Personal and Contextual Requirements Engineering

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Abstract

A framework for requirements analysis is proposed that accounts for individual and personal goals, and the effect of time and context on personal requirements. The implications of the framework on system architecture are considered as three implementation pathways: functional specifications, development of customisable features and automatic adaptation by the system. These pathways imply the need to analyse system architecture requirements. Different implementation pathways have cost-benefit implications for stakeholders, so cost-benefit analysis techniques are proposed to assess trade-offs between goals and implementation strategies. The use of the framework is illustrated with two case studies in assistive technology domains: e-mail and a personalised navigation system.

1. Introduction

Functional requirements have traditionally been considered as specifications that satisfy the goals of the majority of users. Although the concept of establishing sub-sets of requirements matched to different stakeholder groups has been advocated in the viewpoint tradition of requirements engineering, e.g. VORD [1,2], the concept of specifying requirements for individual users has not been explored. It is worth noting that in human computer interaction, requirements are seen as an individual concern for customising the user interface and matching the mix of functional requirements to individuals [3].

Variability and specialisation of generic requirements to fit more specialised usage domains has been investigated in the product line literature [4] as variation points that specify where generic requirements may be tailored. The individual dimension of requirements has been partially addressed in the i* modelling language where the capability and abilities of agents can be specialised to model the skills and preferences of individuals [5] allowing requirements for individual users to be matched to ability profiles. Recognition that requirements may change over time because the system environment or context changes has been explored in Requirements Monitoring [6], where monitors track system conformance to a requirement over time to evaluate the match or mismatch between system operation and particular goals.

In spite of these initiatives, no comprehensive method for analysing individual or contextual requirements has been proposed. We argue that a framework for individual-level requirements is necessary as technology products become personalised. Furthermore, with the growth in ubiquitous computing, requirements may not only vary by individuals but may also change over space and time in location-aware systems [7], [8]. In this paper we propose a framework for Personalised and Contextual Requirements, a method for their capture incorporating a trade-off analysis to decide how personal requirements should be implemented. The following section describes related work, then section 3 the framework and implications for architectural requirements; section 4 applies the framework and method to two assistive technology case studies, followed by the cost-benefit trade-off analysis in section 5; the paper concludes with a brief discussion.

2. Related Work

Several requirements taxonomies have been proposed that classify requirements into different categories of non-functional requirements [9], [10], functional requirements and services [11], [12]; indeed, taxonomy is an accepted means of managing requirements in RE tools. However, previous taxonomies have classified requirements according to their subject matter rather than to the agents they pertain to. Monitoring the implemented system against requirements so it can adapt to evolving requirements over time was proposed by [6], while the impact of location on requirements was partially explored in the Inquiry Cycle [13], where the location could influence the acceptability of system output. However, there has been no systematic treatment of contextual influences on requirements.

Group-level requirements are familiar in RE methods, e.g., SCENIC [14], Volere [2]. However, change over time is not explicitly modelled apart from concerns over requirements creep and evolution. Change in location is rarely specified, even though globalisation and cultural effects on products are known to be important [15], [16]. Understanding cultural impact on requirements is still in its infancy, although ethnographic studies suggest that very different requirements arise *in situ*. For instance, privacy requirements for automatic teller machines are very different between eastern and western societies [17].

The mutability of requirements to suit individual users has been accepted in human computer interaction where a distinction is drawn between generic task support requirements (i.e., functional requirements) and system features which can be customised for individual user needs [16], [18]. Two architectural approaches to handling personal requirements are adaptive systems in which the system monitors the user's behaviour and then changes services or the interface look and feel to match the user's needs; and adaptable systems where customisation is user-controlled at design time [19]. End-user programming applications often employ mixed initiative dialogues and fusion of these two strategies [20]. Temporal and spatial change in requirements has implications for requirements capture and system architecture which have yet to be fully explored in the RE community.

