy usage is send to the computing layer. In the according model future energy values are predicted. The final part of the architecture is the feedback of the analyzed data to an output system: as in the energy example, energy peaks could be predicted and as such it is ensured that energy commming from solar heaters is supplemented by traditional energy resources. This is a typical input-computation-output approach. As machines do not depend on ears, eyes and smells, sensors can be applied to other areas as well.

A disputed field of research is the "movement“ of persons in the digital world. The paradigm of the *knowledge worker* that has become true for most of the western society proclaims a new working model: The knowledge worker achieves his tasks by non-routine problem-solving approaches encompassing a usually non-linear sequence of steps like problem definition, information seeking, planning of solutions approach with the help of a Personcal Computer and the internet. As his work is fairly non-linear, workflows are of interest for companies to keep the knowledge as an essential good. Extracting workflows from elementary actions, i.e. operations on programs and documents, is difficult. The same documents and programs can be used in different contexts, users act in automated ways to achieve their goals, but orders of higher level activities (searching for information, elaborating presentations . . . ) are permutated. This work tries to answer the question, if it is possible to extract meaningful workflows ("Process Mining") from sensoric data ("Protocol Data") by applying a new form of Biological Intelligence, called Hierarchical Temporal Memory (HTM). In analogy to the former example, the sensoric data is transmitted to the HTM algorithm, that is able not only to model behaviour but also predict next steps. The results are abstracted to information in terms of knowledge work in order to get a workflow model. The results are fed back to the user and serve as basic for a knowledge management system.

The thesis is has strong psychological implications, that will become clear in the following chapters: For one, the HTM-CLA (Cortical Learning Algorithm) was designed in analogy to the working principles of the human brain. This will the touch the areas of intention research in psychology as knowledge and knowledge acquistion are tied to intention. Second, data acquisition and analysis gained from user interaction with digital devices will become more important in the future. This work gives a hint at how this could work.

The work is structured as follows: In the Related Work 2 the existing approaches for knowledge mining are introduced and the problems are defined. The the HTM is elaborated and distinguished from known classical AI approaches. Its psychological relevance is emphasized and compared to the psychological research of intention. In the the chapter Own Work 3 the implementation of the HTM is elaborated. Experiments and results are shown. The work concludes with an outlook.

