An Integrated Approach to Supporting Interaction Evolution in Home Care Systems

Tony McBryan, Marilyn R McGee-Lennon and Phil Gray
GIST, Department of Computing Science
University of Glasgow
Glasgow, G12 8QQ, UK
{mcbryan, mcgeemr, pdg}@dcs.gla.ac.uk

ABSTRACT
There are many sources of change within the domain of home care. People have changing needs, beliefs, and preferences regarding their care plan and how they might want to interact with existing and emerging home care technologies. The devices and services available to the user are likely to change over time depending on a person's capabilities or location within the home and the current devices and services available. The resulting interaction methods can therefore also change in accordance with the room location, available devices or displays, or preferred modalities. Home care systems therefore need to offer configuration possibilities that support this change. Computer systems offer methods and tools to support configuration in the short term, but do not provide mechanisms for supporting configuration over both short and long term. This paper presents an approach that addresses this issue in the home care domain by integrating methods for interaction requirements engineering with system support for turning those requirements into a working configuration. Both the methods and system support are designed to address a gradual process of change – 'interaction evolution' in home care. We present the key features of our approach using a home care scenario and consider our progress to date in implementing and validating the approach.

Categories and Subject Descriptors
H.5.2. [Information interfaces and presentation]: Theory and methods. D.2.2. [Software Engineering]: Design tools & techniques: User interfaces.

General Terms
Design, Human Factors, Theory.

Keywords
Interaction, evolution, home care system, context-aware, user preferences, requirements engineering, ageing population, dynamic system, evaluation criteria.

PETRA 2008, July 15–19, 2008, Athens, Greece.

1. INTRODUCTION
An increasing number of people coping with a variety of illnesses, impairments or disabilities (age related or otherwise) prefer to stay in their own home to receive care [4]. This is both socially beneficial - they can remain in a familiar environment, close to family and friends - and economically beneficial – it is costly and impractical to provide sufficient specialized care facilities given the increasing ageing population [14].

Technology can be used to support health and social care at home. We refer to a *home care system* as the technology used to support and realise activities within a network of care; including providing the means to collect, distribute, analyse and manage care related information [12]. Such technology typically includes sensors, devices, displays, data, networks, and computing infrastructures. Traditionally home care systems have been used to monitor situations in the home such as someone being immobile or incapable and therefore requiring outside intervention [14]. Greater networking capability has increased the potential for users to send and receive important care information from their own home to friends and family or to health and social care professionals involved in their care. This may encourage and support self care and the use of health indicators in preventative health management [4]. The potential for home care systems to enable and improve people living at home with care conditions still has to be realised.

Living in the home, and managing health and well being, has unique interaction problems. Our homes can be a highly personalized environment where generically configured devices or systems may be unacceptable, regardless of their potential clinical or well being benefits. It is an environment often shared with our spouse, family, friends and visitors and therefore it is likely in the home care context that user requirements are subject to both change and conflict over time [6], [17]. Changing needs may be as a result of changes in medical conditions, new devices becoming available, family circumstances, what people believe and the way they prefer to or are able to behave and interact with the home care system.

This paper describes the main features of home care that are sources of change (Section 2) and argues that new methods need to be developed to support the dynamic nature of home care systems. Our overall approach is to treat the problem as one of both requirements and system (configuration) evolution. By linking the two aspects via a single unified model, we assert that it is easier to provide rich and appropriate system support for the complex human-facing task of identifying, reflecting on, choosing and reviewing interaction configuration choices. We set out our process model for interaction evolution (Section 3) and identify a set of features needed from a requirements engineering point of view to support interaction evolution (Section 4). We then go on to describe the related system model that makes possible generic and integrated computer-based support for interaction evolution (Section 5). The paper finishes with some brief comments on progress so far in implementing a working concept demonstrator and our validation of the approach (Section 6).

2. COMPLEX AND DYNAMIC FEATURES OF HOME CARE SYSTEMS

2.1. The network of care

Home care systems can involve multiple users and/or multiple stakeholders. There are likely to be partners living in the same space, friends and family living elsewhere who are involved in care or interested in its status, visiting medical personnel such as community nurses and remotely located medical staff, such as a consultant in a clinic that the patient visits [12]. We refer to these people as stakeholders if they have a direct or indirect interest in how the system works, how the system is used, or the data it generates or provides. Many stakeholders may need or want to come in to contact with the data or devices of the home care system themselves directly either in the clients home or remotely. In this case, these stakeholders also have to be considered potential end users of the home care system. Stakeholders would also include external agencies responsible for designing, installing, maintaining and prescribing the available equipment and/or changes in legislation or policy on how the devices or services can be prescribed and used.