3. A Framework for Personal, Contextual RE

The motivation for the framework is to describe not only functions that meet people's goals but also characteristics of the users, and how they would like computer systems to achieve their personal goals. The framework accommodates matching requirements to individual needs, how individual needs change over time, how requirements evolve as people learn and their ambitions grow, and finally the needs for universal accessibility and the ageing user population through universal accessibility [3].

We propose a three-layer framework for personal and contextual requirements, with two change dimensions of location and time which act on each layer, as summarised in figure 1.

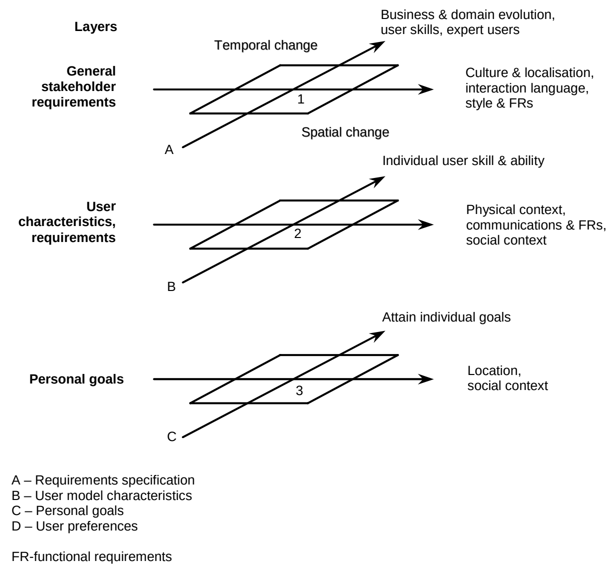

Figure 1. Personal requirements framework and change dimensions

The layers progress from general requirements at the user group level, to individual user characteristics, and to personal goals. At each layer requirements vary over space and time, to encourage not only analysis for evolving requirements but also contextual influences. Contextual influences may vary from the cultural and social system environment to effects of specific locations. At the top level, the change context affects requirements in cultural adaptation of products, e.g. language localisation, change in business processes between European and American models. Time influences how requirements change as business processes evolve and product functionality becomes more complex [21]. At this level the architectural implications are (1) design for customisation to accommodate context effects (language localisation), (2) design of monitors and adaptive functions for mobility, (3) customisable or adaptive user interfaces to deal with user skills change, and (4) a flexible adaptable architecture to evolve as business processes change. Requirements in the user characteristics layer model the needs of the individual person for interacting with technology, and are partially independent of the application domain. User characteristics are an individual user ability profile, which could customise the means of human computer communication for the elderly, disabled, people with different learning styles, etc. Architectural implications are for choice and adaptive communication modalities. In the general user population, baseline knowledge will influence content in website and CAL applications, while in assistive technology this layer is key. Such profiles will influence the delivery of functional requirements at the generic and personal goals layers.

Location affects user characteristics as people's abilities change with place, such as the need for adapting communication modalities in noisy environments, while people's skills and abilities change over time as they adapt, for example, to computer-based training. Personal goals are held by individuals and become important in applications where customisation of individual service is a prime objective, e.g. learning and training applications, entertainment and games, personal knowledge management and assistive technology. While some personal goals may be satisfied by general functional requirements, we argue it is important to analyse requirements from an individual viewpoint, especially in domains where customisation is important. At the user goals level, change over time depends on the stability of people's wishes, while the contextual interaction may be influenced by how their goals affect location and social setting (e.g. social settings may influence privacy and hence display of personal information).

Table 1. Requirements framework and effect of time and location

Requirements level	Examples	Change over time	Context/location change
General stakeholder requirements	Stakeholder-tailored versions of products, product lines	Expert users need power functionality, product lines	Globalisation: requirements tailored for countries, cultures, language
User characteristics requirements (interaction and communication)	modalities & capabilities: accessibility, ageing, but also learning, cognitive and social abilities; individual ways of working- task requirements	Individuals learn and become skilled, adapt to new ways of working, individual styles of interaction	Needs change with context in mobile applications
Personal goals may be functional or non-functional requirements	Personal needs for services, task support, attainment goals for self, linked to motivations	Personal goals have different attainment time scales	Personal goals can be sensitive to physical and social setting, e.g. privacy and social setting in group/alone

The type of requirements at each level and their interaction with the change and context dimension are summarised in table 1.

