Modeling Mediating Artifacts of Non-competitive Social Interaction

Juan Salamanca

Icesi University, jsalam@icesi.edu.co

Abstract: Common sense indicates that the interaction between artifacts and humans is asymmetrical because the artifacts are designed solely to support the accomplishment of human plans and goals. Such asymmetry prevents designers to design artifacts as actual social actors capable of performing social roles instead of just being tools for human action. In order to overcome such asymmetry this research positions smart artifacts as mediators of people's interaction and introduces a triadic framework for the analysis of technologically mediated social interaction. The use of the triadic framework in a staged study revealed that in the achievement of personal goals, people exhibit a *social viscosity* that hinders their interactions. The mediation of purposely designed smart artifacts can reduce such social viscosity and facilitate cooperative interactions between networked actors if they prompt the preservation of social balance, enhance the network's information integrity, and are located at the focus of activity.

Keywords: Interaction design, smart artifact, mediation, Actor-Network Theory, ubiquitous computing.

1. Introduction

Interaction designers traditionally adopt User-centered Design (UCD) as their conceptual framework for the design of interfaces between humans and computational systems. Although the design methods based on UCD account for how people cope with interactive systems [19], they are insufficient to explain how such interactive systems participate in people's social interaction. The main conceptual hindrance posed by the UCD approach is that it assumes that human agents have the control over interactive artifacts, disregarding the artifact's potential for agency [1]. With the advent of ubiquitous computing, interaction design widened its object of inquiry from visual interfaces to smart computational artifacts that inconspicuously participate in people's everyday lives. As a consequence, some interaction design researchers are looking at complementary theoretical frameworks that better explain social interaction mediated by technological means such as Distributed Cognition [8], Activity Theory [9], or Actor-Network Theory [13][11][12]. The ideas about the design of smart artifacts discussed in this paper adopt Actor-Network Theory (ANT) as their theoretical ground.

Post-humanist thinkers such as Callon[4], Law [13], Latour [11] and Knorr-Cetina [10] contend that we are increasingly living in an object-centered society where the roles of objects are not only defined as commodities or equipment but also as activity partakers. In that vein, smart artifacts could be defined as agents involved in social practices mediating and cohering both humans and other artifacts together. According to ANT, humans and smart artifacts are social actors that assemble hybrid collectives while they interact with each other.

This paper offers a triadic structure of networked social interaction as a methodological basis to investigate: i) how collectives of humans and smart artifacts get assembled, ii) how smart artifacts could make sense of their social setting and finally iii) how smart artifacts adaptively mediate people's interactions within social activities.

In order to illustrate the relevance of these questions let us look at a future scenario of urban mobility. Pedestrians and drivers enrolled in the practice of commuting will intermingle with smart artifacts such as a smart traffic light as they circulate, coordinate turns, facilitate traffic flow and control speed. In such ecology of human and non-human actors a smart artifact is a networked social mediator dwelling in a complex adaptive system that procures the efficient flow of the whole community of commuters. The goal of this paper is to present some considerations for the design of smart artifacts that can perform as social mediators of coordinated social interaction.

2. Definitions and notations

A *smart artifact* is a scripted agent that autonomously acts in the world by adapting its own structure while preserving its organization. Its designer *scripts* the smart artifact with one or many programs-of-action. A *program-of-action* is a script of what an actor can do. As an example, a traffic light is smart if it interprets the actions performed by car drivers and pedestrians and consequently adapts its time intervals to benefit pedestrian's flow.

A *collective* is a hybrid social actor constituted at the moment when a human *subscribes* him or herself to the smart artifact's programs-of-action. As an example, a pedestrian constitutes a collective with a smart traffic light (smartTL) if the former abides by the signals of the latter. The actions of the constituted collective are meaningful to other pedestrians and drivers present at the collective's scope of action. A *scope of action* is a subset of the network of agents to which a given action is meaningful and relevant. The actions of the collective may have an impact on remote networked actors who are participating concurrently in the practice of commuting.

