Combining product development methods with activity theory to trigger new concept generation

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Abstract: - This paper reviews literature on product development established processes, showing how these emphasize requirements specification as a starting point in new concept generation. Rather than limiting inputs for new concept generation to verbal requirement lists, industrial design students seem to prefer to be stimulated with ideas in context. Activity theory is considered to the benefit of many human activity processes, as the fundamental ground-laying theory on this matter illustrates. A new method that takes as point of departure human activity to search for new product concepts was developed and is presented in this paper. It supports pushing the envelope of creativity beyond the mere upgrade of existing concepts. Systematic design procedures are also used to evaluate and improve the initial concepts and guide their development. Paradigm shift may represent a great opportunity but also a challenge for widespread adoption of new concepts. The proposed method is put into perspective with activity based methods for systems design. The paper concludes with further application area suggestions for activity theory within the engineering domain.

Key-Words: - Study of human activity; Design theory; Science of design; Conceptual design; Ergonomics

1 Introduction

The background for this study pertains to the author's research experience, involving activity theory, but also to the teaching experience, in what concerns product development methods to both engineering and industrial design students. Design studies portray a strong component of visual Arts, but, especially in what concerns Industrial Design, a technological component must be strongly emphasized in education to achieve a "well rounded" graduate. These two streams need to be balanced, in order to promote adequate education. This problem may be traced back to an issue Michl [1] tackled when most eloquently stating that "the notion of design is still grafted on to a romantic notion of creativity *ex nihilo* rather than to a problem-oriented concept of creativity". Dealing with this dichotomy in industrial design education necessitates bringing together "hard" engineering design approaches to design with "soft" creativity stimulation approaches, in line with Campbell et al.'s [2] futuristic view on the 'hybrid' designer.

Developments relating to awareness of people's experience prove that design and user research methods are evolving [3]. As a result of the aforementioned concerns and in line with these trends, a method based on activity theory, a theory founded by Leontiev that was based on Vygotsky's cultural-historical psychology, is used in class to explore contexts of use and thus generate innovative product concepts. The generated concepts are many times in manifest radical rupture with existing solutions.

It is intended in this paper to explain the educational context that fostered the development of the concept generation method; present both the product development process and activity theory and their proposed convergence for the purpose of concept generation; discuss implications of generating concepts radically departing from existing solutions; and, situate the proposed method in relation to activity based methods that are aimed at the design of multi-user, and, or multi-actor, systems.

2 Specification of requirements

Product development is part of any company's industrial innovation process [4]. Industrial innovation includes all activities preceding the launch of a new product into the marketplace, such as basic and applied research, design and development, market research, production, distribution and sales. Product development encompasses two major phases:

product planning and strict development [4]. During product planning the company willing to place new products in the market identifies in explicit terms what it wants to achieve (in a requirements list specification). With this in mind, the idea finding commences, yielding the generation of one or more promising ideas for a new product. During the strict development phase, the plans for product, production and sales are developed.

Pahl and Beitz ([5], [6]) developed another well accepted method of product development, consisting of four phases: product planning and task clarification; conceptual design; embodiment design, and detail design. Under the label Design for X, a wide collection of specific design guidelines are also contemplated. Each design guideline addresses a particular issue that is caused by, or affects, the characteristics of a product. Pahl and Beitz [6] consider several design for X, or design for properties, examples, such as: design for aesthetics, design against corrosion damage, design to cost, design for ergonomics, design for minimum risk, and, design to standards.

In line with Pahl and Beitz, Hubka and Eder [7], systematically examine the basic goals, general principles, and methods of engineering science and specify product development phases and respective outcomes as follows: elaborate and clarify the assigned task (output - the design specification); establish the function structure (output - the function structure); establish the organ structure (output - the concept); establish the component structure (output - the layout); and, establish component structure in more detailed level (output - representation and description of technical system).

Within the engineering design methodology mentioned, Hubka and Eder [7] and Pahl and Beitz [6], the main apparent objective of product design is to meet functional requirements. It hence dedicates only but marginal attention to the user. The theories of these authors mostly focus on the technical functions and structure of the product and omit the product's relation to the user. Some of the theories, as is the case for Pahl and Beitz [6], provide limited guidance on how and where in the design process some of the user aspects should be dealt with (for example, identifying and understanding user needs).