It is likely that with multiple occupants in the home, multiple end users, and multiple stakeholders that people's needs, perspectives and accountabilities [7], [9] will differ and in addition might change over time as the condition of the person and the possible behaviours of the systems change. A system's configuration may be acceptable for some but not for others. For example, the user may wish to have care messages and alerts presented by speech, but this might be annoying and disruptive to the carer if delivered via loud speakers while they are in the home. Similarly, information provided on a television might either be disruptive of TV use by others in the household or it might allow private and potentially embarrassing health information to be read by others.

This can result in complex, dynamic and potentially conflicting needs and requirements and therefore novel methods are needed for identifying, negotiating, and resolving these changing requirements and interaction needs as the stakeholders interact with and use the home care system.

2.2. Care needs and conditions

It is common in an ageing population that the people being cared for will have a cluster of conditions to manage [4], some of which might interact with each other. This means that a home care system must be capable of dealing with decisions on which rules to follow if health indicators from different conditions or symptoms are conflicting with each other. There is of course the added problem that conditions are not only multiple within one person but can be spread between the persons living within the home.

Users of home care technologies can be of any age and ability but a large number of users are either elderly, or have physical, sensory or cognitive impairments, or some combination of these factors. This results in a user group that should be offered appropriate choices of both traditional and novel methods of interacting with the technology and the information. Offering choices of modalities and interaction is desirable and yet not necessarily straightforward to solve. It is necessary therefore, that home care systems should be able to support preferences and capabilities that vary both between users and as care needs change.

2.3. Available devices and services

Home care systems should be capable of providing implicit, multimodal, and non-standard means of interacting to facilitate a more natural user experience. This is likely to include the use of speech and non speech audio [13], graphical output delivered via mobile devices or digital television, gesture input and tactile output. Allowing users the choice of various modalities for different interaction tasks in different contexts is important [13]. Knowing which combination of these to use at any one time for any one purpose is not straightforward.

New devices and services may become available purely as the person's context or location changes within the home. Presenting information to the television for example makes more sense in the living room than in the bathroom and presenting information to a loudspeaker makes more sense if there is a person who prefers speech output and there is no other audio output to that device at that time. So, as new devices and services become available, the user must be made aware of these and offered ways to interact with these devices and/or services.

2.4. A home care scenario

In order to illustrate our suggested methods to support interaction evolution, we will use the following home care scenario. This scenario has been used previously in stakeholder engagement within the MATCH project and has been validated by social care professionals, assistive technology technicians, and policy makers.

"Fred and Shirley have been married and living together for 50 years. Both are now in their 70's and are living with care needs in their own home. They have a daughter Fiona and a son Robert. Fiona has three young children and lives an hour away by car. Robert lives in Australia and calls them once a week to see how they are doing.

Shirley has worsening arthritis and is no longer able to move around the house easily. She relies on Fred for tasks such as turning on the fire, closing the curtains and most household chores. Fred recently had a stroke. He is still physically fit but has become more forgetful since the stroke. Shirley has to remind him how to prepare the food and when to take his medication. Fred is also hard of hearing and Shirley often has to shout to be heard by Fred. This is becoming increasingly annoying for both of them.

Fred rarely goes out as he is worried about leaving Shirley on his own. He usually manages to go to the local shops every day and takes his mobile phone so that he can call Shirley if he needs to. Shirley enjoys watching TV and reading while Fred enjoys singing and bowling with his local group when he gets the chance.

Fiona visits once a week and brings the shopping. The social care worker also comes once a week and has offered them additional help with their shopping and household chores but Shirley and Fred are happy doing things for themselves for now. They keep in touch with friends by phone and sometimes manage out to the social events at Fred's bowling club to meet up with friends".

3. INTERACTION EVOLUTION

Given the multiple aspects of change presented in Section 2, home care systems should be able to adapt to dynamically changing requirements of the client themselves, other relevant stakeholders and the situation of use. Allowing different users the choice of interaction methods for different tasks in different contexts is important. Previous work has focused on dealing with short-term changes within a home environment such as context aware systems [18], [2] that react to situational changes. There is a gap in the literature of methods for supporting longer term configuration.

In this paper we refer to the concept of *interaction evolution* in a home care system. The concept of evolution we use here is influenced by Dourish [5], MacLean [10] and Fickas [6]. Each of these authors identifies the ability to evolve, tailor and design a system by the user as a necessary feature for acceptance within the home. We define *interaction evolution* as *multiple related instances of interaction configuration (customisation or personalisation) that have a directed goal to change some aspect of the system.* For example, an elderly user might develop a visual impairment (e.g., cataracts) that requires a reduction in dependency on conventional visual displays. Over time the visual capacity of the user might deteriorate, perhaps resulting in the invalidation of the current configuration choice.