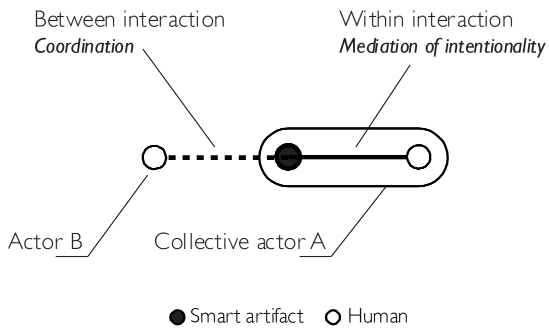

Figure 1. Triadic structure of networked social actors and its within and between interactions

Social practices involve networks of remote and local of actors. In order to simplify the study of the interactions between actors in a network, this research offers a *triadic structure* as a unit of analysis composed at least by two interacting humans and one non-human agent. This triadic structure accounts for the interactions *within* human-nonhuman collectives and *between* hybrid social actors in the actor-network.

Figure 1 depicts a simple network of three actors. Each one of the nodes is either a human or non-human actor and the edges represent the interactions between them. The collective-actor A is the result of the subscription of a human actor to the program-of-action of a smart artifact. The *within interactions* are those that hold together humans and smart artifacts inside a collective, and put forward the collective's assembled meaning for other actors in the actor-network. In Figure 1 the continuous line linking a smart artifact and a human represents the interaction within the collective-actor A. The *between interactions* are the social interactions that occur between collectives and characterize the dominant socio-relational model of the actor-network [7]. The dotted line in Figure 1 represents the social interaction between the collective-actor A and a human actor B. There is no unified classification of social interaction in literature. Conflict, negotiation, cooperation, violence are kinds of social interaction that might emerge between actors. This research project is particularly interested in non-competitive cooperative interaction.

Let us picture the collective-actor A composed by a pedestrian subscribed to a smartTL (the pedestrian abides by the smartTL that reciprocally senses the pedestrian proximity). The actor B is a car driver. The car driven by the driver is another actor in the actor-network but it is omitted in this example for simplification purposes. The social interaction between collective-actor A and B is a hierarchical interaction where A has priority over B. As a result the car driver holds on his or her program-of-action and stops at the corner giving the right of passage to the pedestrian, whose program-of-action is endorsed by the smartTL light color. The interaction between the collective A and the driver B usually ends up in coordinated turn taking controlled by the smartTL. In these cases, turn taking is the emerging form of cooperation. In some countries the driver yields the right of passage to the collective pedestrian-smartTL. But in other countries it is possible to observe that the socio-relational model between drivers and pedestrians privileges vehicular traffic over walkers flow.

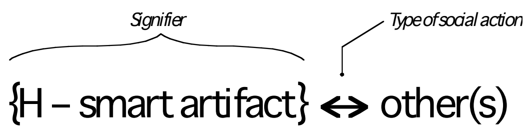

Figure 2. Notation of the triadic structure of networked social actors

Figure 2 presents a text-based form of notation of the triadic structure [17]. The bracketed collective represents the within interaction and the arrow represents the between interaction. As an example, {pedestrian-smartTL}→driver means that the action-meaning of the collective {pedestrian-smartTL} is put forward for drivers as long as the collective persists. The within interaction of {pedestrian-smartTL} exhorts the regulation of driver's circulation flow. The between interaction corresponds to the coordination of passage between {pedestrians-smartTL} and drivers.

3. A notion of agency and the symmetry of artifacts and humans as social actors

As surveyed by Bullington [3] the research on computational agency in social interaction has two major strands of research. On the one hand, there is the human-agent approach represented by the goal of the Turing test. Its object of concern is the socialization of humans with artificial agents, e.g. [2][16][5]. On the other hand, the structuralist approach focused on the analysis of the structure of social groups that emerges from the intersubjectivity of agents. Its object of concern is the bonding structures from which a collective of agents emerge and evolve, e.g. [6][14].

ANT aligns with the latter approach. The symmetry proposed by ANT endows both human and nonhumans with the capacity for social action. Such symmetry does not reduce humans to mere objects, nor does it grant intentionality to objects. To be clear, symmetry does not have a geometrical meaning. The symmetry of social actors is an analytical viewpoint that positions people and objects as members of a social set without dichotomizing them. Under ANT, there is no hierarchy between human and nonhuman actors. Human and nonhumans are social actors that are placed on an equal footing, whose forms of actions simply differ. As Law puts it by drawing a distinction between ethics and sociology, the symmetry between human and nonhuman actors "is an analytical stance, not an ethical position" [13].

