An Ontology for User Profile Modelling in the Field of Ambient Assisted Living

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***Abstract*—The lack of social integration of elderly people, especially with impairments like restricted mobility, is a huge problem. Often, these people become isolated and social contacts become impoverished. Ambient Assisted Living (AAL) IT systems should support elderly people to stay in contact with their social environment and should be adaptable exactly to their personal needs. In this paper, we present a platform offering assistance in communication, information acquisition and learning for elderly people to allow them to stay longer at their own familiar homes. The services of this platform are context aware and personalizable. Many AAL systems are context aware, but often focus on the environmental context and not on the users themselves and their personal characteristics, like health condition, interests, needs, etc. In this work, the context is modelled as an ontology, where the user is the central concept of the platform, in order to realize personalization of services and a better assistance by the system. The ontology developed by the project Person Centered Environment for Information, Communication and Learning (PCEICL) offers a historical view of the user's changing characteristics and environment, is simply expandable and is used within the platform by software agents to communicate between single services to adapt to the users needs.**

Keywords–Ontology, Context, User Centric Ontology, AAL, PaaS, OSGi, JADE, software agents

I. INTRODUCTION

Many solutions in the field of Ambient Assisted Living (AAL) solve problems of home automation, freedom of barriers and emergency diagnosis, as stated in [1], [2] or [3], to allow elderly people to stay longer at home. But when they need, for example, every day assistance, when they are suddenly mobility-disabled, there is the problem of social contact depletion. Especially in rural regions, it is not that simple for older people to keep up their social contacts if they are physically limited. Ordinary things like meetings with friends, family members, or club members or going shopping aren't possible any more. This leads to loneliness, isolation and often mental health problems. To counteract this, personalizable systems, which help them stay informed or assist them in their communication, are needed, especially if they are adaptable to the needs of the elderly people, as discussed by S. Lauriks et. al. [4].

For the personalization of a system and its services, it is necessary to integrate context awareness. The system must have knowledge about the user's interests, preferences, impairments, capabilities, etc. Most of the actual AAL systems consider only the user's environment (e.g., temperature, location, smoke, etc.), but do not see the user as a central element. A step towards this, the person's needs are taken into account and bear in mind the environmental information of the user to get a personalizable AAL platform.

The research project ***P**erson **C**entered **E**nvironment for **I**nformation, **C**ommunication and **L**earning (PCEICL)* targets the development of an age-appropriate platform, which assists the users in their daily tasks of information acquisition, communication and learning in order to live at home as long as possible and at the same time stay socially integrated. Because of the impairments emerging in advanced age, it is absolutely necessary to adapt the user interface but also the service functionality to the needs of each single user. The personalization is important because of the different combinations of impairments and capabilities. The PCEICL platform offers personalized services, which use context information about the user and the environment to adapt according to the needs of the user.

In this paper, context is used as defined in A. Dey and G. Abowd in [5]:

> Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.

There are other definitions only considering the environment of the user, e.g., the location, other people and resources nearby like Schilit et al. in [6]. But for reaching personalized assistance, it is essential to centralize the user's needs and include the actual user's environment. Because A. Dey and G. Abowd determine context as both, i.e., the user and his environment, the definition above is chosen as a basis for this paper.

Section II presents related work showing the different notions of context and context awareness. The use cases of the AAL platform described in Section IV, are shown in Section III. The platform for personalized services uses an ontology for context modelling (see Section V), which is demonstrated in action in Section VI. In Section VIII, conclusions are drawn and future work is shown.

II. RELATED WORK

Due to the relevance of the AAL topic, there are many projects, which develop assistance systems for elderly people helping them to stay longer at home. Most of them use

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some kind of context information to make their systems more intelligent and adaptable. Often in these projects, context is used to define the environment of the user and not the user himself. This is because the majority of the projects develop home automation systems or emergency detection systems. But only a few aim to offer an assistance in staying socially integrated.