# Kapitel 2

# Related work

## 2.1 Knowledge and Task Mining

Context-Aware Systems

In the computer scientific field of knowledge and task mining is no new subject. With the rise of mobile computing devices the term Context-Aware Systems (CAS) was created. The meaning and definition are disputed. First publications referred to a user's location: in different places usually different contextual parameters are relevant. For example a diver that is ascending from deep water has to be made aware of resting times before emerging to the surface.Another example was the *Active Badge Location System* in 1992 that detected the whereabouts of a person and in order to forward relevant phone calls to telephones close targeted person (Want et al. [1992]). Such systems adapt not only to the location but also to other relevant and changing parameters in the surroundings (Schilit et al. [1994]). This definition was widened in 1998 where context was referred to not only the computer accessible parameters of the surroundings but also the emotional state, focus of attention, date and time as well as people in the environment (Dey [1998]). The new aspect of internal parameters like focus of attention was then referred to a further elaboration of the definition: the internal (logical) and external context: Internal context parameters are specified by the user in interaction with the computer like goals, tasks, work context, business processes and emotional state. External parameters are usually measured by hardware sensors, i.e. location, light, sound, movement, temperature, pressure etc. (Hofer et al. [2003]). The contextual parameters can be grouped into four categories: identity (marked by a unique identifier), the location (an entity's position), activity (status, meaning the intrinsic properties of an entity, e.g., temperature and lightning for a room, processes running currently on a device etc.) and time (timestamps, Dey et al. [2001]). An example of the use of internal data for extracting context is the *Watson Project* Budzik and Hammond [2000]. Here the focus is shifted for collecting contextual information from user interaction with the computer in order to proactively support the user. Proactivity is a term that originates in organizational psychology and describes the ability of workers to not react to situations, but sense upcoming situational changes in advance and take control (Grant and Ashford [2008]). As work gets more dependent of the retrieval and analysis of information, a proactive support system shall help the user in his various tasks by providing him with relevant information. This approach had further implications as gathering information from the user interaction with his computer requires techniques from information retrieval and computer linguistics. In this case the documents a user works with are analyzed and keywords are stored as vectors or a bag of words. The relevant keywords shall help to narrow the topical context a user is working on. Keywords than help to start searches with relevant search terms and provide the user with the information he needs (Budzik and Hammond [2000]). As a single user is often not able to find the needed information, his typical search patterns are compared with those of other users. In these cases as *user model* is created, and his search terms are compared to those of other users' and the documents they found. If keywords are matching, documents of those others users are recommended (Anand and Mobasher [2007]). This approach is called Context-Based Recommender Systems (CBRS) recommendation and their related techniques like user-collaborative filtering are applied in search engines like Amazon [1].Attention-Aware Systems (AAS) at last have different focus: The guiding principle of AAS is that users have limited cognitive resources and are distracted easily . They suffer from an *information overload* as they jump quickly from one resource to the next in the same and different workings tasks. Whilst it is beneficial to be able to change foci in certain situations, in others it is exhausting. Therefore systems capable of supporting and guiding user attention have to assess the current user focus, and calculate the cost/benefits of attention shifts (interruptions). As this explanation shows, AAS have a foundation in cognitive psychology, i.e. how attention is elicited, distracted and shifting over time. Experimental setups include multiple sensor arrays like gaze-tracking-, gesture-tracking, speech-detection and systems that measure the physiological cues (Roda and Thomas [2006]). But there are also non-sensory based approaches that record users' interaction with software (Horvitz et al. [2003], Schmitz et al. [2011]). Attention management architectures expand the agenda of context-based systems, as they want not only to detect the current state of the attention of users, but also want provide support. Therefore not only the attentional state has to be tracked but the system needs to establish the users' goals and current tasks and also the happenings in the environment (Roda and Thomas [2006]). Consequently

Context-based Recommender Systems

Attention-aware systems

[1] www.amazon.com

this lead to the proclamation Intention-Aware Systems (IAS). This approach combines CAS and AAS by explicating individual and implicit intentions and plans of users' to reason about attention and context information. Dealing with context and attention means dealing with uncertainty. Explicated task models, so the idea, could help to increase the chances in proactive support. The term "intention" is approached in the following way(Cohen and Levesque [1990]):

> Intention has often been analyzed differently from other mental states such as belief and knowledge. First, whereas the content of beliefs and knowledge is usually considered to be in the form of propositions, the content of an intention is typically regarded as an action. For example, Castefiada treats the content of an intention as a „practition" similar to an action description .... It is claimed that by doing so, and by strictly separating the logic of propositions from the logic of practitions, one avoids undesirable properties in the logic of intention, such as the fact that if one intends to do an action a one must also intend to do a or b. However, it has also been argued that needed connections between propositions and practitions may not be derivable.

The authors further argue that intention is directed towards the future actions and according plans. Intention thus shall be modeled as "a composite concept of what an agent has chosen and how the agent is committed to that choice". The choice can be a desire or goal. Intention therefore can be described as a persisting goal. If intention is defined in a formal theory, then beliefs, goals and desires must be expressed in the same way. As the theory may be correct, the deductions fall short for real world problems. On the other hand, if those terms are used in a very abstract way, they can not be used for a touring machine.

# Kapitel 3

# Own work

# Kapitel 4

# Evaluation

# Kapitel 5

# Summary and future work

## 5.1 Summary and contributions

## 5.2 Future work

# Anhang A

# TITLE OF THE FIRST APPENDIX

# Anhang B

# TITLE OF THE SECOND APPENDIX

**CAS** Context-Aware Systems

**AAS** Attention-Aware Systems

**IAS** Intention-Aware Systems

**CBRS** Context-Based Recommender Systems

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# Index

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