The fact that human and nonhuman actors are not dichotomized enables us to declare them as instances of the same class of behavioral agents. The main attribute of this class is embodiment, and the class' primary function is to react. Behavioral social action was described by Schutz as a reactive action triggered by external conditions [18]. Proactive social action as explained by Schutz is a complementary type of action, characterized as intentional and intrinsic to the acting agent. Simple artifacts are behavioral agents, but both smart artifacts and humans exhibit proactive action. Figure 3 depicts how the Proactive agent class inherits the embodiment attribute and reaction function from the Behavioral agent class, and extends its functions by implementing a higher-level function: to act.

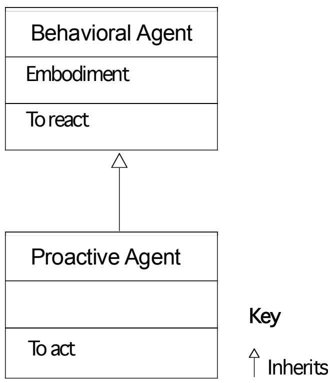

Figure 3. Class structure of behavioral and proactive agency

ANT does not claim that artifacts plan actions but rather they enact programs-of-actions. Albeit nonhuman agency appears to be a contradiction, it is systematically displayed in programs-of-action that involve the participation of artifacts [4]. In the case of humans, it is associated with their intentions. In the case of artifacts, it is associated with the criteria for social action inscribed by their designers. The significance of nonhuman action comes to light as artifacts "allow, afford, encourage, permit, suggest, influence, block, render possible, forbid […]" [12] states of affairs.

Going back to our scenario of smart urban mobility, SmartTLs could be scripted with a program-of-action that privileges pedestrians over manned and unmanned vehicles. Drivers are agents with their own behavioral and proactive programs-of-action. Table 1 presents a simplified description of the actors' programs-of-action.

Table 1. Example of behavioral and proactive programs-of-action

Agent	Type of program-of-action	Description of program-of-action
Smart Traffic light	Behavioral	Change light colors recursively
	Proactive	Privilege pedestrians flow and override its behavioral program-of-action
Pedestrian	Behavioral	Avoid collisions while walking
	Proactive	Walk safely to his/her destination
Human driver	Behavioral	Abide by traffic rules
	Proactive	Drive safely to his/her destination

4. Interpretation of action in a social setting

According to Schutz, the building blocks of an action are simple acts [18]. When an observer perceives an agent acting out its program-of-action some of its acts have been executed, whereas others are yet to be executed. The set of executed acts is referred to as executed-program-of-action (EPA), while the set of the yet-to-be-executed acts is referred to as remaining-program-of-action (RPA).

For example, Figure 4 presents the program-of-action of a person driving to a meeting composed of the following acts: A: get on the car, B: drive for ten blocks, C: park the car, D: get to the meeting on time. The RPA has a subjective meaning that is only known by the driver, i.e., no body knows where he/she is driving. In contrast, the EPA has an objective meaning because it has already been enacted in front of other agents including smart artifacts, i.e., he/she is driving somewhere. At the step present time in the time flow depicted in Figure 4, the EPA has an objective meaning for observers and smart artifacts, whereas the RPA has a subjective meaning known only by the driver.

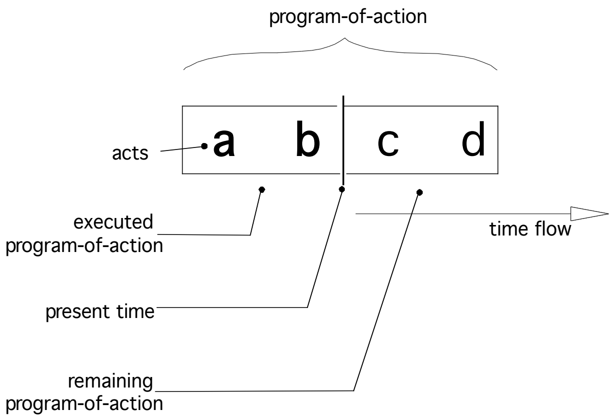

Figure 4. A program-of-action decomposed in single acts. The portion of the program-of-action enacted before the present time corresponds to the Executed program-of-action. The yet-to-be-executed portion corresponds to the Remaining program-of-action

By using pattern finding techniques based on contextual interpretation such as Rough Set Theory [15] this research proposes that smart artifacts can estimate the RPA of human actors enrolled in a collective if the smart artifacts have a robust collection of their own EPA.