The *SOPRANO (**S**ervice **O**riented **PR**ogrammable sm**A**rt enviro**N**ments for **O**lder Europeans)* project [1], for example, developed an open middleware for AAL solutions. The *SOPRANO Ambient Middleware (SAM)* receives user commands or sensor data, enriches them semantically and determines an adequate system response, which is then performed by the connected actors installed in the living environment. If, for example, SAM receives the information that a window is open, it analyses the remaining context information and can inform the user about the open window, before he is leaving the house. The components communicate over semantic contracts and are based on a common domain ontology. This ontology is designed state-driven, that means that every concept (device, person, location, etc.) of the ontology is represented by its actual state. The PCEICL platform, on the other hand, focuses on the user. The most important is to describe the user, since for information retrieval the user's condition is essential. So it is not useful to apply the SOPRANO ontology, which focuses on the sensors and actors, i.e., the environment of the user.

Another example considering the environment of the user is PersonisAD presented by M. Assad et al. in [7]. Some information about the user like his preferences are also part of the consideration of the PersonisAD framework, but aren't detailed enough to reach a good personalization for older people, like the PCEICL ontology.

The ***UNIVER**sal open platform and reference **S**pecification for **A**mbient **A**ssisted **L**iving) (universAAL)* project [8] aims to join different approaches from lots of projects to a unique AAL solution. One of this included projects is SOPRANO [1]. The goal of universAAL is a platform, that makes it viable to develop AAL services. For this, there will be developer tools, a store for distributing AAL services and a runtime environment. So all of the stakeholders will be supported. The universAAL platform is based on OSGi [9] and ontologies are used as a common language for the components, too. Because of its goal to create a standardized AAL solution, it is possible that the universAAL platform and its ontologies will be building a solid base for future work in the PCEICL project. But, at the moment, the universAAL project is still in progress.

MobileSage aims to develop a smart phone based help-on-demand service [10][11]. It means that the smart phone offers context aware, personalized and location aware services supporting the independence of elderly people. Such services could support the navigation, the handling of devices like ticket vending machines or household appliances or other daily tasks. The personalization and context awareness is realized by an ontology, which considers not only the environment of the user but also the user and his characteristics. It is one of the few ontologies in the field of AAL, which models a user profile and the environment of the user. The central concept of the ontology is the user, who is described by his profile. The user profile therefore is divided in subprofiles like a preference profile, a health profile or an interest profile. But for the help-on-demand services the focus is still on the environment of the user to offer, for example, services depending on the location of the user. The PCEICL project places greater emphasis on the user, who has to stay at home and isn't mobile any more. For this, the user must be described more in detail in his health condition to provide him optimal assistance with the daily tasks. Overall, both ontologies describe a user profile and so there are many similar concepts but PCEICL concentrates on information retrieval, communication and learning.

Another ontology that models a user profile for ambient assisted living services is *AALUMO*, which is presented by P.A. Moreno, M.E. Hernando and E.J. Gómez in [12]. *AALUMO* extends the *General User Model Ontology (GUMO)*, which is an ontology for general use in many domains and scopes. So it is not adapted to the special characteristics of elderly users. GUMO is shown by D. Heckmann et al. in [13] and describes the user in detail from the heart beat or the emotional state to the interests or the personal information. AALUMO added concepts like chronic diseases, which is a composition of GUMO concepts (disease, physical and psychological limitations, medication, etc.) for better adaptation to the properties of the elderly users. In the PCEICL ontology, only the information that is really necessary to customize the services in an optimal way will be saved. Additional information about the user, which is not yet covered by the ontology but will be required in the future, could be added easily.

There is also a user profile ontology presented by M. Sutterer in [14], but it is not adapted to the special needs of elderly people. The personalization of service is situation-dependent and therefore the user needs to indicate special preferences for each situation, which are considered when the situation occurs. It is assumed that this is hard to be realized by elderly people and is therefore not the aim of the PCEICL project.