Interaction configurations range from automatically-generated rapid changes based on context to a process of modification driven by regular human reassessments of the system and its effectiveness. Figure 1 illustrates a sampling of this "configuration space". Our approach is intended to address the full range of choices that can be made within this space.

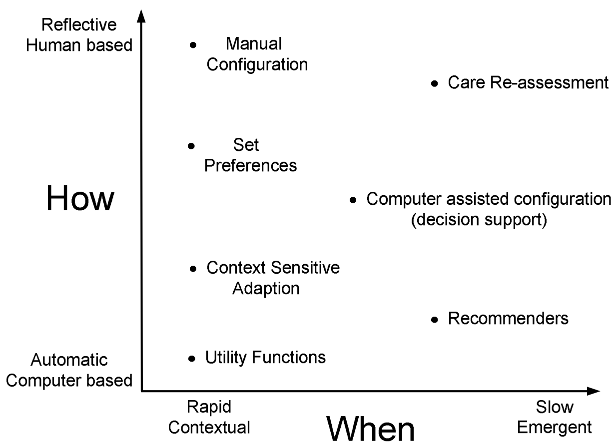

Figure 1. Techniques within the Configuration Space

We model the process of evolution as one or more potentially linked configurations, each of which consists of the following stages which will often occur iteratively:

- identification of opportunities for change
- reflection on alternatives
- decision-making
- implementation

Figure 2 shows this process as a spiral. The first configuration (1) shown by a solid line, shows a configuration which has gone through one and a half iterations while the second (2) indicated with a dotted line, shows another configuration that has only just been identified and the alternatives are under investigation. As shown in the figure it is possible to have multiple configuration processes underway at the same time at different stages of evolution. We now consider each of these stages in turn.

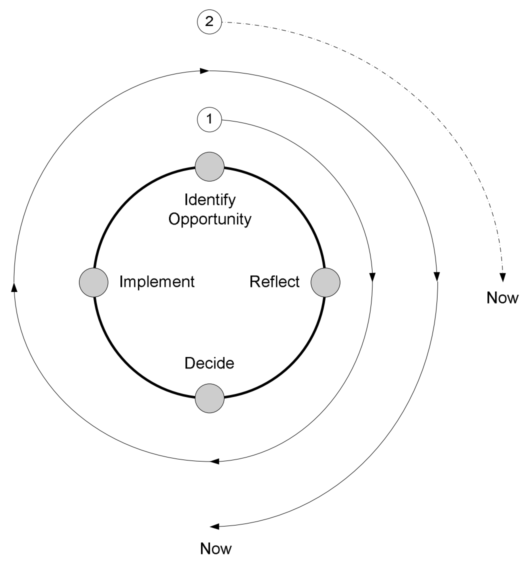

Figure 2. Process of Interaction Evolution

3.1. Identify opportunity for change

For a home care system to evolve it is necessary to be able to identify opportunities for changing the devices and techniques the system uses to interact with the user. An opportunity in this sense can be thought of as a defect in the requirements for the system or in its realisation of the requirements. These opportunities are of many types, ranging from rapidly changing circumstances (e.g., ambient noise level) that need a rapid, probably automated change through slowly emergent conditions that require rigorous (human) analysis and gradual resolution (e.g., deterioration of sight).

3.2. Reflect / judge alternatives

Once an opportunity for change has been identified, it is necessary to characterise the potential options for taking advantage of it. As with the opportunities themselves, the identification, characterisation and analysis of the options may be straightforward and automatable (e.g., presenting information to the user via the output devices currently nearest to them) or it may be complex, difficult to describe and evaluate (e.g., determining the alternatives for delivering a medical alert to a patient with progressive ocular deterioration) perhaps needing the involvement of experts as well as decision-support tools.

Since a home care system is inherently multi-user it may also be necessary to support collaboration between various stakeholders and assist in the description and negotiation of acceptable choices in different contexts.

3.3. Make decision / implement

After reflection has taken place it is necessary to make a decision about whether a reconfiguration will take place, and if so what form it will take.

Both the decision itself and the resulting configuration may be deferred until a later time - that is, the opportunity for configuration may be identified and recorded but the actual configuration does not take place until a later point in time. This may be required in a situation where the user is currently busy and a change in modalities or interaction style would be a distraction to the task at hand. Alternatively, as in the visual deterioration case, the opportunity may be known (e.g., the rate of deterioration may be predictable) resulting in a plan for future reflection and decision-making.

Decision-making, like reflection/analysis, may involve multiple agents and hence multiple criteria.

