Modeling a User-Oriented Ontology on Accessible Homes for Supporting Activities of Daily Living (ADL) in Healthy Aging

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ABSTRACT

Inaccessibility of the buildings is the most common obstacle which presents barriers for older adults with different motor abilities. An inclusive design process, where elderly and designers work together, is required to overcome this obstacle. To do so, this study proposes a user-oriented model (i) to define a knowledge presentation for designers; (ii) to assist them during the development of accessible homes and (iii) to accommodate exemplary home attributes for activities of daily living (ADL). The ontology for this model was first constructed by collecting user information through LEGO® Serious Play® on the four sub-domains of motor abilities: (1) strength; (2) balance; (3) locomotion; and (4) endurance. The findings of this study are significant for future aging studies and mobile computing researches in terms of indicating that diverse motor ability difficulties are associated with different requirements of accessibility attributes, and structured knowledge is required to diagrammatize their association with ADL.

CCS CONCEPTS

• Human-centered computing → Human computer interaction (HCI) → HCI design and evaluation methods

KEYWORDS

Ontology, Activities of Daily Living (ADL), Accessible Home, Assisted Living

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1 INTRODUCTION

Healthy aging is "the process of developing and maintaining the functional ability that enables well-being in old age" [1]. It is dependent mainly on three aspects; physical capacities, mental capacities and lastly, environmental capacities [2]. Built environments, especially accessible home environments, can encourage elderly people to be physically active and allow healthy aging accordingly. However, inaccessibility of the buildings, such as inaccessible access routes, unusable kitchens, and bathroom facilities are common obstacles that elderly with different motor capabilities encounter, and these can present barriers to participate in activities of daily living (ADL).

Although there are lots of studies on accessible housing environments and ADL of older adults, designers are still struggling to make empathy towards their physical activity patterns and accessing related knowledge domains so that they could design home environments where older people could perform basic activities independently and have better quality of life. It is often hard and time-consuming to explore diverse user requirements and match them with their motor abilities. Since measuring motor capability is a complex task, there is a lack of consistency in measurement studies. Also, there is an urgent need for highly structured activity pattern definitions and their integration to intelligent systems. Thus, this study proposes a user-oriented model (i) to define a knowledge presentation for designers; (ii) to assist them during the development of accessible homes and (iii) to accommodate exemplary attributes of those homes with ADL.

The ontology for this model was first constructed by collecting user information through the active user engagement workshop, LEGO® Serious Play® as a hands-on experience, on the four sub-domains of motor functional status. Later, the gathered data are structured into two levels of abstraction; accessibility attributes and ability descriptors relevant to ADL.

The rest of the paper is organized as follows: Section 2 presents related work. Section 3 describes the proposed methodology for constructing the ontology. Section 4 presents how this methodology is applied and how the hierarchical conceptual schema of the proposed ontology is structured. This section also

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discusses an example situation model. Finally, conclusions are presented in Section 5.

2 RELATED WORK

In recent years, ontologies have attracted growing interest as a means for reasoning and modeling. In the context of aging and design studies, ontology-based modeling has been mostly applied in pervasive computing and ambient assisted living regarding elderly care, smart homes, sensor technologies and computerized cognitive rehabilitation. Khoei and Daniel [3] investigate the transfer effect of video games in cognitive training of the elderly by exploring seniors' perceptions and words. The usefulness of playing Xbox Kinect video games as an assistive technology was questioned to construct persona-based ontologies in order to maintain the daily capabilities that elders need in order to continue living independently. Onorati et al. [4] extend an existing ontology, called SEMA4A, which has been implemented to give a knowledge representation for accessible emergency notifications, focusing on three different domains: accessibility guidelines, emergency and communication technologies. Their extended ontology provided alerts depending on abilities and expertise of affected users, characteristics of the emergency and available communication infrastructure. Bae [5] presents an ontology-based approach for recognition of ADL in smart homes which provided opportunities for health monitoring and assisted living applications, especially for elderly people and people with memory deficits. Afacan and Demirkan [6] propose an ontology-based computer-assisted universal design (CAUD) plug-in tool that supported designers in developing satisfactory universal design solutions in the conceptual design phase. The required knowledge processing and representation of the developed tool is motivated by the ontological language.

Most of the ontology studies have focused on monitoring and data management issues. However, data formation and annotation of knowledge domain in ontology-based approaches are more time-consuming and requiring expertise, especially while designing systems for older adults [6]. Since the efficiency of the knowledge support system determines the level of creativity and the quality of the design process, a suitable knowledge support system is also crucial for designing elderly-friendly built environments.