To summarize, the PCEICL ontology is based on concepts of the ontology of *MobileSage* and there will be future developments based on the results of *universAAL*.

III. USE CASE

In this section, the use cases are described to show the usage of the context aware PCEICL platform and show the usefulness of the PCEICL ontology in the evaluation section (see Section VI). First, a brief description of the user is given showing his current situation.

User description: *Mr. F. is a 73 years old widower, has two children and lives alone on a big farm outside a small rural town. One of his children lives abroad, the other in a city far away, so they rarely can visit their father. Mr. F. is a member of a model railway club in the city about 30 km away. Once a week, he used to attend the club meetings. Recently, he broke his leg after he slipped on an icy surface and therefore has mobility limitations and cannot leave the house very often. His children are worried, because his friends and also his club mates from the model railway club don't have much time to visit Mr. F. personally.*

To support Mr. F. in his daily tasks, the PCEICL platform assists him in communication, information acquisition and learning. With this platform, he is able to stay socially integrated. Especially his children can feel more comfortable, by

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contacting him more easily during this convalescence period. Next, the use cases for each of the three main support areas are described.

A. Use Case (Communication Assistance)

Each contact in Mr. F.'s address list has specified several communication channels, like telephone, email, video chat, SMS, etc. Additionally, each contact has defined information about the availability of the different communication channels based on the contact person's daily habits or appointments. It is assumed that there is always at least one communication channel, where the contact can be reached in an urgent situation. Suppose Mr. F. wants to communicate with one of his children. All he has to do, is to select the name of his children from his address list. After this, the PCEICL platform automatically selects the communication channel based on the aforementioned schedule and preferred communication channel (e.g., SMS because his son is busy).

B. Use Case (Information Acquisition Assistance)

Another application on the platform helps Mr. F. find assistance from other people in the countryside. Although he stopped active farming, there are many things to be done on his farm. He has to feed his hare, do lawn mowing, do shopping, repair things once in a while, clean the house, etc. All this is very difficult or impossible for a mobile restricted person. If he needs help, he should be supported by a PCEICL service. Because the platform knows the user's health condition, it offers an "search-and-offer" service automatically. This could be used to search assistance in the aforementioned daily or weekly tasks, but also for special occasions. For instance, if there is a social meeting with the model railway club, he would like to participate in, the system will automatically help him to get a lift or special transportation. If his health condition gets worse and he cannot attend the meeting, the lift will be canceled by the system. Because the system also knows about the environment, e.g., the weather condition, it can automatically organize help, for example, to clear the snow.

C. Use Case (Learning Assistance)

Every day Mr. F. uses the PCEICL platform's fitness service. The fitness service guides Mr. F. through his everyday exercises like arm circles, arm curls or leg straightening. Because of the new change in health condition the service automatically skips exercises which are not suitable for a broken leg and adds some arm movement exercises to reach the same fitness level. As he recovers slowly from his leg fracture, the system can include specific exercises for his legs to restore his mobility.

The use cases described above are basis for the evaluation section (see Section VI) to show the benefits of the newly developed PCEICL platform and ontology.

IV. The PCEICL Platform

Figure 1 shows the PCEICL platform realized as an OSGi Platform as a Service (OSGi-PaaS) inside a cloud infrastructure to benefit of the PaaS scalability and the simple extensibility through the OSGi bundle mechanism. The scalability