In the execution of programs-of-action both human and nonhuman actors get intertwined and social dynamics emerge. While drivers drive, they must abide by the traffic rules reified as smart traffic lights. Concurrently, smart traffic lights regulate the traffic flow by adapting their timing and light color as they sense both cars and pedestrians approaching the intersection where they are located.

Going back to the driver's example, if at present time the smart traffic light turns red, it blocks the driver's action, delaying the execution of the driver's RPA – acts C and D. But, at the same time it enables the programs-of-action of pedestrians and other drivers who were waiting for their right of passage.

In ANT terms, when the actor's programs-of-action get intertwined, it is said that a human-nonhuman collective is composed. Such collectives emerge and dissolve themselves in the execution of their programs-of-action.

5. Proof of Concept

5.1 Description

An early analysis of pedestrians' trajectories in the wild revealed that it is possible to determine the subscription of actors to a crosswalk program-of-action by determining the spatial alignment of their EPA. The analysis showed that there is evidence of a pedestrian's subscription to a crosswalk when his/her executed program-of-action is aligned to the intended direction of travel defined by the crosswalk design, i.e. walking straight across corners. In contrast, pedestrians are not subscribed when they exhibit trajectories other than the ones outlined by the crosswalk. For example, a walker wandering erratically on the crosswalk while he/she smokes a cigarette or talks over his/her mobile phone is not subscribed to the crosswalk's program-of-action. Subscribed and unsubscribed trajectories are both socially valid, but the former is prone to elicit cooperation or collaboration among walkers present on the crosswalk concurrently, whereas the latter can drive conflicting interactions.

Figure 5. Wizard of Oz prototype of the study deployed at the laboratory

5.1 Study design

Based on the above observation, a smart crosswalk was designed and deployed in a laboratory. The smart crosswalk was scripted to dynamically signal the best distribution of the walking space among concurrent pedestrians. To do so, the crosswalk interprets the EPAs of each pedestrian and forecasts their RPAs. The assessment of multiple RPAs allows the crosswalk to identify potential conflicts in the ongoing social interaction and signals a suitable space distribution accordingly. The design tested in the laboratory consists of a striped pattern split along the north-south axis. Figure 6 shows the status of two distributions. The top illustration shows the halves of the striped pattern sliding sideways, the bottom one shows the result of the halves sliding both sideways and backwards.

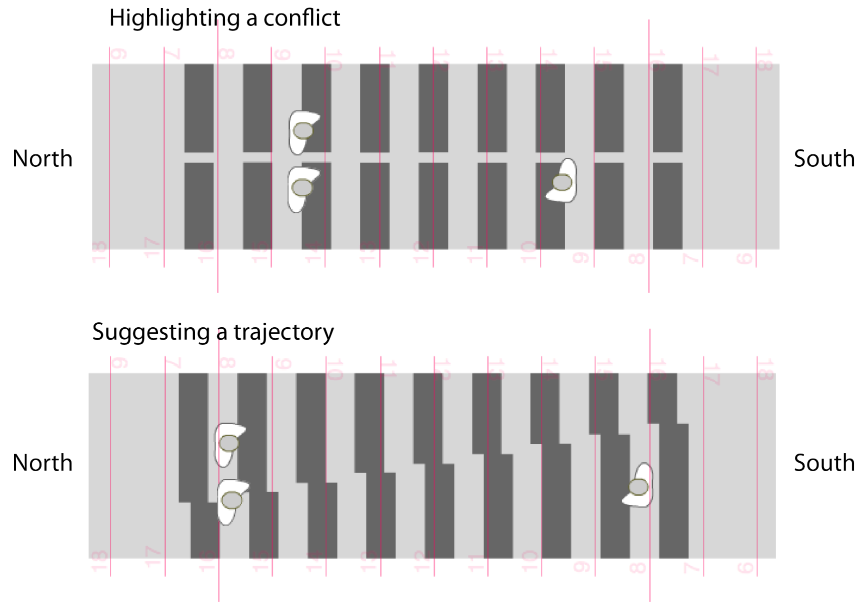

Figure 6. A smart crosswalk signaling forecasted conflicts to pedestrians

Two smart crosswalks' signaling patterns were tested: i) highlighting a conflict of trajectories (Figure 6 top) and ii) suggesting trajectories to circumvent potential conflicts (Figure 6 bottom). The highlighting signaling pattern is intended to raise pedestrians' awareness to estimated trajectory conflicts. Such crosswalk's intervention is neutral because any potential trajectory negotiation is left to the concurrent groups of pedestrians. The suggesting signaling pattern is intended to do a more active intervention because it suggests trajectory deviations to concurrent pedestrians biasing the outcome of any trajectory negotiation.

