Ambient Intelligence Acceptable by the Elderly

Rational Choice Theory Model of Technology Evaluation for Deep Design

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Abstract Ambient systems may support the elderly in many aspects of their lives, bringing new level of comfort, higher safety, and better health. But, as we revealed in parallel research on deep design, there are dissonances in what do the elderly wish and what the intelligent technologies indeed offer. The dissonances may lead to reluctant acceptance or even to rejection of possibly beneficial products. In this paper we borrowed concepts from economics and transformed them into generic model which captures the mental process of evaluation of new aspects of life. Proposed model is specifically aimed on ambient intelligence products, viewed from the eyes of possible elderly users, though not necessarily limited to this particular focus. The process of evaluation, leading either to acceptance or to rejection, may be described as a sequence of rational selections from available options, based on perceived benefit (utility) and cost (in terms of time, effort, support from others). Simplifying preconditions introduced in the paper reduce the model to optimization problem of linear programming. In conclusions we discuss limitations of the model and suggest further possible refinements and evaluation.

Keywords: ambient intelligence, acceptability, evaluation, rational choice, the elderly, linear programming.

Introduction

Idea of human-centric design is not entirely new. E.g. Norman [1] focused on the role of emotions in our cognition, Callejas et al. [2] suggested to include users in early phases of design, Vogiazou et al. [3] introduced a „design for emergence, " where users are being observed in their daily activities, technology probes promoted e.g. by Hutchinson et al. [4] may get close to users and Jordan [5] refused common task-centric design as dehumanizing. Actually, we hope, dream, sorrow, fear, desire and aspire, and that make us human. With deep design, the innermost

sources of affinity which people feel to certain object or service are being targeted. Successful products have to pass all phases of evaluation and appropriation _ attract attention first, show rewards soon, be appropriated into habitual usage finally. Failure in any of the steps effectively means refusal of the product. [6] High-order reinforcers stemming from the deep needs constitute the power which causes, whether certain product will succeed use in the long-term. [7]

If we wish to overcome scepticism, qualms, and anxiety which many older people feel towards technology and motivate them to learn new things, it is even more important to target their needs as precisely as possible. According to [8] the elderly in general do not wish to be monitored, but they wish to keep their independence, they wish to live in their home, to stay in touch with their close, to feel competent and helpful and dignified. Current sensoric monitoring systems (fall or other crisis detection) or cognitive support systems (e.g. reminders pushing users to take medication timely) actually focus on care-givers more than on care-receivers themselves. [9] To deliver technologies acceptable by the elderly and perceived by them as improvement to their lives, we should hold back of technology and put ourselves in their pattern of thinking [6]. We already followed the path of research and concluded in formulation of deep design approach [8], which emphasizes revealed deep needs of users as the most important foundation for subsequent design.

Once we revealed the deep needs, we may examine the problem of acceptability and mental processes behind from various perspectives, stressing psychological, sociological, technical or health aspects. Each of the approaches may be beneficial, but if we wish to achieve a model formal enough to allow calculations, good way is to go out of economy. Gary Becker proved that the approach may be fruitful. He captured various aspects of human life and behaviour [10] including discrimination [11], crime and punishment [12], addiction [13], beggary and compassion [14], human capital [15], love, marriage and family [16] into rational choice theory, which transcends narrow borders of pure economy. According to the theory, nearly all human behaviour may be explained as rational reasoning. Rational person decides as if balancing costs against benefits. [17] Person's aim is to maximize his advantage.

The general model of evaluation introduced in the paper describes early phases of evaluation, when somebody is thinking whether to try certain product or not, with particular focus on ambient and similar technologies evaluated by elderly users. The model should help to answer questions, such as: How elderly users perceive ambient technologies aimed to improve their lives? Which steps may be identified in the process of the evaluation? How do they compare alternatives if there are any? What causes that the technologies are being refused? While in economy advantage is being measured with money, rational choice theory emphasizes more subtle determinants of comfort, such as self-worthiness and social relations (Bentham [18] or Marshall [19]), which closely resonates with our deep design approach, focused on inner feelings. Similarly, cost in our model instead of its monetary representation falls into range of softer expenditures _ effort, time, external support. Model is defined generally, as a foundation for further formaliza-

tion and further concretization in terms of particular shapes of introduced functions and their coefficients. The concretization should be based on statistical research.