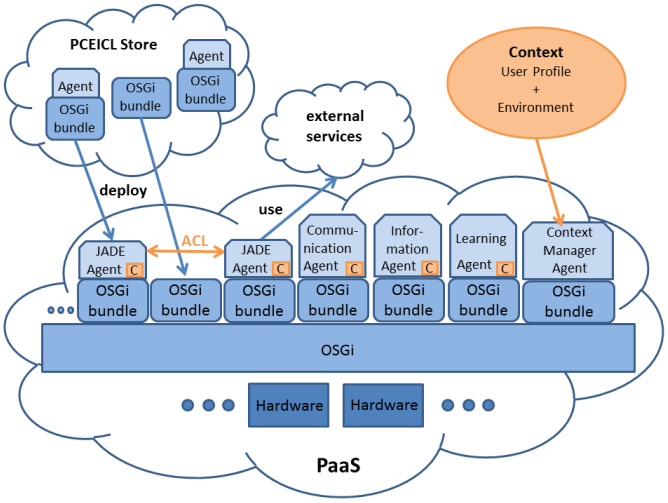

Figure 1: The PCEICL platform

is needed for CPU intensive functionalities, like image and speech recognition. More and more OSGi bundles in the field of home automation and health care are appearing and can be easily integrated [15]. A specific OSGi bundle of the PCEICL platform is a software agent OSGi bundle, which facilitates the development of intelligent behavior and realizes standardized communication between agents by using Agent Communication Language (ACL) [16]. ACL defines the use of ontologies, which we realized with the PCEICL ontology (as shown in Figure 1). For the software agents, the Java Agent DEvelopment Framework (JADE) [17] has been chosen. JADE is widely used and already provided as an OSGi bundle, which makes an integration of the agents in the OSGi environment straightforward.

Agents are well known, when developing intelligent systems, for their support for standard communication between them, and for helping the integration of external services. External services could be existing services like nursing services, communication services to contact a doctor, weather services, etc. For example, the user personalized platform could use the user information to exchange data between the PCEICL platform and the nursing service's system to indicate the necessity of a visit to the elderly person.

The distribution, installation and deployment of the PCEICL services is realized by an OSGi bundle store (PCEICL Store, see Figure 1) equivalent to modern app stores for smart phones or operating systems. These services can be selected by the elderly users, by a personal assistant, by a relative or by the system itself, to automatically update services or suggest new services to be installed to satisfy the needs (interests, impairments, etc.) of the user.

The profile and environment of the user is modelled by the PCEICL ontology. This ontology includes all the information about the person and its personal relevant environment to adapt the PCEICL services and applications (e.g., impairments, interests, hobbies, etc.). The stored profile of the user is managed by the PCEICL platform in the form of a *Context Management Agent* (see Figure 1), deciding which service is getting what kind of information about the user. Because

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of the privacy data minimization principle, not every service should get all information. For example, the communication service providing audio and video telephone calls should not get information about the health condition of the user. It gets access to information about the volume, the contacts and possible colours or font sizes for the user interface.

The needs, interests, health condition, etc. are gathered in several ways. On the one hand, there is a manual acquisition of user data during the initialization of the system by the user or a personal assistant and on the other hand there is a continuous analysis of context data through, e.g., sensors resulting in the adaption of user and environment data. The environment context is managed by the *Context Management Agent*.

In Figure 1, there are special agent OSGi bundles for the three support areas of the PCEICL platform: communication, information and learning. These agents realize an assistance of the user with the context information given by the context management agent.

V. The PCEICL Context Ontology

For an optimal personalization of the PCEICL system, the user context must be modelled, a semantically underpinned agent communication is needed, the information should be semantically connected to each other and there should be rules describing the usage of the single information. As a result, the context information and the ACL ontology part is modelled in the form of the PCEICL ontology, which enables the description of information relationships and the deduction of new data out of existing information. For example, if the system knows about the health condition of a user, capabilities and impairments could be deduced from it. This ontology is used in the Foundation for Intelligent Physical Agents-Agent Communication Languages (FIPA-ACL) [18] and is managed by the context manager agent of the PCEICL platform.

The procedure of the ontology design for the PCEICL platform is based on the approach of N. Noy und D. McGuinness [19]. The ontology is developed iteratively and, for this reason, there will be adjustments of the ontology in the whole lifecycle of the PCEICL project. Automatic updates of the concepts or just the individual elements of the ontology must be possible.