Contextual enquiry by surveys and prototype evaluations in different cultures are necessary to specify product versions for different cultural markets. The architectural considerations are design of products with variation points so they can be configured for different cultures, although the extent and nature of cultural adaptations are still poorly understood.

User characteristics are important because of the ageing population and disability legislation now enacted in most OECD countries. Models of individual users have always been important for educational applications where the abilities of each individual are matched to content and pedagogical delivery. The user characteristics layer describes the users' physical and mental abilities, so this affects requirements for interaction directly as well as functional requirements indirectly. User characteristics requirements imply the need to develop individually tailored versions of applications that are either configured for the user at design time or automatically adapt to the user's needs. Change over time occurs as people learn system functions and need new styles of dialogue as they become more skilled. Slower change, e.g. age-related declines in cognitive and motor abilities, necessitate change in magnified visual displays and slower response times. The range of individual user abilities needs to be analysed against inventories of modality abilities, knowledge and capabilities, and general cognitive abilities. User characteristics are assessed by psychology-based questionnaires and tests to measure cognitive, physical and perceptual abilities (e.g. [22]) or by interviewing users to gather information on general abilities, experience and skills [23]. Assessing the user's characteristics also produces an inventory of specific skills that we assume the user possesses to successfully operate the system given the user interface requirements for communication and interaction which will be implemented. These user characteristics are a complementary specification of what we can reasonably expect of the user (individually and collectively), and what needs to be implemented to enable effective use of the system.

Personal goals can be realised either by design or customisation, e.g. by configuring the toolbar in drawing applications, or by automatically adapting solutions to the individual's needs. Personal requirements may be contextual and location sensitive. For example, non-functional requirements such as privacy, security, and information accuracy can interact with functional requirements, such as information display, according to location. Some personal goals may be implemented as preference settings under user control, e.g. the presentation of information (graphs and/or tables), and aesthetic details such as screen savers and ring tones on mobile phones. Personal goals are assigned attainment levels on a 1 to 5 scale so we can assess how well the system and user have approached the ideal achievement of each goal. The attainment levels also specify the assumptions associated with each goal, such as the necessary customisation of the software, modification to requirements (i.e. re-design) and user training.

Consideration of personal and contextual requirements produces a new set of meta-level requirements: the need to develop user models, monitors and mechanisms for adaptive systems or customisation editing/design facilities. The implications of personal requirements on architecture are summarised in figure 2.

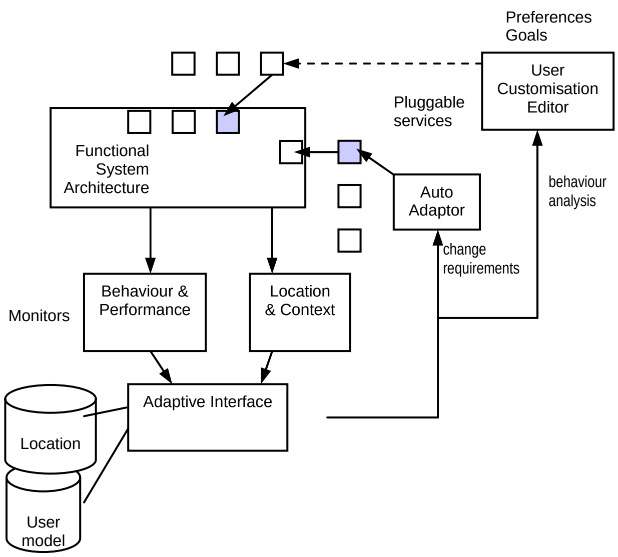

Figure 2. Relationship between the requirement layers framework and system architecture

