Defining an ontology for fall prevention system design

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Abstract. The fall is one of the leading causes of death for elderly. Falls in elderly are caused by multiple factors, such as the aging process itself, persons' behavior, habits and environment. Expert knowledge about all these risk factors is required to provide the right recommendation in order to prevent falls. We have worked on the design of a knowledge-based system. An ontology was defined capturing the core knowledge to be used in the system in order to allow falling risk evaluation and definition of the adapted recommendations.

Key words: knowledge model, fall prevention, ontology.

Introduction

Health systems, in and outside the hospital, must now consider the patient as a central actor of his health. In the context of fall prevention, a large number of stakeholders can be considered, such as physicians, nurses, physiotherapists, close family members, caregivers, and the person herself. Various fall prevention systems have been proposed, often based on sensors (Chaccour et al., 2017), but very few are based on a software system. Since expert knowledge is required to provide the right recommendation, a knowledge-based system could help to involve non-expert stakeholders in fall prevention through individual applications that share patient's records together with embedded expert knowledge.

This paper proposes an ontology for fall prevention with the core knowledge to support the design of a system that allows an appropriate and constant follow up of the person through a pedagogical and educative approach, including the falling risk evaluation and adapted recommendations. The paper is organized as follows: section 1 present first the context of fall prevention; section 2 presents the design methodology and the proposed ontology; section 3 explores how the ontology contributes to the design of a fall prevention system.

1 Fall prevention

Today, the population aged 65 and over is very important due to the spectacular increase of life expectancy. Among those persons, one out of three will fall within the year (person living at home), and the problem also occurs in retirement homes and in the hospitals. This frequent event is the first cause of traumatic death in this population and is a multifactorial problem [Haute Autorité de Santé, 2014] et [Bourdessol et Pin, 2008]. The fall risk factors find their roots in the aging process itself, but are also influenced by the person's behavior, habits and environment. Falls can thus be prevented by addressing these risk factors. Fall prevention is achieved through interventions that aim to reduce the risk of falling. Several studies focus on the interest and effects of these interventions [Huang et al., 2018]. The possible interventions include: exercise, visual improvement, hazard environmental modification, disease management, education, drug modification, nutritional supplements, health assessment, consultation, referral, assistive devices. Because of the variety of possible interventions, and according to physicians specialized in fall prevention, it is important to select a little number of interventions that are the best adapted to a specific person. Selecting the right recommendations for a given person, according to his/her specific case requires expert knowledge about the fall risk factors and adequate

recommendations. Ontologies [Uschold and Grüninger, 1996] are a validated way to provide a general shared knowledge model. We thus propose an ontology to support the design of a software system for fall prevention.

2 The Ontology for Fall Prevention

2.1 The Ontology Design Methodology

To specify the ontology, we followed a methodology (Figure 1) defined based on [Uschold and Grüninger, 1996] [Noy et al. 2001] composed of four steps: the *purpose* of the ontology is to support the evaluation of risks of falls in the elderly in order to prevent falls through recommendations. This ontology is the basis for the development of the fall prevention software system. The *conceptualization* requires the definition of the ontology's scope by setting competence questions (i.e requirements in the form of questions that the ontology must answer) and from that the definition of concepts, relations and constraints (axioms). It represents the knowledge modeling itself. The *formalization* implied write the ontology with OWL, using Protégé tool. Finally, the *validation* was done by physicians' analysis and by instantiating the ontology with real cases collected from the historical database of the hospital unit.