Therefore, the developed ontology should go beyond specification of human dimensions, visualization of ergonomics data or task analysis tools. It should be user-oriented. For example, Sim and Brouse [7] construct ontologies based on explicit specifications of the concept of persona in representing users' knowledge and characteristics, and the concepts of viewpoints, goals, scenarios, tasks, and requirements for Web application domain. However, there are not user-oriented ontology studies in the context of accessible design domain for the elderly applications. In this respect, this study not only contributes to the literature by interfacing hands on user data with an ontological knowledge-based approach for the first time but also develops a structured knowledge pattern for designers to capture, organize, represent and model the relationship between motor ability and activities of daily living in healthy aging.

3 PROPOSED METHODOLOGY

The proposed methodology consists of four key stages.

Stage I – *Define* is the process where three significant domains of the study are specified; one is accessibility attributes of home environment. Second sub-domain is the motor function, and the third one is ADL. This study defines home accessibility as the extent to which the physical environment of home supports the autonomy of users in their daily activities [8]. Accessibility within a home refers to the compliance of home features with international and national design standards [9] such as circulation, internal doorways and hallways, ease of use in kitchen/bathroom and adequate space in rooms. Regarding the second domain, the study defines four sub-domains of motor functions [10]: (1) strength as the capacity of a muscle to initiate movement; (2) balance as the ability to maintain an upright posture; (3) locomotion as the act of moving the body from one place to another; and (4) endurance as the overall fitness. The third domain is based on an adapted version of the Barthel Index [11]. ADL items in the study are toilet use, feeding, transfer, mobility, dressing and bathing.

Stage II – *Elicit* is evaluating built environments and assessing the elderly's potential housing demands, which are messy activities that require contextual criteria and specific methodologies. In this stage, Lego® Serious Play® (LSP) was applied. LSP is a creative methodology developed by Johan Roos and Bart Victor in 1996, in which user builds a scenario with bricks and tells a story. Applying techniques like the use of LSP allows designers to gain nuanced and diversified insight into the experience of elderly users [12]. To maintain quality and safety, each older person should be actively involved in that environment activity patterns. Compared to other traditional elicitation techniques, LSP as a hands-on approach, helps to extract more visual cues, patterns of behavior, and design opportunities [12].

Stage III – *Construct* is the process where class diagraming, concept specifications and relationships among concepts in an ontology environment are done. Data from LSP play key roles to structure elderly user needs and diagrammatize them into the three ontology domains of the *Define* stage. Concepts are ADL classes, intermediary associations among concepts (defined entities of accessibility attributes) and instances of the classes corresponding to motor function abilities.

Stage IV – *Represent* offers knowledge retrieval based on access to the proposed features of a software tool. It acts as a key mechanism that supports the digital information flow for designers. This stage is first responsible for interfacing the ontology environment with its classes, concepts and instances while designers are creating accessible home environments for healthy aging.

Then, the interface facilitates data flow among these ontologies during creation, modification and display of the relevant design knowledge. However, this stage is in progress and is not studied within the framework and scope of this paper. It is the future study of the developed ontology and will be completed to ease the design process.

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4 APPLICATION OF METHODOLOGY

4.1 User-Oriented Data Through Lego® Serious Play®

During the LSP workshop, in the *Elicit* stage, various aspects of ADL, home accessibility and motor function abilities were discussed. There were 16 older adults (8 female and 8 male) with a mean age of 79.8 who participated to the LSP. They were divided into the groups of four people according their motor function disabilities. After a short introduction and trials, each group were asked first to build a scenario and then to develop their LEGO® model for an accessible home considering the relationships between motor disability and ADL.

Older adults in the first group had strength difficulties. They needed grab bars and additional safety devices to enable a person to maintain balance during transfer, mobility and toilet use activities. While playing with their Lego pieces and constructing their model, they highlighted appropriate size and space for their approach as well: *"To me, maintaining my balance while using the shower, is very important"*.

Participants in the second group had balance difficulties. Their focus was on fall problems. A wide corridor, which is free from any obstacles, was crucial for them. They emphasized a simple design of furnishing and color contrast for any level changes in order to safely orient their body parts: *"The distance between two kitchen counters should be wide enough to eliminate any hazardous events*".

Participants in the third group had locomotion problems. They considered accessible kitchen cabinets to be important for feeding activities. Like the first group, grab bars were highly necessary for them. Moreover, appropriate sitting areas for dressing activities were deemed important: *"I want to rest while I am dressing"*.

For the final group, who had endurance difficulty, a comfortable and safe transfer from bed was considered to be significant. They gave emphasis on interior rooms having large windows with a view of nature. Ease of reach to wardrobes in bedroom and accessible heights of kitchen cabinets were modeled as significant attributes of an accessible home: *"If I could not get up comfortably from my bed, I would consider that as trouble"*.

Figures 1-4 illustrate the created models by the overmentioned four groups and group them according to their sub-domains of motor abilities.



Figure 1: Group I (Strength) LEGO® model created in the LSP workshop.



Figure 2: Group II (Balance) LEGO® model created in the LSP workshop.

