Using a Requirements Modelling Language to Co-Design Intelligent Support for People Living with Dementia

James Lockerbie and Neil Maiden

Cass Business School, City, University of London, London, UK
James.Lockerbie.1@city.ac.uk

Abstract

Context and motivation: this research developed a new AI application to support people with dementia to maintain quality of life. **Problem**: the research explored methods for co-designing models of goals that users of an AI application will seek to achieve. **Principal result**: An effective co-design method for enabling domain experts to externalize and validate expertise about dementia care. **Contribution**: A co-design goal modelling method effective with dementia care workers, but still untested with experts in other domains.

Keywords: Dementia, quality of life, goal modelling, domain expertise.

1 Supporting People with Dementia

Dementia is a decline in mental ability that affects memory, thinking, concentration and perception. It occurs because of the death of brain cells or damage in parts of the brain that deal with thought processes. The number of people with it worldwide has been estimated at 47.8 million, a figure predicted to double in the 20 years [Pri15]. This rising cost is limiting the volume and nature of traditional dementia care services that many societies can deliver. New forms of more cost-effective dementia care service are needed. Some of these new forms of service will exploit artificial intelligence (AI). One is to support planning to maintain quality of life with dementia.

The symptoms of dementia create numerous barriers to quality of life, and many people with dementia have co-morbidities – illnesses such as Parkinson's disease, diabetes and anaemia – that add to these barriers. A defined quality of life derives from the World Health Organization's definition of *health*, and concerns not only the absence of disease or infirmity but also the presence of physical, mental and social wellbeing [Wan18]. Yet whilst there is a literature describing it, new AI applications to describe and reason about a person's quality of life with dementia are still missing.

This paper summarises research undertaken to design a new model of quality of life with dementia that can be manipulated computationally in an AI application. The research was in two stages. In the first, knowledge about maintaining quality of life,

 In: M. Sabetzadeh, A. Vogelsang, S. Abualhaija, M. Borg, F. Dalpiaz, M. Daneva, N. Fernández, X. Franch, D. Fucci, V. Gervasi, E. Groen, R. Guizzardi, A. Herrmann, J. Horkoff, L. Mich, A. Perini, A. Susi (eds.): Joint Proceedings of REFSQ-2020 Workshops, Doctoral Symposium, Live Studies Track, and Poster Track, Pisa, Italy, 24-03-2020, published at http://ceur-ws.org

which was documented in written form in existing social care frameworks, was codified using the *i** goal modelling language from which automated reasoning could be developed. In the second, the focus of this paper, experienced professional care workers manipulated playful physical versions of the model, to change and validate the codified care knowledge, and to capture and incorporate care knowledge not documented in these frameworks. The use of these physical *i** models was an effective means of capturing expert knowledge about human goals that could be codified explicitly, and translated into facts and rules used by the new AI application during reasoning.

2 Modelling the Goals of People Living with Dementia Using *i**

To enable the precise representation of and logical automated analyses about quality of life with dementia, existing written knowledge from social care frameworks was described using the *i** goal modelling language [Yug10]. Some of the *i** model semantics mapped well to content that was extracted from the quality of life frameworks, indicating that it could be an effective precise language with which to describe the intentions of people living with dementia. *i** soft goals were effective for describing types of state that a person with dementia desired to achieve in relative rather than in absolute terms, such as qualities of life and selected personal outcomes. Examples of these soft goal types included *social life maintained* and *cognitive function maintained. i** tasks were effective for the types of activities that the person sought to undertake to add meaning to their lives, for example *to visit a café with friends* and *to play bingo*. And *i** contributes-to links could be applied to describe how the completion of types of meaningful activity contributed to achieving different types of soft goals, and how soft goal type achievement contributed to the achievement of other soft goal types. For example, each instance of *playing bingo* contributed positively to achieving both the *social life maintained* and *cognitive health maintained* soft goals.

To develop a first version of the quality of life model using the *i** language, we reviewed the extensive academic literature on quality of life. The model was developed to be a general model that would describe the types of goal that would hold for most people living with dementia. As a consequence, it described types of goal such as *engaged with neighbourhood* rather than instance-level goals such as *engaged with my village's neighbourhood watch*.