3.4. Iterate / repeat

This entire process of handling change is iterative and ongoing to support evolution of interaction.

People do not necessarily know in advance which interaction techniques and devices will and will not work in different circumstances and may need to try it first before deciding. This implies that each iteration would include an evaluation phase as part of identification of opportunities for change to determine if the new configuration meets the needs of the users better than it did previously. The users would typically have to be involved in this step to make this judgment

As should be evident from this overview, the process is best viewed as a collaborative activity involving multiple human stakeholders interacting with the system itself (the target of change) and potential computer-based support tools. For that reason, we have adopted an approach that attempts to *link* these aspects via a common model. In order to illustrate this integration in the rest of the paper, we use the following scenario.

4. REQUIREMENTS ENGINEERING FOR INTERACTION EVOLUTION

For the human-facing aspect of interaction evolution, we believe that novel or adapted Requirements Engineering (RE) methods offer a fruitful approach. The key to this claim lies in the provision of dynamically adaptive interaction frameworks that enable the realisation of these requirements via selection and configuration of components; this will be discussed further in Section 5.

However, most existing RE methods fail to offer the flexibility required in the home care domain. With people's care needs and living circumstances potentially changing over time, and the complex network of care that can influence the system requirements, RE methods need to be modified to cater for a combination of (1) multiple distributed and possibly conflicting stakeholder needs and (2) longer term configuration and evolution of these needs. The rest of this section sets out a set of requirements for home care requirements engineering, based on investigations we have carried out of current practice and needs in the home care domain.

Above all, RE methods should be capable of monitoring and adapting requirements [6] over longer periods of time as a person's care and living circumstances change. Requirements can and should be revisited to identify possible change or conflict. Decisions made on how the system should be set up or behave when the technology is first prescribed by the social worker may not necessarily remain supported as the person interacts with the device or system and realises that something about their care condition, their living space, or their relationships means that their initial requirements and needs have changed.

Ways to identify change may include (1) technology no longer being used or being used inconsistently, (2) a change in a person's care regime or medical condition, (3) a change in the living space and those sharing that space, or (4) a planned care meeting at a pre-prescribed point of time. If any of these things occur, original requirements can be reconsidered to see if recasting them would improve interaction with the home care system and/or the person's health and well being.

The following is a list of features that should be included or supported in RE methods [11] that allow for interaction evolution. We will use the home care scenario presented in Section 2.4 to indicate how this can be achieved.

(1) Identification of and engagement with appropriate stakeholders to elicit high quality requirements.

Appropriate methods for engagement with all stakeholders need to be explored further [11], [15]. Traditional focus groups and interview methods can be useful, especially with older home users. Fred and Shirley's social care workers on the other hand may want a more formal and metric way to record their requirements and prescribe the technology in conjunction with the engineers and designers of the assistive technology. Scenarios and role playing can also be useful when multiple stakeholders with varying backgrounds and experience are involved [15]. Novel methods have also been explored such as live interactive theatre which allows multiple stakeholders with differing levels of expertise, backgrounds and goals to state and discuss requirements using live acted out care scenarios [15].

(2) Participatory elicitation and negotiation.

As many of the people involved in Fred and Shirley's network of care as possible should be invited to contribute their requirements at an early stage before the prescription of technology. Early potential conflicts can be identified and potentially resolved socially during care plan meetings with social and health care professionals. Shirley and Fred should be able to state what they want the technology to do for them and professionals should be able to describe and demonstrate the devices, services, and interaction methods available to them.

(3) Distributed elicitation and negotiation.

Given the wide range of stakeholders identified [12] it is likely that many of them will be distributed in both time and space. So remotely located care staff or friends and family involved or interested in Fred and Shirley's care should be able to express their requirements for inclusion in the negotiation from their offices or home if necessary; Shirley's consultant across the city and Fred's son in Australia can both potentially be included in the requirements capture.

(4) Iteration affording rounds of eliciting, balancing and validating requirements.

In addition, all stakeholders should be able to restate their requirements over time as their needs or preferences change. So as Shirley's arthritis worsens speech input can be used instead of a touch screen for example (a change of interaction device and technique). And as Fred's memory declines, he can request increasing frequency of medication reminders (a modification of an existing technique).

(5) Prioritisation or weighting of requirements.

Different stakeholders may need to be given different priorities at different times depending on the context. If the client is perceived to be at risk to themselves or others, for example, then the social care or health care professionals' requirements may be weighted as higher than normal. If usability and acceptability is perceived to be the main factor in the introduction of a new device or interaction methods then the clients requirements may be given a higher weighting.

(6) Retention and traceability of requirements over time.