One of the challenges in trying to achieve a balance between technical and artistic inputs into product development education of industrial design students, is being able to introduce the technical systems design view presented in this section, and intertwine with another (rather more user / person centered) approach. In an engineering school that teaches Industrial Design students, it becomes apparent that rather than mostly using verbal requirement lists as inputs for new concept generation, these students seem to prefer to be creatively stimulated with ideas in context. Activity theory is being used as a basis to achieve this end.

3 Activity theory

In a framework derived from activity theory, any task, or activity, can be broken down into actions, which are further subdivided into operations. In a design context, using these categories can provide the designer not only with an understanding of the steps necessary for a person to carry out tasks, but also with the motive and goals of the person's actions.

The objectives and motives of any human activity, the social and material or physical perceptions, and the needs of the human determine the activity and its structure [8]. The means for carrying out an activity include techniques and skills, procedures, artifacts, where language and tools such as products can be included.

Activity theory can be used to inform product development efforts, through the study of use. This is presented in this section, following the general outline of the development of activity theory.

3.1 Evolution of activity theory

An overview of the path of activity theory, from Vygotsky's early conception, through Leontiev's contribution, reaching today's form is proposed in this subsection.

Activity theory first appeared and was developed in the Soviet Union. The foundations of this theory include the philosophical ideas of Hegel and Kant, as well as the theory, developed by Marx and Engels, of dialectical materialism. The theory had evolved from the work of Vygotsky, as he had initially formulated a new method of studying thought and consciousness. Vygotsky had been working on this theory at a time when the prevalent dominant psychological theories were based on reflexology (stimulus-response based school that at a later stage was developed into behaviorism) and psychoanalysis [9]. By reducing all psychological phenomena to a series of stimulus-response chains, reflexology attempted to eliminate consciousness.

The mentalist tradition, according to Vygotsky [10], confined itself to a vicious circle in which states of consciousness were comprehended through the use of the concept of consciousness. This consisted of the major objection Vygotsky pointed out towards the mentalist tradition. Vygotsky claimed that if consciousness were to be taken as a subject of study, then the explanatory principle had to be sought within a different layer of reality. Socially meaningful activity might play this role, serving as a generator of consciousness, was what Vygotsky suggested. The suggestion that individual consciousness is built from the outside through relations with others was Vygotsky's first step towards the concretization of this principle. Human higher mental functions ought to be viewed as products of mediated activity, according to Vygotsky. The role of mediator is played by psychological tools and by means of interpersonal communication.

Vygotsky's first ideas about how consciousness was mediated were formulated after he had appropriated a few Marxist ideas about how tools (or instruments) mediate the work activity. Vygotsky then extended those ideas to encompass the manner through which psychological tools get to mediate thought.

Work was, for Marx and Engels, the basic form of human activity [11]. Their analysis emphasized that not only did humans transform nature in their carrying out of work activity, but they were also themselves continuously and repeatedly changed in the process. The level of work activity at a particular stage in history was seen as a direct reflection of the tools that were available at that time. Therefore, new kinds of instruments would always be necessary to carry out the perpetually changing new forms of work activity. The reciprocal implication of the afore-mentioned dialectical considerations is that each new level of tool or instrument development leads to the rise of yet another generation of a form or manner of conceptualizing and acting on the world.

One of the main cornerstones of Vygotsky's psychological constructs was the resemblance between Marx's notion of how the tool or instrument mediates overt human work activity and the semiotic notion of how human social processes and thinking can be mediated, and are in fact often mediated, by sign systems. In both cases the point is that instruments are not only used by humans to change the world, but these instruments also come to transform and regulate humans in this process of changing the world around them [11].

According to Vygotsky [10], psychological tools are artificial formations. By their nature they are social, not organic or individual. They are directed towards the mastery, or management, of behavioral processes, in a comparable way to the way by which technical means are directed towards the management of processes of nature. Verbal communication, systems for counting, mnemonic techniques, algebraic symbol systems, works of art, writing, schemes, diagrams, maps, mechanical drawings, and all sorts of conventional signs can serve as examples of psychological tools and of their compound systems [9].

Each psychological tool alters the entire flow and structure of mental functions as long as it is included in the process of behavior. A tool with a psychological nature does this by determining the structure of a new instrumental act, in the same way that a technical tool alters the process of a natural adaptation by determining the form of work operations.