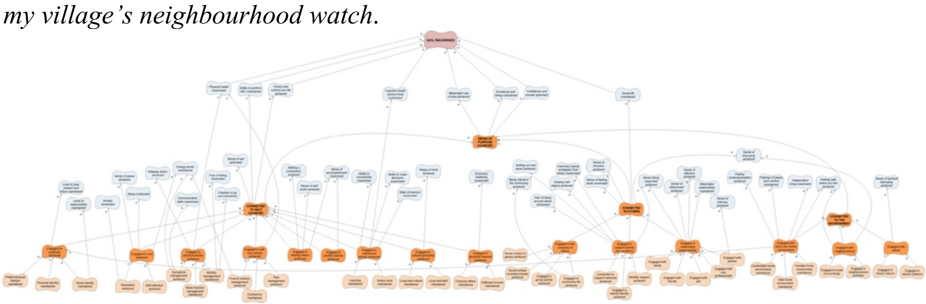

Figure 1: First quality of life goal model represented using the graphical *i** notation

A small number of types of goal associated with qualities of life that all people living with dementia would seek to achieve were associated with a larger number of types of goal extracted from goal examples reported in the personal outcome frameworks. An even larger number of the types of goals extracted from the meaningful activities were associated with the personal outcomes goal types. The first complete version of the quality of life goal model derived from existing frameworks is shown in Figure 1. The model was composed of 101 different soft goal types and 115 contributes-to links between these soft goal types. It described that the greater achievement of different personal outcome soft goal types contributed positively to the achievement of these quality of life domain goal types.

3 Co-Designing the Goals of People Living with Dementia

It was unlikely that all knowledge about quality of life was described in the model's 101 soft goal types and 115 contributes-to links extracted from the written social care frameworks. Experienced professional care workers were predicted to have additional knowledge of meaningful activity types and their impact on quality of life. Therefore, our research also sought to capture this knowledge about goals that people with dementia seek in life and use it to validate the model. The knowledge was used directly to model explicitly the rules and facts that were part of the reasoning mechanism that could be used to explain decisions and recommendations to be made by the AI application. A key challenge was how.

Whereas most methods that design for dementia encourage participation of people with dementia (e.g. [Tre19]), our aim was to involve experienced carers of people with dementia. Methods such as shadowing and observing the care workers were rejected due to the difficulties associated with gaining access to people's homes and debriefing the busy care workers afterwards. More direct methods such as interviewing the care workers were also rejected due to the potential difficulties of verbalizing complex care goal types and associations. Likewise, verbal techniques for eliciting domain expert knowledge such as laddering, card sorting and repertory grids (e.g. [Cor89], [Rug92]) were judged to be insufficient for capturing the networks and different types of association that exist between large numbers of types of goals and activities. Instead, the authors developed a bespoke method based on design thinking with physical prototypes [Sti12]. This method was designed to enable the care workers to externalise their own care knowledge by adding to, editing and removing elements from the physical model themselves, rather than by verbalising complex knowledge to researchers directly.

3.1 The Method

The participants were 12 paid domiciliary care workers from the Alzheimer's Society in the United Kingdom who made 1 or more weekly visits to care for people living at home with dementia. All were selected because of their experience and practical knowledge of selecting and adapting meaningful activity types that contributed to achieving the desired qualities of life of the individuals in their care. The care workers had an average of 10 years of experience of caring for people with dementia, and the most experienced had 22 years of care experience. Each workshop involved a care worker with at least 7 years of relevant care experience.

The physical model was constructed with small pieces of card of different colours to represent model soft goal types, pieces of string to represent contributes-to links between soft goal types, and wooden pins to attach the string to the cards. The string and wooden pins were selected to enable care workers to change the model easily. The cards and string were pinned to white foam boards, and laid out with the same structure of the quality of life model shown in Figure 1. Each physical model was then positioned horizontally on a table so that care workers could reach all parts of it. Examples of physical representations of the model parts are shown in Figure 2.

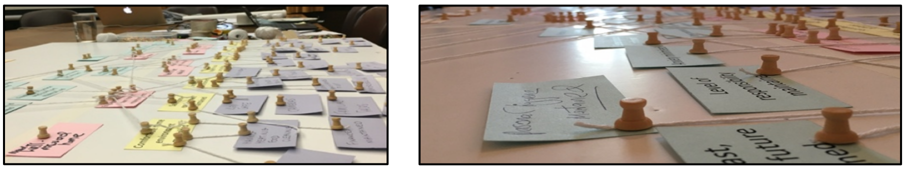

Figure 2. The physical prototype of one of the quality of life model parts as set-up at the start of each design workshop

The complete model of 101 goal types in Figure 1 was deemed too large to validate during one workshop. Therefore, the model was divided into 3 overlapping but coherent parts. Each part was bounded using the reported different forms of connectedness for categorizing types of meaningful activities. Each model part described approximately 50 goal types and their links related to connecting to *oneself*, to *others*, and to *one's environment*. Each design workshop involved 4 care workers and lasted approximately 2hr30m. Each began with introductions, a short video that described the project and a single slide that described how an AI implementation of the model might be used. Each workshop was then a sequence of 4 exercises:

Share experiences: the care workers were asked to report their experiences of changing meaningful activities in a person's life that impacted positively on the quality of that life, to generate common ground for discussion between the care workers;