The PCEICL ontology is the base for saving and interpreting context information. It specifies the way of describing the user, his properties and his environment for all components of the PCEICL platform, particularly for the personalized services. The ontology describes primarily the user and his properties but additionally the user's environment like weather, time, date, devices/sensors, etc. Figure 2 shows an overview of the basic concepts of the ontology. A more detailed description can be found in [20].

In addition to the mandatory user data, like the personal information (name, address, date of birth, contact information, etc.), there are some more specific and more complex concepts, like the interests, preferences, capabilities, or the health condition. Many of the ontology classes are fixed defined classes, defining the properties an individual of this class must have. This leads to a better consistency of data.

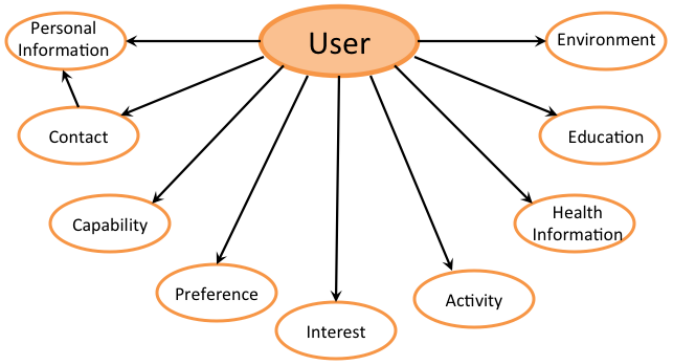

Figure 2: Overview of the basic concepts of the PCEICL ontology

The central role of the user is reflected in the class *User*, as shown in Figure 2. It is connected via properties to almost every other main class of the ontology. The *User* class is derived from the defined class *Person*, shown in Figure 3. For all instances of this class it is necessary to have exactly one id and exactly one personal information. So, every person is defined uniquely in the system.

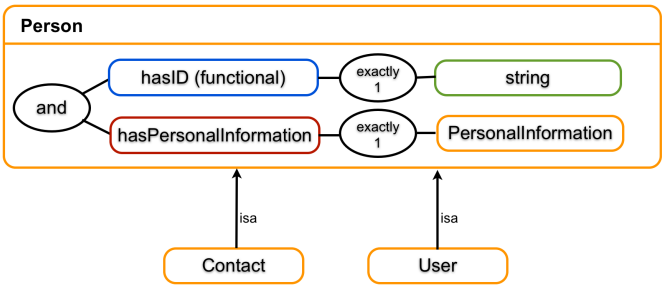

Figure 3: Class *Person*

For the PCEICL communication services of the platform, it is necessary to have a contact list. Every *Person* in this list is represented by an instance of the class *Contact*, which is also derived from class *Person*. Additionally to an ID and the personal information, there is a categorization of each contact to give the system knowledge about the relationship of the contact to the user. So, the system could distinguish between family members and, for example, doctors. For each contact, photos could also be saved. The information about the communication channels of the persons are saved in the concept *PersonalInformation*.

The class *Education* contains only information about the user's academic status, e.g., foreign languages the user speaks. This class can also be used to save data about learning progresses of the user. More information about the education of the user is at the moment not relevant for the platform and therefore, this information should not be saved. If it will be relevant in future to save more information, the ontology could easily be extended by other attributes.

The interests are represented by the class *Interest*. To differentiate between interests, like sports watching on TV and actively exercised interests, like actively playing a sport, the class *Activity* is also part of the ontology. Figure 4 shows

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the concept of the class *Interest*, which is almost the same as for the class *Activity*. In addition to the name and the type of the interest or activity, it is possible to store more specific information, like pictures, websites, or descriptions (class *AdditionalInformation*). The class *Interest* should also have a property *hasLevel*, which describes how much the user is interested in something.