Three implementation paths are suggested for user characteristics requirements and personal goals: (1) development as conventional system functions, (2) implementation as user-customisable features, and (3) as automatic system adaptations. Figure 2 illustrates the architectural considerations of the second and third paths, which also necessitate specification of architectural requirements according to the chosen development pathway. Monitors capture information on the users' behaviours, errors, location and environmental context. Intelligent interpreters have to infer higher-level states from monitored data either using knowledge of the domain and user to make inferences, or via learning mechanisms. The use of such inferences then depends on the choice of either (a) automated adaptive mechanism, or (b) providing information to help the users make customisation decisions supported by editing and configuration facilities. The system architecture has to be modular and configurable following product-line specification to enable change via either route. Acquisition dialogues may also be necessary to capture personal goals and help user-driven customisation from a toolkit of services. Alternatively, the system selects services to fit the user's goals. The implementation pathways have different cost-benefit trade-offs for designers and user stakeholders. For instance, customisation imposes a learning burden on the user who has to learn how to customise the application. Cost-benefit analysis techniques are described in section 5.

Case study I: e-Mail for Cognitively Disabled Users

We applied the personal RE framework to two projects, an e-mail system [25] and a navigation support system for cognitively disabled users [34]. The top-level goals in both projects are to empower these users socially and personally so they can communicate with one another and use public transport to meet others, etc.

Table 2. Requirements framework for the TAL e-mail application illustrating one personal profile out of six users

Requirements layer & goals	Functional requirements	Temporal change	Spatial context
Group level: cognitively disabled users	Compose, send, read, delete, reply to message, incoming message summary, identity of sender	More sophisticated functions may be needed as confidence grows, e.g. save, print message, folders, copy, forward, add address	Privacy requirements use in public place may be inhibited
User characteristics: Michael's problems are attention; initiation, short-term memory	Reminders, hints, simple commands and displays	Some improvement learning more commands	None
Personal goals: Learn new skill (e-mail); Communicate with friends and family; Improve social skills; Expand range of social partners	Supportive learning environment, training. Controlled address list, e-mail filters. Style checkers on message, review function. Solicit new partners	As skills improve may need to add: - new functions - more partners in list - improve style checkers	Failure anxiety in public use

The requirements for the (Think And Link) TAL e-mail case study are illustrated in table 2. The first layer gives the group-level view of an e-mail system for cognitively disabled users, which is a simplified version of standard e-mail functions. The subsequent layers focus on an individual, so space precludes describing the breadth of requirements (for the six individuals in the study) in this paper, although the diversity of requirements encountered will be discussed.

At the group level, requirements were gathered by interviewing and focus group techniques with reference to the functions provided by existing e-mail products. Requirements have to take account of the diversity in cognitive disability, which include language problems (aphasia, dyslexia), working memory and wandering attention, planning and executive function disorders, poor learning and problem-solving abilities. These lead to requirements that supplement the e-mail application requirements with communication and support needs for this user population, e.g. monitors to keep them on task, reminders and task-completion lists, learning facilities and wizards. Note these requirements are present for all users, in particular to support learning and help systems. However, in assistive technology communication and learning support, these requirements assume a more prominent role. Change over time can be anticipated as users acquiring skills, although the exact nature of change can only be measured at the individual level. We have not illustrated requirements in detail for other stakeholder groups at this level, but care providers and family respondents are two key groups who have requirements for e-mail communication and abilities to monitor the cognitively impaired users.

At the individual characteristics layer, requirements were gathered by the CORE method [24-25], which uses a combination of user interviews, expert judgement and performance tests for application and computer operation tasks. This creates a capability profile which is employed to select a sub-set of the group-level communication and learning support requirements to match the individual, as "prescription" for his/her profile. The requirements have to be inferred from the clinical profile, so user characteristics are similar to non-functional requirements in that they have to be satisficed by computer support functions or training. In the e-mail domain, we developed a 50-item skill inventory that complemented user characteristic requirements, rating each skill on a 1 to 3 scale as missing/ sporadic/possess. [25]. In Michael's case (not his real name), attention-focus and short-term memory problems indicated requirements for reminder agents to help with task initiation. Some examples of his skills profile were adequate skills for motor coordination – using keyboard, mouse; visual acuity – and screen use. Personal goals can be non-functional in nature in that they set aspirations which Michael wants to achieve. The attainment scale for achieving the overall personal goal "to use e-mail" was set in consultation with the user, to produce the following list:

- Level 1 (not attained) not able to learn how to use e-mail even after 1 month's training and practice.
- Level 2 can e-mail, but only with continuing prompting and help by a co-present helper.
- Level 3 can e-mail with some prompting and help (machine-based, and carer on call).
- Level 4 can e-mail with no prompting or help.
- Level 5 (fully attained) can teach others how to e-mail.