RE tools should support logging of the interaction requirements and allow appropriate ways for users to review previous and current requirements and their realisations (i.e., the implemented techniques). It might be beneficial for example to see which requirements have and have not been satisfied or to be able to try out a current requirement realisation. This could act as a tool to support traceability of a user's changing care needs over time and could be used in conjunction with the care assessment. This would be useful to evaluate and assess appropriate (and inappropriate) prescription of technologies.

(7) Annotation of requirements to enable both negotiation and traceability.

A tool for actually annotating the requirements either at the time of capture, at the time of change, or both, could also assist in assessing the success or failure of the assistive technology [3]. Allowing stakeholders to attach rationale to their decisions can support the negotiation process. For example, as Fred states his desire for 'medication reminders' he can annotate this with other assumptions and constraints such as 'must remind me more than once as I am always unsure if I got the first message', 'must be presented to the TV if possible as I find that the most useful way to make me remember' and 'send it to my mobile phone if I am not near the TV as I often go out to the shops just after lunch before my pill is due'.

(8) Identification and categorisation of requirements conflict.

Stakeholders will have different needs of and expectations of the home care system depending on their background and their motivations. For example, an Occupational Therapist for Shirley might see getting her more mobile as the main priority whereas a clinician might see the main priority as reducing her pain. Shirley's main motivation on the other hand might be neither of these. She may see independence as her primary requirement.

(9) Resolution of requirements conflict.

There should be a facility to support the negotiation of multiple requirements. This could be achieved for example by revealing each other's requirements in order that different perspectives can be explained and empathised with. Or it might be dealt with by assigning weights or priorities to different stakeholders and a tool could reason about the conflicting set of requirements. Outcome measures may need to be socially negotiated as the best clinical outcome might not always be preferred over the best well being outcomes.

(10) Correlation with other processes and work practices such as care assessment.

Given the constraints on resources of health and social care professionals, any tools or methods introduced must be perceived as beneficial in the first instance. They must also be perceived as having little or no impact on workload and time. Requirements methods should be lightweight enough to be easy to use yet rigorous enough to provide all the features mentioned. An added benefit of such tools is the ability to aid assessment and audit of the prescribed technology. For instance, it can capture what is prescribed and why and it can track changes in technology prescription and use as care need change.

5. SYSTEM SUPPORT FOR INTERACTION EVOLUTION

Our systems approach is to model both long term and short term changes within a *unified model* in order to support both types of change and to link them with the requirements engineering methods and techniques discussed in Section 4. In this way, the system should be able to identify and reason about change and/or support human reasoning, and offer configuration options to suit and therefore support the evolution of interaction.

5.1. Identify opportunities for change

We need to be able to identify the opportunities for change within a system. This can include identifying the devices that are available, which are currently in use and which have been added and removed recently to the home care system, as well as the available interaction methods or modality choices.

We define a *candidate for configuration* as a combination of devices, interaction techniques, modalities used and supporting components required to instantiate a new configuration. It is possible to determine the candidates for configuration by using a service discovery subsystem to detect which devices are available to the system at any given time. Ontology based service discovery systems [21] can provide additional reasoning on the devices available to allow for semantic knowledge about devices to be modelled directly within the service discovery system.

This style of service discovery works by allowing devices to register their availability as well as meta-data about the component such as its purpose or the ways in which it can be used. This service discovery allows the system to determine the set of opportunities for change based on device availability.

5.2. Reflect/judge alternatives

Once the options for change have been discovered it is necessary to reason about the available options and determine their suitability. We will discuss some exemplar types of reasoning here referring to the example scenario presented in Section 2.4.

In a homecare environment it is likely that users will have preferences for which devices or styles of interaction to use, but in a multi-user environment it is likely that Fred and Shirley will not have the same preferences all the time or in the same circumstances. Thus it is necessary to be able to model decision making based on potentially conflicting viewpoints on how to accomplish a task.

Fred and Shirley have different capabilities for interaction – Fred has difficulty hearing while Shirley has limited mobility. In this case speech dialogue based interactions may make sense for Shirley as it eliminates problems with physically interacting with a homecare system but may be an inappropriate choice for Fred. These conditions are also likely to change over time and will need to be revisited periodically or when events force a change and this must be supported as an additional interaction within the system.

When a visitor is present, such as Fiona or the social care worker, this contextual change will affect the choice of method of delivering information to the couple. Reminders about medication or household chores may need to be suppressed while other people are present in the home – this problem is exacerbated when the information to be presented to the occupants is of a confidential or embarrassing nature. This requires that contextual information be included in the decision making process. To support these, and other, types of decision that would need to be made we argue that it necessary to provide support for several different techniques for configuration which allow these decisions.