Artificial, or instrumental, functions and forms of behavior ought to be recognized along with natural acts and processes of behavior. The latter first emerged in the process of evolution, and were developed into special mechanisms that are common to humans and advanced animals. The former (artificial functions and forms) are a later acquisition of humans. These are the product of historical development and are a form of behavior unique to humans [10: p.137].

The mediation by psychological tools, at the time, a new method of thinking about consciousness, was then termed the instrumental method. Vygotsky's initial formulation of an instrumental act is shown in Figure 1. A stimulus was thought to be able to play the role of an object towards which an act of behavior was directed, according to Vygotsky. However, in this act, the tool could also play the role of the means by which human beings directed internal psychological operations to solve a problem. In Vygotsky's instrumental method, although the link between A and B was the direct associative connection (from stimulus, leading to response), both the stimulus and the tool could be considered as stimuli affecting the ultimate response.

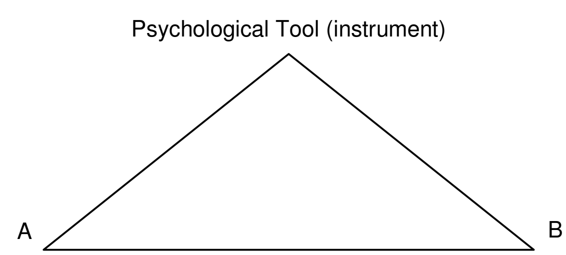

Figure 1: Initial formulation of an instrumental act, according to Vygotsky's early proposal.

In the instrumental act, a new intermediate link, the psychological tool, which becomes the structural center (the feature that functionally determines all the processes that form the instrumental act), is inserted between the object and the psychological operation toward which it is directed. Any behavioral act then becomes an intellectual operation [10: p. 139]. However, to many of the psychologists working on the development of activity theory, this formulation was still too close to behaviorism [9]. They took Vygotsky's idea of artifact-mediated and object-oriented action and reformulated it to take the form depicted in Figure 2.

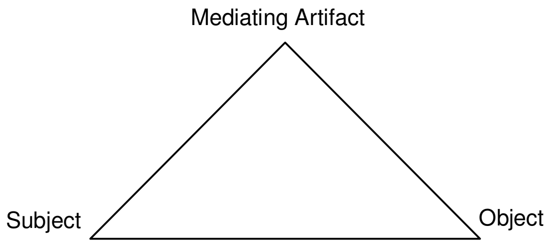

Figure 2: Fist generation of activity theory psychologist’s view of the mediating artifact [9].

According to the conception depicted in Figure 2, which is representative of the view shared by the first generation of activity theory psychologists, an activity is composed of a subject and an object, mediated by a tool. A subject is a person or a group that is engaged in an activity. An object (in the sense of "objective") is held by the subject and motivates activity, giving a specific direction to the latter. The mediation can occur through the use of many different types of tools, material tools as well as mental tools, including culture, ways of thinking and language.

In activity theory, the unit of analysis is an activity, which is opposed to the approach pursued by cognitive psychology, focusing on the study of the individual as a separate entity. In activity theory, context is not considered as an outer container or as a shell inside of which people would behave in certain ways [12]. Rather, people consciously and deliberately generate context (activities) in part through their own objects (or objectives). Context is both internal to people, involving specific objects and goals, and, at the same time, it is external to people, involving artifacts, other people, and specific settings [12]. The crucial point from this perspective is that in activity theory, external and internal perspectives are fused, or unified.

Collective activity would become the turning point marking the onset of a second generation in the development of activity theory. The unit of analysis in Vygotsky's early work was object-oriented action mediated by cultural tools and signs. There was no recognition of the part played by other human beings and social relations in the triangular model of action. Leontiev extended the theory by adding several features based on the need to separate individual action from collective activity [9]. The distinction between activity, action and operation was added to delineate an individual's behavior from the collective activity system.