Turning personal goals into specific requirements needs design suggestions from the requirements engineer. Furthermore, some solutions may be manually implemented in the social system, such as soliciting new e-mail partners who will then be registered by adding them to Michael's recipient list. Change can be tracked at the individual level either by automated monitoring software, e.g. the REQMON system [26], or by interview sessions with the users and care providers. Automated monitoring is economical but limited in the inferences that can be made from low-level data streams, e.g., messages sent, distribution of message by partners, words per message, latencies and time to compose messages, etc. Currently we intend to use latencies to drive a simple task-list reminder function, while other monitored data is collected for manual analysis. Interviews will be employed to monitor the change in personal goals over time, for instance if Michael's confidence grows, new partners and functionality (print and save messages) may be added to his configuration.

Case Study II: Navigation Support System

The requirements for the second application are summarised in table 3. In this case, the top-level goal was to help individuals make more unassisted journeys by all modes of transport: bus, taxi, walking, or community mini-van. The personal goals for six users in this case study were to increase their independent mobility for social meetings with friends, shopping, recreation (cinema, bike rides) and volunteer work [34].

Navigation is a demanding task for most people. Possible requirements at the group level are for navigation support, e.g. in-vehicle route finding, providing maps, route-following instructions, location of self, re-orienting help when lost, progress indicators, pathway history, frequently followed routes, highlight key landmarks, and viewpoint controls. For our users only a sub-set of this functionality would be appropriate in order to keep the system simple and easy to learn. Time-sensitive requirements are task-initiation support by schedule reminders since subjects often forget to make regular scheduled journeys and mistake their destination. Temporal change also has to account for learning effects, adding new routes, and more importantly the dynamic change of instructions according to the subjects' location. Location is vital for delivering appropriate instructions, and triggering re-orientation help if users deviate from the expected route.

Table 3. Requirements for the GO navigation support application

Requirements layer & goals	Functional requirements	Temporal change	Spatial context
Group level: enhance independent mobility	Schedule reminder, route instructions, route map, bus transport guide	Learning effects – add new routes, select route	Appropriate instructions, map display, re-orientation help
User characteristics: short term memory loss, forgets purpose, location, time and destination	Schedule reminders, route following walking, bus journey instructions, destination reminder	Add new routes, instructions for new modes of transport	On route tracking for appropriate instructions, destination reminders, off route re-orientation
Personal goals: social meeting; recreational trips; journeys to job	Fixed route support, reminders for regular journeys, new routes	As above. Add new routes	As for user characteristics plus privacy of instructions in public places

Requirements for individual users were captured using an adaptation of the CORE method with Wizard of Oz simulation of the route-following task. Normal and traumatic brain injury (TBI) users were asked to follow the navigation instructions given on a Personal Digital Assistant (PDA) display with speech in an earpiece. Two observers followed the user, one simulating the navigation instructions and dialogue using wireless communication between PDAs, with the other acting as an ethnographer recording user behaviour, problems and carrying out problem diagnosis interviews. This produced individual requirements profiles as well as contributing to the group-level requirements gathering.