It must be possible for a user to manually configure interaction such that they are the ultimate arbitrator over a configuration and can have the maximum level of control at the expense of dynamic adaptability. It must also be possible to include several analytical reasoning components which operate over the set of possible configurations. Examples of these might be location, preferences or contextual results such as ambient environmental factors which can be directly measured, analysed and decided upon. It must also be possible to include techniques which interact with the user on an ongoing basis to maintain relevance as opposed to a "fire and forget" configuration which would become less appropriate as conditions changed.

It may be possible to assess alternatives based on a record of their previous usage (e.g., identifying alternatives that have proved successful or otherwise in similar circumstances). This may be based on logging of user-system interactions or a record of special events of interest (indicators of satisfaction or dissatisfaction) about the current configuration. In addition to using this information to evaluate alternatives, it may also be the basis of further evaluation, trying out new configurations on an experimental basis.

Collaborative techniques, ranging from collaborative filtering [8] to negotiated choices between interested parties, are clearly important in a multiuser home and it is necessary to support this ability to allow for conflicting sets of values to be combined to decide on the best configuration to use.

We discussed several techniques in this section that range from fully manual techniques with no user interaction to techniques which involve ongoing interaction with the user as their primary concern. Clearly not all of these techniques are appropriate in every situation but we regard the ability to allow for a range of manual and automatic reasoning techniques as a minimum requirement for an effective decision on the correct configuration to use in making both short and long term changes.

To do this we propose that a selection of these techniques may be present at any one time within a homecare system, of which only some may be used. Each technique could derive its preferences and provide its rankings of the suitability of a configuration to a central configuration manager which can combine the votes to produce a solution.

This approach shares some similarities with the process of voting in an election. There are many voters, each with different ideas of how things should work and who have each used different techniques to arrive at their conclusions. These votes will be in conflict with each other and some may be wrong or inappropriate choices for the situation. Likewise, homecare systems have multiple users with different ideas and some votes may be submitted by automated techniques as delegated to by human voters and different techniques can be used to derive votes.

5.3. Make decision/implement

Since the act of choosing an interaction style inherently involves conflict between different parties a voting system is the natural choice of modelling this as it is the current standard for resolving these issues in the real world.

Multiple voters would be present in a home care system and their votes must be combined to make a choice of interaction. To do this we propose the use of a technique similar to electoral systems, which may be based on modern voting systems, which are capable of taking the votes and choosing the winner(s) of an election.

Using this approach allows us to combine the votes from various sources, even if they are conflicting or contradictory, and determine a solution.

As with real election systems there are different benefits and drawbacks resulting from the choice of voting system used to combine votes. Common issues arising from voting system are preventing dictatorship of one voter, maintaining pareto efficiency and independence of irrelevant alternatives. However, we are not necessarily limited by the same constraints – for example in some situations it may be the case that one voter's opinion actually does matter more than others.

To cope with the issues presented by different types of voting system we propose that the electoral system itself would also be dynamic and there may be multiple such systems in use at the same time – both as multi stage elections as well as separate elections for different interaction tasks.

Unlike a traditional election system we can also choose which voters are allowed to vote in a particular election allowing the choice of which decision making techniques to use.

We believe that this offers a rich representation of the different techniques involved in the decision making process and allows a natural expression of how each participant in a situation is treated.

5.4. Iterate/repeat

Over time new criteria will emerge that will need to be reasoned about in order to choose the best candidate for configuration, examples of these might include new people or devices moving into the home or a change in what aspects of the candidates are really important. To do this it must be possible to add new techniques or change the techniques in use within the home, we approach this by allowing additions or removals from the active election models at runtime.

The concept of ongoing re-evaluation, discussed previously, requires a process of evolution to improve the situation over time and through changing circumstances. To accommodate this it must be possible to decide when it is appropriate to perform these evolutionary steps. It may be desirable to change the active configuration as soon as a new device or context change occurs, but in some circumstances it may be desirable to limit the number of changes that take place or to cause them to occur at a fixed time or after a certain other event has taken place.

We model this by allowing voters to change their mind on how they wish to cast their votes and signal this as a notification to the election system. The election system may then immediately call a new election or may instead impose limitations on the frequency of re-elections.

As this approach is continual and applied on an ongoing basis this allows for an iterative decision making process to support evolution of interaction within the home. This design for system support builds upon the ideas for evolution as multiple related instances of personalization or customization by allowing for multiple instances of reflection and judging of alternatives performed by voters which are capable of individually reasoning over the candidates for evolution which are then combined to allow for decision making to take place.