The following extract from Leontiev’s own writings [13] vividly characterizes the essence of collective activity: “a beater, for example, taking part in a primeval collective hunt, was stimulated by a need for food or, perhaps, a need for clothing, which the skin of the dead animal would meet for him. At what, however, was his activity directly aimed? It may have been directed, for example, at frightening a herd of animals and sending them toward other hunters, hiding in an ambush. That, properly speaking, is what should be the result of the activity of this man. And the activity of this individual member of the hunt ends with that. The rest is completed by the other members. This result, i.e. the frightening of game, etc., understandably does not in itself, and may not, lead to satisfaction of the beater's need for food, or the skin of the animal. What the processes of his activity were directed to did not, consequently, coincide with what stimulated them, i.e., did not coincide with a motive of his activity; the two are divided from one another in this instance. Processes, the object and motive of which do not coincide with one another, we shall call "actions". We can say, for example, that the beater's activity is part of hunting, and the frightening of the game his action” [13: p.210].

The beater is engaged in actions that result in the opposite of what he is immediately seeking (food for survival). Instead of shortening the distance to the quarry, he is pushing the game away. This makes sense only if he knows that someone is waiting to achieve his goal (consciously shared with others) at the other end. The sense of his action was not in the action itself but in his relation to other members of the group [9].

The emergence of action as a coordinated part of social activity performed by an individual must be accompanied by shared meaning of the action that is reflected consciously by the actor. Therefore, the necessary, conscious division of work in human society is the most obvious indicator of the individual human's societal nature. The individual is truly human only in society. Indeed, a still stronger conclusion can be argued: that human individuality itself is achievable only in society [9]. It is apparent from the description above that more than one action can be used to achieve a goal, both the beaters and the hunters in the activity system above are carrying out actions which will result in a successful hunt. But their actions are different.

The third hierarchical level which Leontiev added to the theory of activity was the level of operations, which are performed automatically. As Leontiev states, when learning to shift gears in a standard automobile: "initially every operation, such as shifting gears, is formed as an action subordinated specifically to this goal and has its own conscious orienting basis. Subsequently this action is included in another action, such as that of changing the speed of the automobile. At this point, shifting gears becomes one of the methods for carrying out this action-that is, it becomes an operation necessary for performing the action. It is no longer carried out as a special goal-directed process. The driver does not distinguish its goal. So far as the driver's conscious processes are concerned, it is as if shifting gears under normal circumstances does not exist. He/she is doing something else: he/she is driving the automobile from place to place, driving up steep inclines and across level expanses, bringing it to a stop in certain places. Indeed, we know that this operation can "drop out" of the driver's activity entirely and can be performed automatically" [13: p. 64].

Eventually Leontiev's model of activity was reformulated to take the form described in the following description: "the uppermost level of collective activity is driven by an object-related motive [or objective]; the middle level of individual or group action is driven by a goal; and the bottom level of automatic operations is driven by the conditions and tools of action at hand [15: p.4]. As a result of the need to consider the shared meaning of activity, the initial theory was reconfigured by the addition of rules, community and the division of work and was renamed the activity system. An activity system is a way of visualizing the total configuration of an activity. This is the current hierarchical conception of activity that may be diagrammed as depicted in Figure 3. There is an inherent correspondence between activity and motives, action and goals, and operation and instrumental conditions.

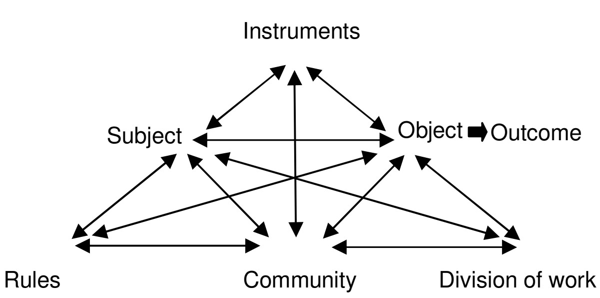

Figure 3: Activity system as a way of visualizing the total configuration of an activity [9].

According to Mappin [9], in this model of an activity system, the subject refers to the individual or group whose point of view is taken in the analysis of the activity. The object (or objective) is the target of the activity within the system. Instruments refer to internal or external mediating artifacts which help to achieve the outcomes of the activity. The community is comprised of one or more people who share the objective with the subject. Rules regulate actions and interactions within the activity system. The division of work discusses how tasks are divided horizontally between community members as well as referring to any vertical division of power and status.

A general outline of the development of activity theory was just enunciated. Its essence is based on the premise that transforming the objective into an outcome motivates the existence of an activity. The following subsection shows how activity theory can be used to inform product development efforts, through the study of use.