At the individual user level we focus on one user, John, whose clinical characteristics are severe short-term memory loss leading to attention failure, forgetting to turn up for regular trips, forgetting purpose of a journey and the destination. The personal requirements for this individual are clear instructions for a limited set of routes, bus journey guide, reminders for timetabled journeys and monitors with reminders when the destination is close. John is relatively young so there is a reasonable chance that he may improve with experience, hence the system may need to be adapted with more advanced facilities and more routes. Spatial context implications are similar for all users, namely the need for tracking to make sure the individual is on the route; re-orienting help is given if not. John's personal goals were increased independent mobility for meeting his family, recreation (sightseeing, cinema, festivals and undertaking his volunteer job at the YMCA). These goals specify the instructions and information content (route maps, landmark cues); however, while some routes are fixed (family, job) the recreation trips are time and location variable, so there is a need for his carer to configure new routes.

Requirements for the navigation system were several monitors for location and progress tracking using GPS, progress tracking with a pedometer when walking, simple location awareness by light intensity and noise levels to improve reasoning about location when off-track (e.g., noisy or quiet streets, in building or outside). The adaptive sub-system is a key component because of the need for re-orientation and error correcting dialogue, so in this application system initiative will be used to help the user to regain the route, with instructions on looking for local landmarks and re-orientation. This will be backed up with a simple "find me" button for emergencies, connected directly to a care provider who can locate the user's approximate position with GPS. We are also considering voice communication to the carer to help reassure the user.

When we proposed technical solutions for personal requirements it became clear that these solutions had different impacts on individual users, and on other stakeholders. This led us to consider how the costs and benefits of different technical solutions might be assessed.

4. Cost-Benefit Analysis

Personal requirements at all levels imply a cost to individuals, either in customising the system themselves or in adapting their behaviour to a system that has changed automatically. For example, the costs of learning and using a computer system can outweigh the benefits for our TBI users even though the social and personal self-esteem rewards for many individuals are very important. The chosen implementation pathway also influences the distribution of costs and benefits between users and designers. For instance, configurable applications outsource design effort to the user. Furthermore, trade-off between the user's costs and benefits influence other stakeholders, particularly the care providers in our case studies. A conventional RE approach would be to use design rationale or goal modelling to investigate such trade-offs. Hhowever, such approaches do not afford comparison. To address this problem we propose a simple cost-benefit modelling technique that supplements design rationale or goal modelling. The technique consists of:

- Estimated benefits of achieving the desired goal. In our personal RE framework this will be assessed as a collective group or individual benefit according to the type of goal.
- Costs of each design alternative (sub-goal/functional requirement) proposed to achieve the goal. We distinguish between costs of learning to use the system, operational costs imposed on the user, and costs imposed on other stakeholders by that solution.

- Cost penalties if the solution alternative in question does not achieve the goal. This is a measure of reliability, as a composite assessment of the probability of failure, the severity of impact of failure, and the cost of recovery.
- Other NFRs can be added as potential costs if they are infringed. Alternatively, the achievement of NFRs may be considered to be part of the benefit of achieving the overall goal.

Benefits are assessed by first asking users to estimate the potential satisfiability of the goal by the proposed technical solution (on a 1-10 scale). Benefits may also be assessed at the user characteristics level by expert judgement of value to the individual and how the system functions might fulfil their motivations, e.g., self-esteem, learning, social inclusion, etc. User costs are learning to use the system, operational effort, and cost or error recovery, which are added to indirect costs of customisation effort, and learning how to use customisation facilities. Costs may be estimated by requirements engineers, based on observations of user problems, or by interviews with users to acquire their perception of learning and operational cost.

Benefits estimate the potential for a given design option achieving the goal. A simple percentage-satisfaction metric is calculated using the benefit estimated on a 1-100 scale, depending on the probable contribution of the solution alternative to achieving the higher-level goal, minus the sum of all the costs:

$$\% \text{ Satisfaction} = \text{Benefits} - \text{sum}(\text{costs}^{1-n})$$
$$\text{where sum max}(\text{costs}^{1-n}) = 100$$

The analysis also guides functional allocation decisions, i.e. whether to automate a requirement, or implement it partially and supplement the computer system by training the user, or allocate the duty to another stakeholder.