Sixteen subjects, selected from a pool of volunteers recruited by email on social networks, were asked to walk on both a smart crosswalk prototyped with the Wizard of Oz technique and a staged regular crosswalk. Subjects were grouped in groups of up to three people. In a series of 10 runs, subjects randomly assigned to two groups located on both ends of the smart crosswalk were asked to walk from the north to south end of the crosswalk and vice versa. The data collected were: i) the pedestrians' trajectory at each step, ii) stride speed and iii) target accuracy.

5.2 Study observations

Overall, studies found that people walking on smart crosswalks have smaller trajectory deviations and higher target accuracy than people walking on regular crosswalks. However the walking flow of people on smart crosswalks slowed down. It appears that there was an inverse correlation between the trajectory disturbances and the walking speed. In other words, in order to walk fast pedestrians needed to sort out disturbances. Such disturbances were represented by the presence of other human actors enacting their own programs-of–action. The general observation is that pedestrians hinder the execution of each other's programs-of-action forcing themselves to constantly adapt or overwrite their original programs-of-action.

5.3 Analysis of observations and results

The following analysis applies the above-described triadic structure to the interaction of subjects in the study. The two human actors of the triad are the pedestrian or group of pedestrians heading north (PHN) and the pedestrian or group of pedestrians heading south (PHS). The nonhuman actor is the smart crosswalk. The network of actors has two triads: {PHN – smart crosswalk} → PHS and {PHS – smart crosswalk} → PHN. The programs-of-action of both human and nonhuman actors in the actor-network are presented in Table 2.

The within interaction of the collective {PHN – smart crosswalk} holds these two actors together, co-shaping the mediating meaning of a hybrid signifier. Such signifier is composed by the pattern signaled by the crosswalk and the actions of the pedestrians heading north on the smart crosswalk. The PHS actor interprets the signifier and adapts its actions accordingly. The between interaction of the triad can be observed in the dynamic negotiation of trajectories carried out by both groups of pedestrians circumventing potential collisions. Conversely, the complementary triad {PHS – smart crosswalk} → PHN has the same within and between interactions. Such networked triads constitute an adaptive system in which the modification of one actor's program-of-action affects the enaction of others' programs-of-action.

Table 2. Programs-of-action of pedestrians and smart crosswalk in the proof of concept study

Agent	Type of program-of-action	Description of program-of-action
Smart crosswalk	Behavioral	Afford pedestrians crossing from one end to the opposite
	Proactive	Either highlight potential conflicts or suggest trajectory deviations
Pedestrians heading north or south	Behavioral	Avoid collisions while walking
	Proactive	Walk to his/her/their destination preserving their clique's cohesiveness

The observations of the walking flow in both regular and smart crosswalks show that the within and between interactions have a double-edged effect in the actor-network. While the within interactions pull actors together, the between interactions offer resistance to the execution of the human actors' programs-of-action. As a result, people cooperate when they have conflicting programs-of-action or collaborate when they have aligned programs-of-action. Both cooperation and collaboration require that people coordinate their actions.

While smaller collectives coordinate easily, larger ones struggle to maintain coordination. The high trajectory disturbance observed in the study reveals a sort of friction between actors that are enacting their programs-of-action. Such friction, which ultimately renders the actor-network *viscous*, seems to thicken when people act under limited access to environmental information. It is under such limited conditions when actions of smart artifacts have higher impact in the actor-network's viscosity and benefit communal action flow across the actors in the network. This research defines *social viscosity* as the natural resistance of an actor-network to the fluidity of its actors' actions caused by the mutual disturbances elicited while they enact their programs-of-action.

While well-coordinated action reduces the actors' mutual disturbances, the process of achieving such coordination hinders the fluidity of actors' actions. The empirical studies show that the mediation of social interaction by means of smart artifact mediators improved human actors' degrees of coordination if such mediation i) prompts the preservation of social balance by enacting the dominant socio-relational principles, ii) enhances actor's information about the whole actor-network, and iii) is present at the focus of the social activity.

6. Conclusion and future work

The articulation of Actor-Network Theory principles with interaction design methods opens up the traditional user-artifact dyad towards triadic collective enactments by embracing diverse kinds of participants and practices, thus facilitating the design of enhanced sociality.