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Figure 3: Group III (Locomotion) LEGO® model created in the LSP workshop.



Figure 4: Group IV (Endurance) LEGO® model created in the LSP workshop.

4.2 Hierarchical Conceptual Schema of Ontology

As a result of the user-oriented data gathered during the LSP workshop, six ADL classes were identified including toilet use, feeding, transfer, mobility, dressing and bathing. Figure 5 illustrates the initial understanding of the ontology domains. In the conceptual schema, the domains are expanded and additional accessibility attributes are identified. An ontology is easily structured using ADL classes and related accessibility attributes. Each class has different object properties depending on the motor ability.

Figure 6 illustrates an exemplary class of toilet use. For example, *"An older user uses toilet with grab bars"*, is a general statement for a designer. Not every older user requires grab bars. As found in the study, according to older users with strength problems, grab bars are more important than the other accessibility attributes. It means that an accessibility attribute could be a design solution for some older adults which could be a barrier for some adults. Thus, to overcome this inclusivity challenge, the study proposes constructing a hierarchical model composed of intermediary associations. As illustrated, toilet use is also associated with four subclasses of the class of motor function ability. Thus, for an accessible toilet use activity, the study structures multiple associations among environment class, activity class and motor function ability class to find an optimum design solution. To guide the designer and overcome the challenge of accessible design for older users, the study defines the relationships between different classes as follows: The association between the subclass of ADL and the class of the motor function ability is defined as: *hasAccessibilityAttributeof*. The association between subclass of ADL and the class of the environment is defined as: *hasActivitiesof*. The association between ADL and subclass of the environment is defined as: *needsSpacesof*.

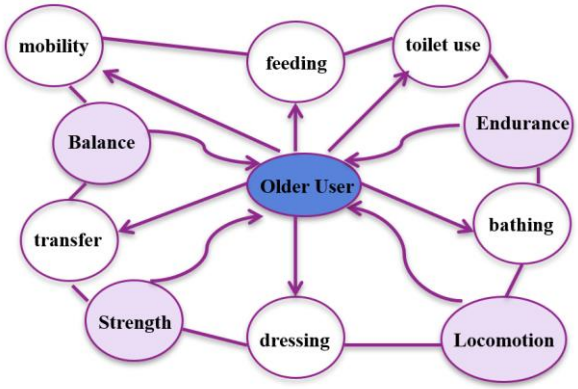

Figure 5: The initial understanding of the ontology domains in the context of accessible homes for supporting ADL in healthy aging.

5 CONCLUSION

As people age, their motor abilities decline, and their ADL performances decrease, which consequently affect healthy aging. Designers are struggling to create accessible spaces to accommodate diverse needs of older adults because highly structured background knowledge processing is required. In order to address the lack of literature, this study proposes a user-oriented ontology. The user-oriented ontological approach tries to overcome the limitations in design practice by (i) providing an efficient management processing of older user requirements through their active participation, and (ii) integrating their motor functioning knowledge. The proposed ontological language enhances not only defining, elicitating and structuring diverse user data for healthy aging but also retrieves these data for accessible design process. The findings of the study are significant for future aging studies and mobile computing researches in terms of indicating that diverse motor ability difficulties are associated with different requirements of accessibility attributes, and structured knowledge is required to diagrammatize their association with ADL. In the future, a software application for the ontology will be developed and implemented for a prototype environment.

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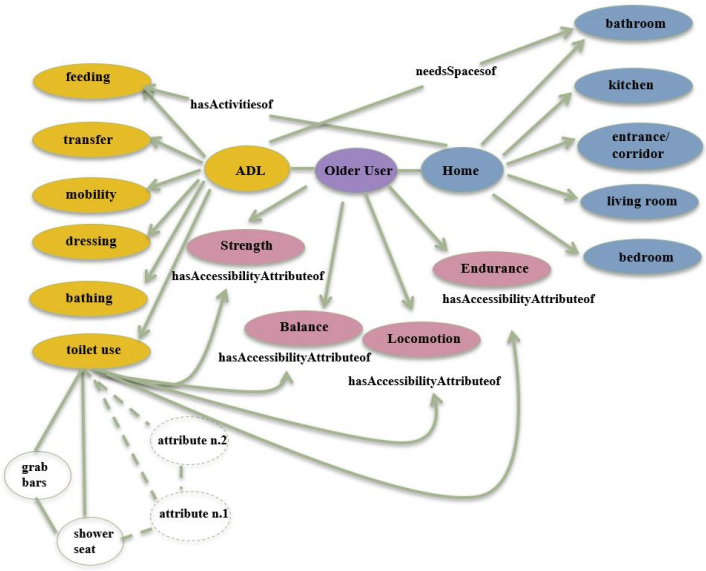

Figure 6: An exemplary diagram to illustrate class of toilet use.

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