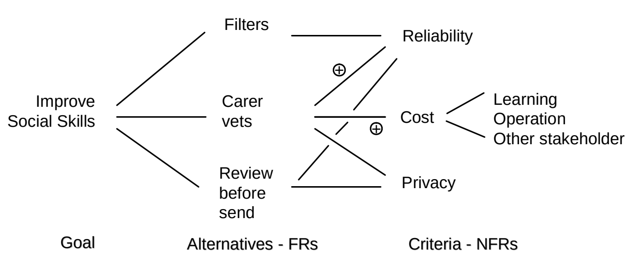

Figure 3. Design Rationale diagram for the goal Improve Social Skills, using gIBIS notation [27]

For example in figure 3 the options for achieving the Improve Social Skills goal for Michael are to implement filters to trap any anti-social words and phrases with a stop list and style checker, or to add an enforce-review-before-send so Michael has to read and check his message before sending, or to send his message to his carer so he/she can check it for any offensive words or phrases. The non-functional requirements or argument criteria that assess the trade-off are the costs of implementation, the reliability of attaining the goal, and avoiding infringing on Michael's privacy.

A sample of the cost-benefit analysis for the Improve Social Skills goal is given in table 4.

Table 4. Cost benefit analysis for the Improve Social Skills personal goal

Alternative solutions		Filters	Carer vets	Review before send
Benefits		50	80	30
Criteria: costs	Operation	5	0	6
	Learning	2	0	7
	Reliability	9	5	10
	Other stakeholders	0	20	0
	Privacy	0	20	0
Net cost/ benefit		34	35	7

Benefits are estimated on a 0-100 scale, while costs are scored on 100/cost-variable, so in table 4 each cost is rated on a 1-20 scale, yielding a potential net benefit of zero with maximal costs and maximum benefit, and a negative trade-off if costs are high and benefits small. Operation and learning costs map to the design rationale diagram, as do reliability of the option being effective, and privacy. The carer vetting outgoing e-mails has the highest probability of achieving the goal, compared to filters which have a 50% chance of preventing unwanted e-mails, while the review-before-send relies on Michael's diligence in checking his messages before sending. This was judged to be more risky. For Michael the costs of operation and learning were small for the filters option, but more effort would be required for reviewing messages. The carer option was cost-free for him, but a burden for the carer. The potential impact of errors reflected the cost of not achieving the goal and the costs of recovery, i.e. apologising to offended friends and family. The downside of the carer option becomes clear when Michael's privacy is considered, since all his e-mail would be available to the care provider. Furthermore, this option imposes a considerable workload on the carer who has to check all outgoing e-mails and edit them. These penalties reduce the net benefit of this option to nearly the same as the filters option even though it has a higher initial benefit. While the estimates are subjective judgements, the value of the cost-benefit analysis is in using it as a sensitivity analysis tool to explore requirements trade-offs.

The design rationale for a second goal, Keeping the User on Track so their attention does not wander, is shown in figure 4.

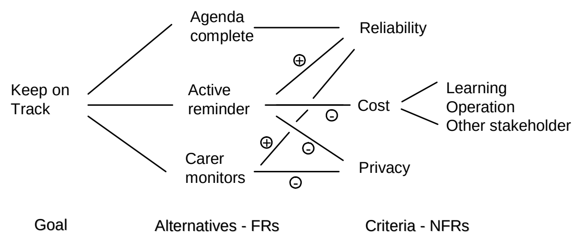

Figure 4. Design rationale for the keep on track user goal

The issue in this case is helping the user to complete the e-mail composition task, when users' attention frequently wanders. Design alternatives are to (a) display a task completion agenda, similar to reminders in standard office products, (b) to make the system actively monitor and remind the users if no action had been taken after a set time period, or (c) the carer could monitor the user via a video link. The criteria or costs by which the alternatives can be judged follow the pattern we describe earlier. The cost-benefit analysis for this user goal is given in table 5.