The experimentation made with the Wizard of Oz prototype shows that smart artifacts that put forward forecasted conflicts between networked human actors are prone to facilitate either kind of social interaction: cooperation or collaboration. Cooperation and collaboration are two types of social interaction akin to balanced forms of sociality. Further development of computational algorithms and higher fidelity prototypes is needed to validate the observations made in the laboratory.

Smart artifacts can be designed not only as tools that allow people to accomplish their tasks, but also as relational objects that step into social activity by suggesting actions that may benefit the whole community. As the example {pedestrian – smart crosswalk} → pedestrian shows, smart artifacts can act as signifiers of the social activity of a group of people and mediate forms of coordination between them. Cooperation is only one type of social action, however, the position offered here could be extended to other types of social action such as collaboration, conflict resolution or adhesion.

The design of socially apt smart artifacts demands that designers decompose social action by identifying the programs-of-action of all the interacting parties. The position discussed in this paper suggests a new role for smart artifact designers: the delineation of artifact's programs-of-action. By identifying potential triadic structures in the network of actors, and analyzing how action unfolds in each triad, designers can refine the social responsiveness of smart artifacts rendering them more socially apt.

Finally, social viscosity is the natural resistance of an actor-network to the fluidity of its actors' actions. It has a direct correlation to the size and density of the network.

7. References

[1] Agre, P. (2001) *Human-computer interaction*. Lawrence Erlbaum Associates, Hillsdale, N.J. , 177-192.

[2] Breazeal, C.L. (2002) *Designing sociable robots*. MIT Press, Cambridge, Mass.

[3] Bullington, J. (2009) Agents and Social Interaction: Insights from Social Psychology. In: Trajkovski, G., Collins, S.G. (Eds.), *Handbook of research on agent-based societies : social and cultural interactions*. Information Science Reference, Hershey, PA , 35-80.

[4] Callon, M., Law, J. (1995) *Agency and the hybrid collectif.* South Atlantic Quarterly 94 , 481.

[5] Cassell, J.B.T. (2003) Negotiated Collusion: Modeling Social Language and its Relationship Effects in *Intelligent Agents. User Modeling and User-Adapted Interaction* 13, 89-132.

[6] Epstein, J.M., Axtell, R. (1996) *Growing artificial societies : social science from the bottom up.*

Brookings Institution Press, Washington, D.C.

[7] Fiske, A.P. Relational Models Theory 2.0. In: Haslam, N. (Ed.), (2004) *Relational Models Theory, A Contemporary Review*. Lawrence Erlbaum Associates, Inc, Mahwah, NJ, 3-24.

[8] Hutchins, E. (1995) *Cognition in the wild*. MIT Press, Cambridge, Mass.

[9] Kaptelinin, V., Nardi, B.A. (2006) *Acting with technology : activity theory and interaction design*. MIT Press, Cambridge, Mass.

[10] Knorr-Cetina, K. (1997) Sociality with Objects. *Theory, Culture & Society*, 1-30.

[11] Latour, B. (1992) Where are the Missing Masses? A Sociology of Few Mundane Objects. In: Bijker, W.E., Law, J. (Eds.), *Shaping Technology/Building Society. Studies in Sociotechnical Change*. MIT Press, Cambridge, Mass., 151-180.

[12] Latour, B. (2005) Reassembling the social : an introduction to actor-network-theory. Oxford University Press, Oxford ; New York.

[13] Law, J. (1992) Notes on the Theory of the Actor Network: Ordering, Strategy and Heterogeneity. Centre for Science Studies, Lancaster University, Lancaster.

[14] North, M.J., Macal, C.M. (2007) Managing Business Complexity. Discovering Strategic Solutions with Agent-Based Modeling and Simulation. Oxford University Press, New York.

[15] Pawlak, Z. (2003) Rough set theory and its applications. *Journal of Telecommunications and Information Technology* 3, 7-10.

[16] Picard, R.W. (1995) *Affective computing*. Perceptual Computing Section, Media Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.

[17] Salamanca, J., Gregory, J. (2011) Repositioning Users with Smart Artifacts as Participants in Collective Action. Proceedings of IASDR, TU Delft, Netherlands.

[18] Schutz, A. (1972) *The phenomenology of the social world*. Northwestern University Press, Evanston, Ill.

[19] Shackel, B. (2009) Human-computer interaction - Whence and whither? *Interacting with Computers,* 21, 5-6, 353 – 366.