The Utility

Both in economy and rational choice theory, utility acts as a measure of perceived benefit. Personally unique utility (payoff) function reflects personal preferences. Actions driven by the utility function are constrained by budget, abilities, time available. The same basic idea is behind the proposed model of evaluation. Our research on attitude of the elderly towards intelligent technologies [8] resulted in four main clusters of deep needs of the elderly. Let's call them *sources of comfort* A .. D (or comfort sources) in our model. Each source of comfort has finite real number assigned, reflecting perceived level of fulfilment of the source by certain person's life situation:

A .. social touch
B .. autonomy with anticipated support
C .. feeling of being competent
D .. feeling of helpfulness and self-worth

Let's have a *utility function* U, which reflects personal preferences on importance of the sources of comfort. The function assigns total utility value to each combination of comfort sources:

$$U = U(A, B, C, D) \tag{1}$$

Simple form of the utility function assigns weight to each of the comfort sources. Let's have *aspects of life* $i_1 .. i_n$ (or life aspects) as a complete set of determinants of comfort sources of size n. Aspects of life may be e.g. “living with the family”, “walking daily”, “having a telephone” or “having a telephone call every day”. Each aspect of person's life may influence each of the sources of comfort. The influence of aspects of life on comfort sources may be captured as a set of *influence vectors*:

$$\begin{aligned} i_1 &= [a_1, b_1, c_1, d_1] \\ i_2 &= [a_2, b_2, c_2, d_2] \\ &\dots \\ i_n &= [a_n, b_n, c_n, d_n] \end{aligned} \tag{2}$$

Influence of certain aspect of life on certain source of comfort (e.g. b_2, the influence of aspect i_2 on comfort source B) may by either positive (raising the comfort source) or negative (lowering the comfort source). Total level of each comfort

source is fully determined by influence of all aspects of person's life on the comfort source:

$$A = sum(a_1 .. a_n)$$
$$...$$
$$D = sum(d_1 .. d_n) \quad (3)$$

According to the utility function, each aspect influences overall utility. As well as utility function, effects of life aspects are subjective. E.g. though many people perceive living with their family as highly beneficial because it strongly increases level of social touch, some may prefer living alone, because they feel more competent this way and the positive effect of higher competency outweighs lowered social touch in their case. Both assigned weights and utility functions play roles in the evaluation. Changes in the set of aspects of life may capture dynamics of changes in person's life. Introducing a new aspect of life (e.g. new cell phone) adds relevant element (line) to the set of aspects in the model. Similarly, replacing one aspect for another (weekly visit of children changed for daily phone calls) removes one aspect from the model and adds another.

First Phase of Technology Evaluation: "Is it Beneficial?"

The first step in the process is evaluation is reasoning on anticipated benefits, constraints (cost, time, etc.) do not matter. Adoption of certain life aspect influences total utility, dU_n is the *utility difference on adopting aspect* i_n:

$$dU_n = U(A+a_n, B+b_n, C+c_n, D+d_n) \_ U(A, B, C, D) \quad (4)$$

In the equation A .. D are levels of comfort sources before introducing the new technology and $a_n .. d_n$ are influences of the new aspect. To pass the first stage of evaluation, evaluated aspect (e.g. new product introduced into life) has to influence the total utility positively. Anticipated dU_n must be higher than zero, otherwise it will be rational to refuse the aspect i_n. Seemingly paradoxical situation, when certain technology is being refused by the elderly even though they do not need to pay single penny, exhibit significant effort or sacrifice time, may be explained as a failure in the first evaluation stage, which we call *refusal of the first kind*.

Second Phase of Technology evaluation: "Is it Reachable?"

Multitude of life aspects with positive influence on total utility is available, but not all of them are reachable. Reachability of life aspects is limited by certain con-

straints. Economy emphasizes monetary dimension of the constraints, calling them "budget". We in the contrary assume, that cost does not play role at all in the way how the elderly evaluate aspects of life. The assumption reflects situations where those who evaluate a product (the elderly) are not those who bear relevant financial expenses, someone else, either children or an institution, is the one who has to pay. Also, the model reflects situations where cost has been paid already (e.g. somebody already bought a gift, presentee is about to evaluate). As more relevant to our scenario we take another constraints called *resources* into account, though could be easily put back, if necessary:

T .. time (time necessary to manage/appropriate/perform the aspect of life)
E .. effort (effort and abilities necessary)
S .. support by others (help from family, care givers and others)

In our model we presume, that all the resources are limited. Each person has only certain time available for all his activities (24 hours daily, or less if we deduct the time for necessities), certain amount of power, determination, intellectual and mental skills etc. (involved in compound "effort" resource), and may ask certain level of support from others (determined by their willingness in the case of family members, and e.g. by received pension in the case of care givers – introducing cost indirectly). Let's have *exert function* f_n, which describes which amounts of resources (t_n, e_n, s_n) are necessary to manage, appropriate and/or perform aspect of life i_n:

$$f_n = f_n(t_n, e_n, s_n) \tag{5}$$

Aspect reachability is binary in our model. With given combination of resources, each aspect is either reachable (and possibly accepted) as a whole, or not reachable; aspect can be accepted neither only partially, nor more than fully. So, f_n may return value 1 or 0, where $f_n = 1$ means that aspect i_n is reachable exerting the given combination and $f_n = 0$ means aspect i_n is not reachable. If certain aspect is not reachable (requires more time, effort or support than available), it can't be accepted though perceived as beneficial, which leads to *refusal of the second kind*.