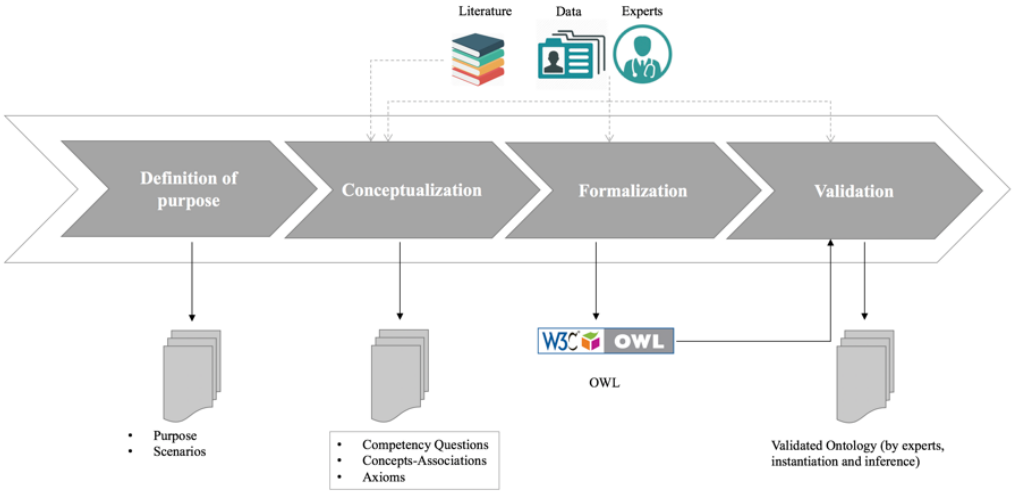

Figure 1 – Ontology Design Methodology

Three competency questions were defined: (1) What are the important characteristics to be observed for a person at risk of falling? (2) What are the falling risk factors? (3) What are the appropriate recommendations for fall prevention? The first two competence questions are strongly interconnected once the characteristics of a person we seek to identify are those that are implied in risk factors recognized by physicians. Based on the characteristics of the elderly and the risk factors he/she has, physicians define specific recommendations. Aware of that, we organized the ontology in two sub-ontologies: one focused on the elderly person at risk of falling (first two competency questions, presented in section 2.2) and one focused on the recommendations (third competence question). Both sub-ontologies were defined based on the literature, by the interview with specialized physicians on fall prevention, and by the analysis of a historical database from a hospital unit specialized in the treatment of fall for elderly. The conceptualization of the ontology was a long and iterative step of analysis and consensual of terms definition from all these sources with the physicians.

2.2 Sub-ontology about Elderly Person at Risk of Falling

Trying to understand the elements that make a person having a risk of fall requires to understand a lot of elements about her *pathologies*, the *medication* she takes, her *daily activities* as well as the *environment* she lives. Each one of these elements can be refined considering the potential risk it may cause. First of all, the

primary attributes of a person (*age* and *sex*) are important when evaluating risk factors. Even though these attributes are not considered in an isolated way, they can influence in the evaluation. For instance, women are more likely to fall than men [Tinetti et al., 1995]. Moreover, the combined effects of aging and age-related pathologies accentuate the risk of falls [Tinetti, 2003] and [Bourdessol and Pin, 2008]. In this context, according to [American Geriatrics Society et al., 2001], some *chronic* or *acute disease* are known to increase the risk of falling in the elderly.

We organized all the kinds of risk in a taxonomy partially presented in Figure 2. We distinguish between *severity factors* and *incidence factors*. Incidence factors are associated with the causes of fall, whereas severity factors are related with the gravity of the consequences of the fall when it occurs, such as injuries and complications. From this taxonomy, we defined associations with the concepts related to the person (see for example the association in Figure 3 about fall risk factors associated with daily life activities).