6. PROOF OF CONCEPT AND VALIDATION

As a concept demonstrator we have designed a home care system framework that incorporates both support for an evolutionary requirements process and software components to support the dynamic nature of home care systems and the interaction evolution as described in Section 3.

The software approach used in this framework (see Figure 3) is based upon application tasks, similar in structure to ConcurTaskTrees [16], which can achieve the high level goals of the system (e.g. monitoring some sensor streams, notifying the user about relevant events) while remaining interaction style independent. The Interaction Manager component is responsible for mediating the choice of interaction configuration using the techniques discussed in Section 5; this includes connecting the tasks to appropriate input and output devices as well as instantiating supporting subtasks required.

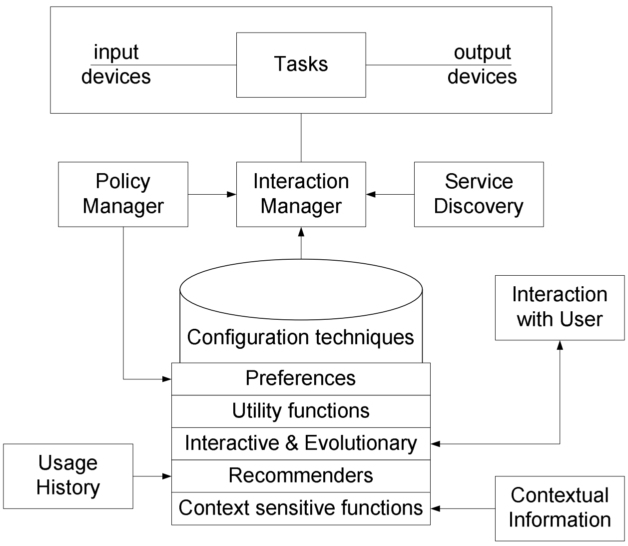

Figure 3. System Architecture

The system includes a representation of policies which can specify rules to coordinate the presence of application tasks within the system. The Interaction Manager may be triggered by these policies; either as a result of ongoing policy review or as a result of changes made by the user to the policies. The interaction manager relies upon a Service Discovery system to determine the available devices it may use. Several configuration techniques can be used by the interaction manager to perform this role.

Configuration techniques may further rely on additional information (such as usage history or contextual information) or may initiate further interactions with the user (in the case of human driven techniques). The interaction manager may additionally be triggered to review the choice of configuration by the techniques currently in use – allowing rapid reconfiguration when necessary.

We have implemented an initial prototype of this framework, including the interaction manager, which has been demonstrated to be able to use several of the techniques discussed (in Section 5). The framework is currently being developed to add more techniques and allow them to be used as well as structural support for combinations of techniques in election schemes.

Figure 4. Prototype Demonstrator

An early demonstrator application built on this framework is shown in Figure 4. This demonstrator is capable of selecting an appropriate interaction technique for a monitoring task from a set of available interaction techniques. In this demonstrator the temperature is to be presented to the user on one or more of 3 devices; a console, an emulated TV and a speech synthesis system (hosted on an emulated mobile device). The system can choose which of the devices to deliver the temperature information to based on their availability, user preferences or the user's location with the ability to switch between selection techniques at runtime.

The features that need to be supported in requirements methods for home care have been identified. An application is being prototyped in conjunction with stakeholders that can act as a tool to support many of the features described in Section 4. Case studies such as the scenario in Section 2.4 are being used to explore and validate how these features can support the process of evolving, multi-stakeholder requirements. In particular, we are working with stakeholders to evaluate the process of deferring requirements as care needs change over time.

7. CONCLUSIONS

This paper argues that due to the dynamic nature of home care, novel methods are required for the development of home care systems. The paper details the features that characterise home care and illustrates the complexity of the home care domain. It suggests several features that should be available in requirements engineering for home care technology and describes methods for system support for interaction evolution in home care systems.

Future work on the requirements engineering techniques will involve continued development of a tool and case studies to validate the value of the features detailed in Section 4. Development of the computer-based support will focus on implementation of support for management of multiple evaluation functions concurrently as well as allowing combinations of evaluation functions to be used together.

We believe that the approach of explicitly modelling evaluation criteria as functional components allows for a more consistent approach as well as more flexible combinations of criteria. We have implemented a prototype incorporating these ideas in the home care domain. Our current prototype is capable of reacting to changes in context and user preferences and determining the correct output modality and device to use based on the results of voters.

We are continuing to develop our ideas and concepts within the home care domain and specifically with interaction methods as it offers a rich variety of challenges such as highly dynamic and complex environments which change over time but this research is applicable in principle to a wider range of situations involving multiple stakeholders and decision making within interactive systems.