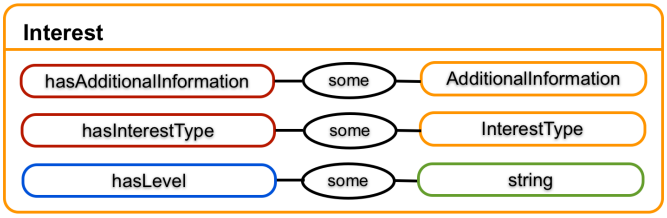

Figure 4: Class *Interest*

In the class *Preference*, distinction is made between *Personal Preference*, which is structured like the class *Interest* and *System Preference*. Personal preferences could be, for example, the favorite color or the taste of music. In the class *System Preference* settings of services or the platform itself could be saved. This settings could be derived from other information. For example, there could be a user who cannot differentiate between red and green. As a result, the system should not use red and green for the user interface. In such cases, the system should automatically derive the system preferences from the health condition or other information, which are given about the user. In the system preferences, account information is also stored, which can be username and password, a certificate, etc.

The class *Capability* is divided into *CognitiveCapability* and *PhysicalCapability* and is also structured like the class *Interest*. The capabilities and limitations stored in this class should also be derived from the health information of the user.

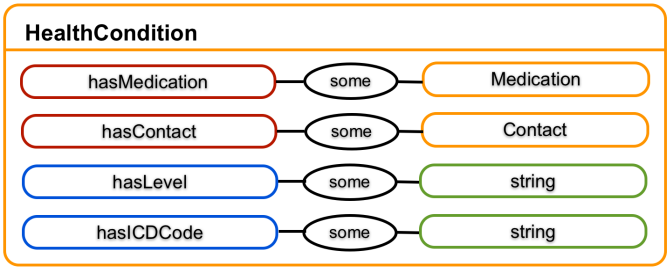

Figure 5: Class *HealthCondition*

The most important information is the health condition of the user. A lot of other information could be generated knowing about the impairments of the user. Therefore, a class *HealthCondition* exists, which is presented in Figure 5. Every single instance describes the impairments and diseases of the user. So, information can be saved about the medication of the disease or the physician treating the disease, who is saved as a contact in the list. Each impairment or disease can be rated by the property *hasLevel* by saving information such as the dioptre numbers or the status of disease. For the correct medical description of the disease, you can save an *ICD-Code* for each instance of the class *HealthCondition*. ICD means *International Statistical Classification of Diseases and Related Health Problems Code* [21] and is a worldwide used coding of diagnoses. So, a uniform and correct description of the health condition of the assisted person can be reached.

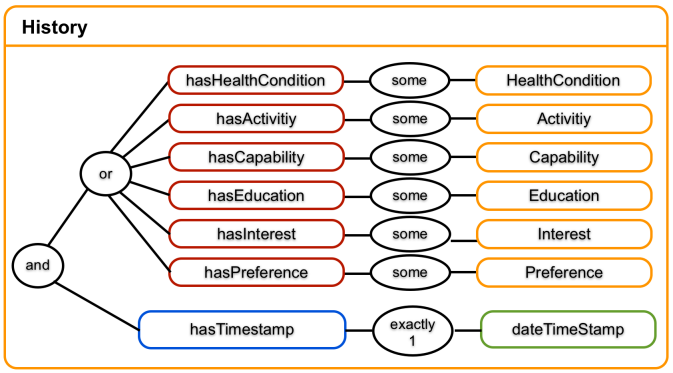

Figure 6: Class *History*

The PCEICL ontology also offers a concept to consider the context historically. So, you can observe the changes of the learning behaviour or of the capabilities and impairments, for example. Therefore, a class *History* is designed taking an expired instance of one of the classes shown in Figure 6 and combining it with an actual timestamp. For example, if the user has a cold, this information will be saved as *HealthCondition* instance. If the cold is overcome, the instance will be combined with a timestamp and will be saved as a history object.

A. *PCEICL Ontology Example*

Figure 7 shows an example of the user profile information covered by the concepts of the ontology. It represents the user profile of Mr. F., who has been introduced in the use cases of Section III.