3.2 The study of use informed by activity theory

Karlsson [16] developed a framework to study 'use', i.e., the relation between human and artifact. The focus is on the individual and his/her relation to the objective and the mediating artifact. The framework is intended to provide a basis for the discussion, description and evaluation of different approaches to the design of the user-artifact relation. In this framework, the unit of analysis is the use activity, and she adopts a holistic approach that includes a system view of user-task-goal-artifact and environment. In this approach aspects such as product features and operations are studied, but the key point is that they must be related to the overall level of analysis. The framework is composed of five factors, each of which is represented in three different levels of analysis. In this view of the user-artifact relation, the purpose of employing an artifact (product) is to make use of its functions in order to achieve a goal. However, the actual benefit acquired from 'use' is dependent upon the properties of the artifact and the properties of the user, as well as other local conditions, such as the environment where the activity takes place [16].

Use implies a goal (use for what?), an instrument (use what?), a person (use by whom?) and an environment and context (used where?) [16]. to this set of four short questions, a fifth may be added concerning the activity per se: "use how?" which expresses the mode of interaction between user and artifact. This is quite relevant, as a dimension, since it is central to activity and hence, if consciously considered, may raise interest in aspects of use quality. Use quality may be considered as including characteristics such as user friendliness or beauty.

4 Activity based concept generation

The method that is central to this contribution is bounded by the larger process of design, where it gives a contribution at the stage of concept generation. The bounding process of design that is considered is in line with the report of Lewis and Bonollo [17]. These authors performed an experimental investigation to unveil the design skills most influential to professional success, in order to have design education adequately train student in those skills. Given the nature of the examples provided and the literature sources considered, it is fair to assume that Lewis and Bonollo's concerns were in line with the ones motivating this paper: valuing engineering design approaches in industrial design education and seeking to make these compatible. In order to structure their research, Lewis and Bonollo [17] harnessed a 5 stage operational process of design, based on selected literature of their choice [18]. This process is comprised of five sub-ordinate processes. These are: task clarification, concept generation, evaluation and refinement, detailed design of preferred concept and communication of results.

The proposed new concept generation method is based on the adaptation of an ergonomic design approach structured by activity theory, established by Coelho and Dahlman [19]. The method was developed for use in the classroom, in the author's Product Design course within the second year of the undergraduate program in Industrial Design, and takes as a point of departure human activity, in order to search for new product concepts. It is meant to be considered in the concept generation stage of the design process, once all the task clarification steps have been carried out.

A description given to students is intended to trigger them to apply this way of starting concept generation in their particular assigned projects. The method is then based on searching for answers to the question "how can this human activity be enhanced, supported or enabled by an artifact?" This process is based on considering the goals, instruments, person and context information, structured according to activity theory, besides establishing a "tout court" requirements list specification which is then abstracted to reveal the fundamental problem [5]. The method is believed to hold the potential to trigger the generation of concepts beyond existing solutions, and pushing the envelope of creativity beyond the mere upgrade from existing concepts.

It is arguable that the nature of human activity will change according to the nature of the artifact that supports it. Hence, when generating alternative concepts, based on the consideration and exposure to the activity analysis, concepts and human activity are in flux with each other and modification of one may bring upon changes on the other. The decomposition of the aspects of the task clarification subordinate process of the design process that are relevant as inputs for the concept generation activity based method take place prior to the concept generation stage *per se*. A schematic diagram is shown on Figure 4 depicting the rationale underlying the execution of the method, in the stage of concept generation. Task clarification plays an important role in providing inputs for the activity analysis. While it is acknowledged that these stages of the process of design encompass a set of actions that goes beyond the scope of the illustrations, the aim in their making was to focus in the contours of the proposed method. Evaluation and refinement follow the concept generation sub-ordinate process, but since no significant modifications are made to established methods, there is no illustration provided of stage 3 of the operational design process and further beyond.