8. ACKNOWLEDGMENTS

This research was carried out within the MATCH (Mobilising Advanced Technologies for Care at Home) Project funded by Scottish Funding Council (grant HR04016).

9. REFERENCES

[1] Al-Rawas, A. & Easterbrook, S. (1996) Communication Problems in Requirements Engineering: A Field Study, *In Proceedings of the First Westminster Conference on Professional Awareness in Software Engineering*, Royal Society, London, 1-2 February 1996.

[2] Bellotti, V. and K. Edwards (2001). Intelligibility and Accountability: Human Considerations in Context-Aware Systems. *Human Computer Interaction* 16: 193-212.

[3] Decker, B., Ras, E., Rech, J., Jaubert, P., Reith, M. (2007) Wiki-Based Stakeholder Participation in Requirements Engineering, *IEEE Software*, March/April 2007, pp. 28-35.

[4] Department of Health (2006). Our health, our care, our say: a new direction for community services. London: The Stationary Office.

[5] Dourish, P. (1995). Developing a Reflective Model of Collaborative Systems. *ACM Transactions on Computer-Human Interaction* 2(1): 40—63.

[6] Fickas, S. (2005) Clinical Requirements Engineering, *Invited paper at the 27th International Conference on Software Engineering*, St. Louis, May 2005.

[7] Garde, S. & Knaup, P. (2006) Requirements engineering in health care: the example of chemotherapy planning in paediatric oncology, *Requirements Engineering (2006)* 11: 265-278.

[8] Goldberg, D., D. Nichols, et al. (1992). Using collaborative filtering to weave an information tapestry. *Communications of the ACM* 35(12): 61-70.

[9] Liu, X., Veera, C. S., Sun, Y., Noguchi, K., Kyoya, Y. (2004) Priority Assessment of Software Requirements from Multiple Perspectives, *In Proceedings of the 28th Annual International Computer Software and Applications Conference* (COMPSAC'04).

[10] MacLean, A., K. Carter, et al. (1990). User-tailorable systems: pressing the issues with buttons. *Proceedings of ACM CHI'90*, Seattle, Washington, USA, pp. 175-182.

[11] McGee-Lennon, M.R. (2008) Requirements Engineering for Home Care Technology Design, *To appear in Proceedings of ACM CHI'08, Vol. II*, Florence, April 2008.

[12] McGee-Lennon M.R, and Gray P.D. Including Stakeholders in the Design of Homecare Systems: Identification and Categorization of Complex User Requirements, *INCLUDE Conference*, Royal College of Art, London, April 2007.

[13] McGee-Lennon, M., Wolters M., et. al. (2007). Audio Reminders in the Home Environment. *International Conference on Auditory Display*s, Montreal, Canada.

[14] Miskelly, F. (2005) Science and Technology Committee, House of Lords, UK Parliament, *http://www.publications.parliament.uk/pa/ld200506/ldselect/ldsctech/20/20we16.htm.*

[15] Newell, A.F., Carmichael, A., Morgan M., and Dickinson, A. (2007) The use of Theatre in Requirements Gathering and Usability Studies, *Interacting with Computers*, 18 (2006), Elsevier, pp.996-1011. ISBN: 09535438.

[16] Paterno, F., C. Mancini, et al. (1997). ConcurTaskTrees: A Diagrammatic Notation for Specifying Task Models. *Proceedings of the IFIP TC13 International Conference on Human-Computer Interaction*: 362-369.

[17] Pinelle, D. & Gutwin, C. (2001) Collaboration Requirements for Home Care, University of Saskatchewan *HCI Lab Technical Report*, HCI-TR-2001-01.

[18] Schilit, B. N. and M. M. Theimer (1994). Disseminating active map information to mobile hosts. *Network, IEEE* 8(5): 22-32.

[19] Tinker, A. & Lansley, P. (2005). Introducing assistive technology into the existing homes of older people: feasibility, acceptability, costs and outcomes, *Journal of Telemedicine and Telecare*, 2 (suppl 1), pp 1-3.

[20] Toivanen, M., Hakkinen, H., et. al. (2004) Gathering, Structuring and Describing Information Needs in Home Care: A Method for Requirements Exploration in a "Gray Area", *MEDINFO 2004*, Fieschi et. al. (Eds.), Amsterdam: IOS Press, pp. 1398-1402.

[21] F. Wang, L. S. Docherty, K. J. Turner, M. Kolberg and E. H. Magill, Services and Policies for Care At Home, in J. E. Bardram, J. C. Chachques and U. Varshney, editors, Proc. 1st. Int. Conf. on Pervasive Computing Technologies for Healthcare, pages 7.1-7.10, Institution of Electrical and Electronic Engineers Press, New York, USA, November 2006.