VI. PCEICL Ontology in Use

In this section, the introduced use cases of Section III are called into play to show the platform services using the concepts of the ontology. The development of some parts of the PCEICL platform is still in progress. When the prototyping phase is completed, there will be a socio-scientific accompanying evaluation of the services by a group of persons aged 60 and older.

A. *Use Case (Communication Assistance):*

The communication app itself is just a simple client service getting only the information needed to interact with the user. Therefore, the main context information is about the contacts saved as individuals of the class *Contact*. For the communication app, information about the system preferences of the user are used to adapt the GUI. Most of the settings can automatically be derived from the health condition of the user (ontology class: *HealthCondition*). For example, if the user has a red-green colour blindness, these colours should be excluded from possible system settings or if the user has a hearing deficiency, the volume should not be set under a minimum level. These pieces of information could be saved

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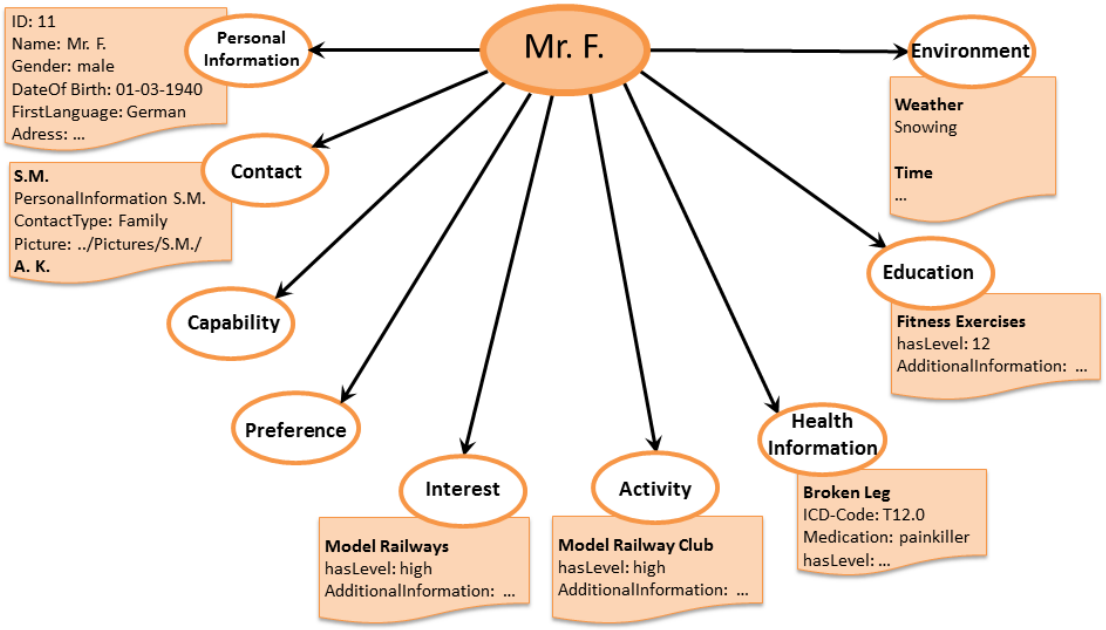

Figure 7: PCEICL ontology example

in the class *SystemPreferences*. Other information must be collected manually, like information about existing accounts.

For the organization of club meetings, information about the other club members is needed. This is also realized by the *Contact* class, which offers the possibility to order the contacts in a category *club members*, so the app can show only the relevant club persons. When the elderly person wants to organize a meeting at his home or when the system searches for a ride to an external meeting or event, this grouping functionality gives great support.

B. Use Case (Information Acquisition Assistance):

For the application which assists the user in organizing information acquisition, primarily knowledge about the health condition (ontology class: *HealthCondition*) and environment (ontology class: *Environment*) of the user is helpful. The main advantage of this app is, that it asks if it should organize assistance in something depending on the actual context. Context could be for example the condition of the user, his impairments, the weather, the time, the sensory in the house, etc. Due to the information given by the concepts of the ontology, the system can decide if there is a need for a special service or not. The user is always asked if help by the system is needed without being patronizing.