Brainstorm meaningful activity types: the care workers stood in front of the physical model with only the leaf-node goal types visible. They were asked to recall types of meaningful activities undertaken with the people in their care, and associate these types of activities with the soft goal types in the model that were visible. When no relevant soft goal type was visible, the care workers were instructed to add new soft goal types by documenting them on different coloured cards and adding the cards to the model. Each care worker documented each meaningful activity type on a new card and pinned it to the board. The care workers were then encouraged to walk through and verbalise each meaningful activity type's impact on each visible soft goal type;

Explore impacts of meaningful activity types: the complete physical model was revealed to the care workers. One of the researchers explained that the model had been generated from existing frameworks and required inputs using their expertise to increase its completeness and correctness. To demonstrate how different types of meaningful activities might impact on different goal types, the researchers picked 2 example activity types and walked through the model to report different impacts on each on the modelled soft goal types. The care workers were invited to agree or challenge each impact, and to amend and/or add new soft goal types. The care workers repeated this process with different meaningful activity types that they had incorporated into the model, to describe explicit rules and facts of the AI reasoning mechanism;

*Explore goal type constraints and trade-offs***:** the care workers were asked to report other factors that would affect a person's achievement of his or her life goal types. Examples of these factors included constraints on the person that might stop meaningful activities being undertaken, trade-offs between goal types, and types of goal more important to quality of life. Again, these factors evolved into rules implemented in the reasoning mechanism of the AI application.

3.2 Results

Each design workshop took place with 4 care workers and ran for the planned 2h30m. The first exercise elicited a total of 11 shared care experiences across the 3 workshops. The second generated a total of 101 documented meaningful activity types, including 3 activity types to be undertaken by the person's family members. After removing duplicates and extracting single entries, the content analysis identified 83 unique types of meaningful activity undertaken by people with dementia. In some cases, these activity types were specializations of more general types of activities. For example, the types *singing in a choir* and *singing for the brain* were different specializations of *singing*, and the types *out for a walk* and *walking with a family pet* were specializations of *walking outside*. The third exercise generated a total of 37 documented changes to the physical models as well as goal and activity types to prioritize to deliver more cost-effective care. the care workers also prioritized some types of meaningful activities as having greater positive impacts on the qualities of life of people living with dementia. These included reminiscing and sensorial activities such as visiting a sensory garden, using twiddle blankets, exploring nature and developing relationships with pets. Therefore, the model was extended so that these meaningful activity types were *Make* rather than *Help* contributes-to links to soft goal types. In the fourth exercise the care workers reported trade-offs between 5 pairs of goal types and a small number of constraints on delivering care to improve quality of life.

The workshop results led to a substantially more complete and correct quality of life goal model that informed the design of the AI application's reasoning mechanism.

3.3 Method Reflections

During the post-workshop focus groups, the care workers reported that the modeled goal types and associations were understandable to them from their different perspectives and levels of expertise. Care workers in 2 workshops described the resulting models are "*natural*" to them, and: "*With all our experience, of all our years of experience you know exactly where they fit. At the time you're looking at it, that's right,* *that goes there you know*", and "*It's just putting your expertise you know and all our work knowledge, putting it on paper really*".

The physical prototype of the model was reported to be important. Comparing it to the digital version, one care worker said: "*It's more hands on this way, it's really good*". Another reported: "*And not only that, I don't know, for me and kind of aesthetically I got to see how this string links to that, now that really helps me, because if that string wasn't there – you say, oh that links to that – no, I find them being linked and showing how they cross and how they link to more than one, really helped me*."

The care workers in all 3 workshops reported that the modeling supported them to contextualize their care expertise. For example, one reported: "*To us, we just do what we do. You know, we don't class it as a job. So looking at that now [the model] you don't realize what you do looking at it on paper. You think oh gosh, do I do that, do I do that? Ooh, you know isn't it. We don't realize a lot of it*.".

4 The Resulting Implementation of the AI Application

A larger, more complete version of the model was produced that included all of the changes listed in the results including the new 83 meaningful activity types – a set that was subsequently evolved into a more complete set of over 850 types of meaningful activity linked to model soft goal types. This version of the model was operationalised using the Controlled English (CE) language and implemented in a model-based reasoning engine called CE-store [Ces20]. The implementation combined the quality of life goal model with information about older individuals. A bespoke set of propagation algorithms triggered a set of 57 queries and rules applied to up to 53,147 facts to infer how well users have achieved their main goals based on activities undertaken and alternative activities the user might want to consider in the future. Because of the explicit knowledge modelling undertaken using *i**, the inference rules were relatively simple, and enabled simpler application updates and user-requested explanations.

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