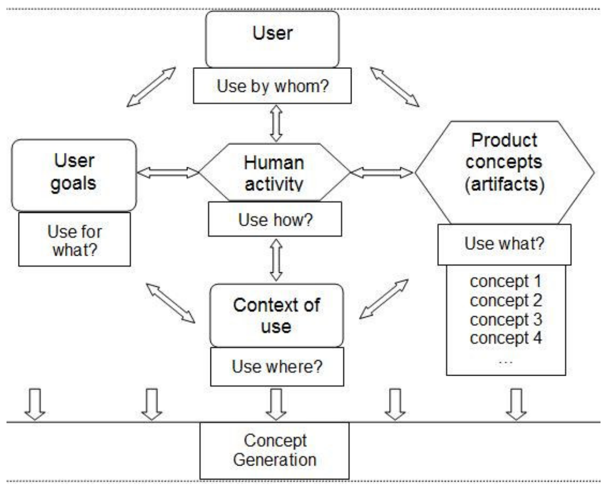

Figure 4: Activity analysis depicted as a way of triggering new concept generation. The activity is at the centre of the analysis. The use relation is characterized at every step. Answering the question "how can this human activity be enhanced, supported or enabled by an artifact?" aims at generating multiple concepts.

Within the concept generation stage, abstraction of the fundamental problem from the design specification may benefit considerably by keeping the "main problem" under the light of the activity framework. In rather complex tasks, for instance those dealing with machinery or automated equipment, functional analysis is a fit process for technical systems and establishing solution principles. In this education scenario, functional analysis of the task to be performed is also introduced, albeit it is less useful for radical new concept development of simple concepts. Many projects that are developed in class concern unsophisticated devices, such as furniture, or simple appliances, with a common theme being directly supporting human activity. Brainstorming is quite useful as an explorative tool in the concept generation phase, and it is used in conjunction with abstraction, functional analysis and activity analysis to support, or nurture, the creative process.

It is acknowledged that goal establishing and analysis is not foreign to setting requirements when creating product specifications ([4] - provide a thorough categorization of goals, objectives and requirements). These goals are essentially geared at product properties. However, focusing on human activity goals to trigger concept generation, particularly, is something which is deemed additional and enriching to the aforementioned approach to goal analysis.

The method proposed is also based on systematic design procedures to evaluate and improve the initial concepts and guide their further development [20]. These systematic design procedures include, for instance, evaluation of alternative concepts according to multiple dimensions and selection of the fittest solutions for further development. It does not however explicitly establish links and relationships between design variables, performance specifications and user needs, and, or, utility function, as is suggested by Ulrich and Eppinger [20], given the clash of this approach with a non requirement list focus, which is one of the main drivers in the method. This approach could also be somewhat deterrent from radical new concept generation, which is sought by the use of the proposed method.

Many educational results obtained that were outputs from the creative methodology for new concept generation based on human activity, seem in abrupt discontinuity with existing concepts to support the activities these concepts are intended to support. This radical nature affords reflection, outlined in the following section.

5 Radical new concepts

New concepts involving a paradigm shift may represent a great opportunity but also a challenge for their widespread adoption. The aforementioned student results can serve as a basis to point out opportunities and challenges pertaining to what radically new product concepts embed in general. These may involve a paradigm shift and represent a major challenge for their widespread adoption, even if they behold a big attractiveness in several dimensions (e.g. efficiency, usability, comfort, etc.). The method proposed contains the potential to trigger the generation of concepts beyond existing solutions, and therefore may be helpful in pushing the envelope of creativity beyond the mere upgrade of existing concepts.

Radical product development projects, which are undertaken to create new categories of products, present significant challenges to development teams [21]. In such settings existing formal processes may be limited or inappropriate, and objectives may be ambiguous and changing. McDermott and O'Connor [22] claim that radical innovation within an organization is very different from incremental innovation and that it is critical to the long-term success of firms. However, these authors also support the idea that it is more difficult to get support for radical projects in large firms, where internal cultures and pressures often push efforts toward more low risk, immediate reward, and incremental projects. McDermott and O'Connor [22] state that there is considerably less knowledge available in literature about the effective management of the product development process in the radical than in an incremental context. Hence, the bigger challenges lie ahead of radical new concept generation, but the goal of the method presented herein is to foster such outcomes, regardless of their possible immediate application or envisaged hardships in implementation.

5.1 Implications for the design of multi-actor systems

The potential of activity based methods to support systems design rests in their ability to expose interaction between multiple users and system agents, and to express goals and artifacts in an activity oriented manner. The benefits that can be reaped from activity oriented methods depend not only on the extent of their consideration, but on the actual possibility of implementing new solutions that represent an archetypal departure or leap in relation to existing ones. While simplification is always deemed necessary when modeling complex phenomena, it must be carried out in a consciously weighted effort, concerning the advantages and disadvantages of leaving out a particular aspect from the model. Activity theory puts some added focus into aspects which might be otherwise overlooked. Still however, some of the available activity based design methods may incur in over-simplification of the structure of activity, curtailing the possibilities of benefiting from their application. A typical example of the first case mentioned is considering tasks instead of broken-down activities, and not going in to the latter and exploring their structure.