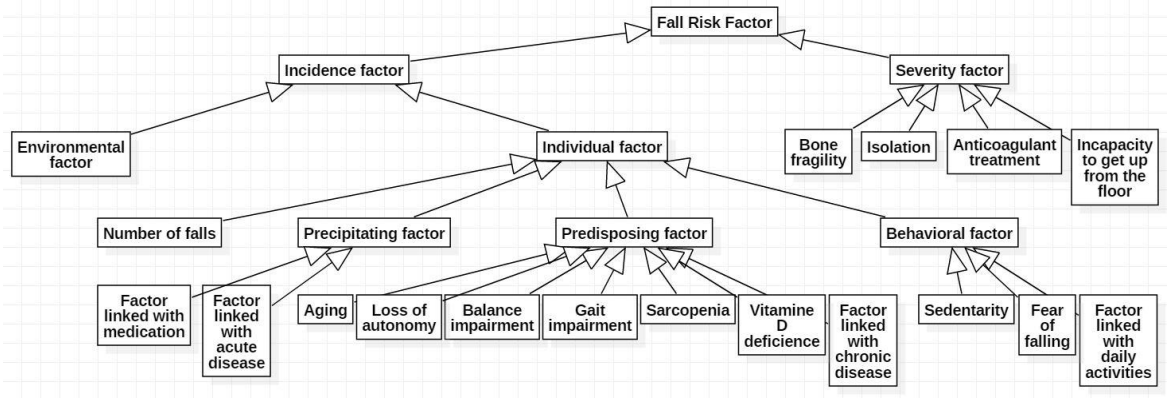

Figure 2 – Part of the sub-ontology of the elderly at risk of falling

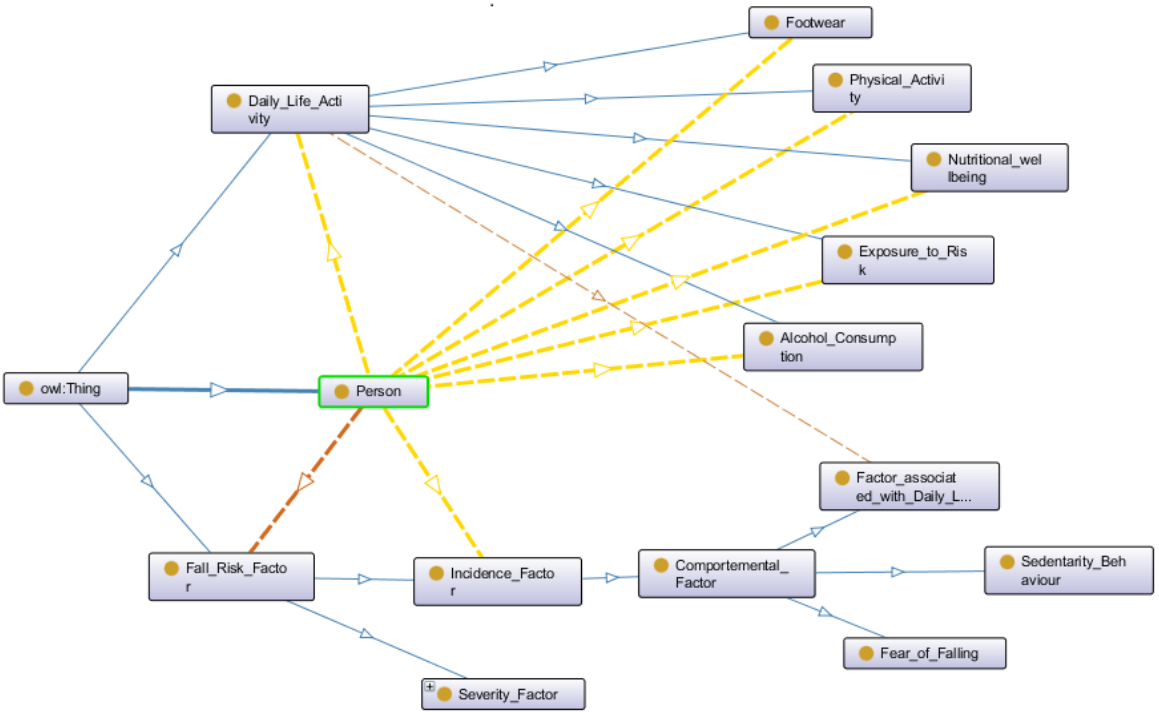

Figure 3 – An example of associations between concepts of the ontology in Protégé.

3 Exploring Ontology for Fall prevention system Design

The above ontology provides a solid base regarding the identification of important characteristics of the person, fall risk factors and recommendations. In order to provide a system for users who are not expert in fall prevention, some additional aspects have to be considered regarding causal links and correlation between some concepts. For example, alcohol consumption increases the risk of balance impairment. These relationships can be useful when the description of the case to be studied is incomplete. More precisely, the updating of beliefs in unobserved variables given a partial description of the person would allow benefiting from this statistical general knowledge. Ontologies are not designed to model neither causality nor statistical correlations, though several interesting proposals integrate uncertainty in ontology [Carvalho et al. 2017]. In order to benefit from that kind of knowledge, we propose using probabilistic graphical models called Bayesian networks [Jensen and Nielsen, 2007] since they include probabilistic relationships and allow inference.

The main steps to define a Bayesian network are the variable selection, the graph definition and the parameter learning (local conditional probability distributions). The ontology is of great interest for the first step. The analysis of literature and interviews with experts allows identifying some pieces of information about the structure of the graph. However, more work is required to get a complete definition of a causal graph of a Bayesian network. Finally, data are essential for the learning of the parameters of the probabilistic graphical model, and can also contribute to improve the structure of the graph.

Conclusion

We propose an ontology to support the design of a fall prevention system based on expert knowledge. This knowledge modeling is a fundamental step. Indeed, fall prevention requires a pedagogical approach, meaning that the evaluation of the fall risk and the updating of recommendations to reduce the number of fall risk factors have to be done regularly, involving a large set of non-expert stakeholders. The definition of a probabilistic knowledge model benefits from the ontology, even though it requires different pieces of knowledge. The selection of the variable that must be embedded in the software system is a major step for which the ontology provides answers.

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