Third Phase of Technology Evaluation: "Is it the Best Choice?"

Even if beneficial and reachable still we do not know enough to say whether an aspect will be accepted. If resources are limited, rationally deciding human will compare all available choices to select the most beneficial combination available. The third phase of evaluation takes into account anticipated benefits, resources available, and resource intensity of life aspects. In reality, resources may be substituted, e.g. insufficient abilities may be compensated with increased help from others or with more time spent. But to keep the model simple, for further reason-

ing we presume incommutable resources in exert function. It means that there are certain externally determined optimal input proportions given for each person's aspect of life. And because exert function is binary, it would be useless to add more resources above the optimal (minimal sufficient) levels.

So, let's have three available aspects of life i_1, i_2, i_3 and we wish to compare them in the context of available resources to choose the optimal combination. The aspects of life have potential to influence total utility by dU_1, dU_2, dU_3 respectively according to subjective utility function. If $[t_1, e_1, s_1], [t_2, e_2, s_2], [t_3, e_3, s_3]$ are vectors of optimal resource levels necessary to adopt the aspects, corresponding exert functions are defined as:

$$\begin{aligned} &f_1(t >= t_1 \wedge e >= e_1 \wedge s >= s_1) = 1;\ f_1(t < t_1 \vee e < e_1 \vee s < s_1) = 0 \\ &f_2(t >= t_2 \wedge e >= e_2 \wedge s >= s_2) = 1;\ f_2(t < t_2 \vee e < e_2 \vee s < s_2) = 0 \\ &f_3(t >= t_3 \wedge e >= e_3 \wedge s >= s_3) = 1;\ f_3(t < t_3 \vee e < e_3 \vee s < s_3) = 0 \end{aligned} \quad (6)$$

The goal of rationally reasoning human is to maximize total U within borders of reachable opportunities (defined with levels of available resources T, E, S). He asks which aspects of life (out of available i_1, i_2, i_3) should be adopted. Adoption of aspect of life i_n is expressed as variable x_n, which may take value 1 or 0 (the aspect is being adopted and aspect is not being adopted respectively). The model may be expressed as follows:

$$\begin{aligned} &dU = x_1dU_1 + x_2dU_2 + x_3dU_3 \\ &\quad \max(dU) \text{ on condition} \\ &\quad T >= t_1x_1 + t_2x_2 + t_3x_3 \\ &\quad E >= e_1x_1 + e_2x_2 + e_3x_3 \\ &\quad S >= s_1x_1 + s_2x_2 + s_3x_3 \end{aligned} \quad (7)$$

The model may be solved as optimization problem of linear programming. Aspects of life which do not pass the third stage of evaluation suffer from the *refusal of the third kind*.

Conclusions

In the paper we applied rational choice theory methods on the problem of acceptability of intelligent ambient technologies by the elderly with aim to formalize possible causes of refusal. According to the findings, product has to pass three levels of rational evaluation to be accepted and in contrary three kinds of refusal may occur, refusal of the first kind if a product is not beneficial, refusal of the second kind if a product is not reachable and refusal of the third kind if a product does not belong to the most beneficial reachable set of aspects. General model of acceptance introduced in the paper reflects the evaluation process. Intentionally we designed the model as concise, simple and easily understandable rather than

highly formal. Arbitrary simplifying presumptions including binary exert function (aspect of life is either reachable or not), and limited and incommutable resources (time, effort and help can't be substituted) allowed to express the model in the form of optimization problem of linear programming. To reflect reality better, the model could be refined, e.g. the presumption of incommutable resources could be released. On the other hand, for practical application further simplifications of the model would be necessary. From the virtually infinite set of aspects of life only certain life aspects would have to be selected, either the most influential or the most relevant to the area of interest. Statistical research will be necessary to find appropriate shapes of utility and exert functions including function coefficients. Statistical evaluation may help also to examine how closely the model matches the real process of evaluation. The model may be proclaimed as inappropriate or useless based on statistical data if we find out, that it is not possible to concretize e.g. influence of aspects of life on sources of comfort.

Despite the inaccuracy caused by simplifications, socio-economic and psycho-economic models may help to grasp processes in our minds and may help e.g. to reveal weaknesses of technologies and products. Parallels of our model with economics suggest interesting analogies, such as income and substitution effects as an explanation how changes in requirements on resources influence acceptance of *other* aspects of life. With the help of the models we may not only bring more acceptable products, but also deepen our understanding of each other, and even understanding of ourselves. Regardless to any possible refinements, it is necessary to interpret the models with high caution. Human mind is highly complex system and any model brings only very rough insight.

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