Due to the acquisition of the interests, activities and personal preferences of the user, it is possible to offer the user the "search-and-offer" service assistance of finding all kinds of support. Since the user in our use cases has a broken leg, he could get a snow shoveling offer automatically, during winter time. The model railway passion of Mr. F. can be supported by helping him to get a lift for the weekly meetings by the "search-and-offer" service. It uses the information saved in the instances of the classes *Interest* and *Activity* for providing personalized functions.

C. Use Case (Learning Assistance):

The fitness status of Mr. F. can be gathered by the *Education* class. If he reaches a new level of fitness by doing all the required exercises, the level can be saved in this class. Through the *History* class, it is possible to consider the whole progress of fitness condition. If there are steps backwards, the exercises could be adapted accordingly. The health condition information makes it possible to automatically offer only the exercises that are feasible for the user with his current impairment.

VII. PCEICL Ontology Summary

There are several advantages of the newly introduced PCEICL ontology: (1) centralized user view, (2) services adaptable to user's needs, (3) historical view, (4) usage of the ontology for ACL, (5) expandability. These advantages may be summarised as follows:

(1) Context awareness is a mandatory requirement for an optimal assistance for elderly people. It is also important not to consider only the environment of assisted persons, but especially the assisted persons themselves and their needs. The PCEICL ontology offers a **centralized user view**. Therefore, useful information about the user can be applied to offer personalized services.

(2) All **services are adaptable to the user's needs**. They can use information about the capabilities, impairments, interests, etc. of the person and can tailor their user interface and also their functionality to the abilities of the user. For example, they can control the volume, the font size or the colours, depending on the condition of the ears or the eyes of the user.

(3) Due to the **historical view** integrated into the ontology, it is also possible to react to changes of the user profile. The services can, for example, repeat helpful information if the user begins to suffer from dementia.

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(4) The ontology is used within the PCEICL platform as a common understanding of the user profile data. It is used to semantically interpret the user context in the different use cases and during the **communication between the agents** of the PCEICL platform.

(5) Another benefit of the ontology is its facilitated **expandability**. This is because of the centralized concept *User*, where it is easy to add new properties to expand the user profile. Other reasons are the hierarchical structure and the reuse of concepts by many classes. Only currently useful information is saved in the ontology for a better data privacy. Concepts, which turn out to be relevant in the future, can be easily integrated into the ontology.

VIII. Conclusion and future work

In this paper, we presented an ontology, which constitutes the base of a context aware platform as a service. The PCEICL platform itself is based on OSGi with the opinion to use JADE agents for the integration of semantic intelligence in form of an ontology. The presented PCEICL ontology is the base for ACL communication of the agents. In the future, there will be an OSGi store, where the OSGi bundles can be distributed. Due to the use of cloud technologies, the platform is flexible and scales as needed.

The use of ontologies in the field of AAL is not new, but the centralized role of the user in context modelling is not widespread. In the PCEICL ontology, the user is the central concept. The user is described by his properties like health condition, capabilities, preferences, his social environment, etc. For the exact and correct description of the user's health condition, the ICD-Code *ICD-Code* is used, which is a worldwide applied classification system for diagnoses. With the concepts of the ontology it is also possible to have a historical view on the user and his environment. So, it is possible to analyse the user's development of learning or the development of the health condition to permanently adapt the system to the needs of the user. Due to the centralized user view, also a better expandability of the ontology is reached.

Future work will be a dynamic adaption of the ontology during runtime. Some context information will be captured and analysed automatically and the result could lead to a modification of the ontology. For example, the system could monitor the behaviour and the search requests of the user and could conclude that the interests of the user changed. In this case an adaption of the interest instance in the ontology should occur. Some other information shouldn't be captured automatically. Such an information is, for example, the healing of a disease and should be detected by a doctor. After this detection, the ontology should adapt accordingly.

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