Table 5. Cost-benefit trade-off analysis for the Keep on Track goal

Alternative solutions		Agenda	Active reminder	Carer monitor
Benefits		30	70	80
Criteria: costs	Operation	2	1	0
	Learning	3	1	0
	Reliability	4	10	2
	Other stakeholders	0	0	20
	Privacy	0	3	5
Net Benefits		21	55	53

The benefits of the active reminder and the carer monitoring performance were judged to be similar, since the carer would have to monitor the users continuously to achieve the goal and this was open to some doubt. Operation and learning costs were minimal for the agenda and reminder options; however, reliability impact of reminders was often in doubt since setting the frequency and latency for system intervention was not easy to specify. Privacy was an issue for the reminder and carer options since both would disrupt the user's task or thought processes. The net balance was similar for the carer and reminder options for this goal, but the reason why they differ becomes transparent. In this case the technical solution for an automatic reminder was chosen, while the carer vets option had already been chosen for the Improve Social Skills goal.

Space precludes reporting further analysis at the individual goal level. At the group level the technique has made clear the trade-offs between different design solutions and costs imposed on primary users and other stakeholders (i.e. care providers). Customisation (e.g. add new filters or e-mail correspondents) by the users was ruled out because the additional learning and operating costs reduced the percentage-satisfaction to zero.

Considerable help would have to be available from the designers or care providers (thereby increasing their costs) to make customisation effective, so the overall balance was not favourable even though it was still desirable to increase the fit between system functions and the user's characteristics. However, some set-up configuration costs would be necessary for the solution to scale beyond the immediate locality where the designers can provide support. The cost-benefit analysis can be applied to the carer stakeholders, assuming a large benefit will be altruistic motivation to overcome their costs of learning and setting up the system. While this assumption might be true for family and very dedicated professional care providers, it is doubtful for other less committed carers. This outcome led to the investment to reduce learning and configuration burden as far as possible by CD-ROM advisors and training programmes and trying to distribute the support costs among a large stakeholder group.

5. Discussion

This paper has proposed a new framework which introduces the concept of the individual user and context as a focus for requirements engineering. In assistive technology applications the focus on individuals is a necessary consequence of the wide range of abilities which affect not only human computer interaction but also of matching functional requirements to individual capabilities. We argue that this approach generalises beyond assistive technology applications. Educational technology is one area where individual characteristics are important influences on design as learner profiles; another area is groupware applications where individual profiles often determine security and privacy requirements. However, with the growth in customised products, personal RE is becoming generally applicable to a wide range of office and home/entertainment applications.

Personal RE has extended the boundaries of skills-preference analysis [28] by connecting requirements to architecture, introducing cost benefit analysis, and drawing the distinction between expert assessment of user characteristics and individually held goals. Hui et al.'s [28] framework, based on i* and goal modelling, accounts for the skills profiles using a similar ontology to ours, and their preferences are similar to personal goals although they treat them only as soft goals (non-functional requirements) whereas we distinguish between the function goal and quality in the levels of attainment.

Our technique augments trade-offs between NFRs using decision table-style representation by specifically considering costs imposed on users and other stakeholders, which can then be integrated into more general NFR trade-offs. Setting attainment levels for personal goals was prompted by the GQM framework [29], although we have extended the metrics to include assumptions necessary for level of attainment. These dependencies could be further formalised in goal-oriented modelling methods such as KAOS [30].

The cost-benefit technique is similar to stakeholder trade-off techniques proposed by Macaulay in her Collaborative RE method [31] and it could be supported using generic tools such as House of Quality decision tables [32]. The technique could be extended to a top-down goal decomposition with trade-off metrics at each level following [33]'s development of the analytical hierarchy process.

In conclusion, personal and context requirements engineering has extended RE techniques and methods to account for the individual user and the context in mobile communication and global user interfaces. In many applications where the computer's role is to influence the user's behaviour and knowledge (e.g. training, education, augmented communication, mediating collaboration, games, entertainment, environmental control) personal goals and user characteristics will assume considerable importance. The application of our approach in the field of assistive technology has produced not only more detailed and better structured requirements but also insights into software and socio-technical systems design, which need to be resolved early in the requirements process. However, this work is a first step towards development of a more widely applicable method, so our next step is to test its generality in other domains such as educational and home applications.

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