For the most part, the archetype behind a solution concept for a design problem is intrinsically linked to the nature of the solution, in terms of technology, architecture, and the way tasks are performed. The possibilities of archetypal departure maybe seriously restricted at times, especially due to constraints imposed by applicable regulations and also due to macro-systems lockage into a particular technology. Applicability of activity based methods to support new concept generation at system design level is considered feasible. The underlying hypothesis to this belief is that paradigm shift in activities with a larger scope can be attained from analysis of the broken-down structure of activity, even in multi-actor complex systems. Adaptations need to be considered from the proposed method for new product concept generation.

Activity based methods to support systems design are already used in practice. Bardram [23] presented a design philosophy coined as activity-based computing (ABC), which addresses mobility and cooperation in human work activities. It is based on the ABC framework, which the author describes as a ubiquitous computing infrastructure supporting ABC. The aims of ABC appear to be supporting: human activity by managing its collection of work tasks on a computer, mobility by distributing activities across heterogeneous computing environments, asynchronous collaboration by allowing several people to participate in an activity, and synchronous, real-time collaboration by enabling "desktop conferencing" by sharing the activity across several clients. In this case, system goals are not explicitly considered in the hierarchical task analysis, and activity theory is applied to human actors in the first case discussed [23], but not to artificial actors or system agents. Hence, the scope of analysis provided by activity theory does not seem to be fully harnessed by this design philosophy. A possible explanation for this is that at most this philosophy focuses on prescribed tasks, rather than on the activity (broken-down with the consideration of goals) that is actually taking place in the system.

Another example of the use of an activity theory based framework in systems design is given by Ricci et al. [24]. This is a very interesting example that considers multi-agent collaboration within an environment for social interaction between computer agents. The conceptual framework presented is influenced by research on activity theory applied to multi agent (computer) systems, where both subjective and objective coordination play an essential role. The authors demonstrate how each of these modes of coordination provides effective means for collaborative problems at different abstraction and operational levels: subjective coordination for the co-construction level, and objective coordination for the coordination level. Their work shows the benefits of supporting dynamic transitions between such levels, alternating co-operation stages, in which agents reason about coordination and collaboratively forge coordination artifacts (laws, constraints, norms), and co-ordination stages, where the artifacts, embodied in proper coordination media, are exploited, so as to enact automated, consistent and prescriptive coordination. However, this framework does not explicitly consider in the analysis the goals of human actors within the broken-down activity structure, since these are previously extracted and translated in to a requirements list.

Using the activity theory framework to inform object-oriented analysis and design methods for systems design could improve the quality of collaborative work, both in terms of cooperation carried out between professionals and also in terms of cooperation that takes place between professionals and systems. To this aim, it is suggested that a hierarchical chain of user dependencies, is established, and individuals (both humans and artificial, or system, actors) are identified and analyzed according to the activity theory framework presented and considered in the method, as an addition to the general object-oriented analysis and design methods in use. Computer Supported Cooperative Work (CSCW) application design at systems level is a field that will benefit from activity based design methods. In a CSCW example taken from the clinical care sphere, people (professionals, usually front-end professionals, e.g. nurses and medical practitioners in health care) base clinical record keeping and treatment orders on information systems that percolate through the whole clinical work environment [25]. What is seen in such environments where CSCW takes place is that artificial actors (computer systems) are far from passive. These often have their own "agenda" which is often dictated either by technical limitations originating in software or hardware, or in other biases introduced at the design stage, and that combine to hinder efficient functioning of the system of people, technology and work.

The two examples discussed suggest that concept generation in systems design is bounded by constraints that strongly oppose paradigm shift. This may represent the most important factor dictating fundamental differences between the activity based approaches for systems design and for product design. The potential benefits of performing an activity breakdown analysis for concept generation, spring across design problems, from simple to more complex systems, whether for single users or for multi-user and artificial actors. The limiting constraints to reaping the potential benefits of deploying this approach concern technology lockage and regulation ties, whether from legal requirements or from standards. Increasing complexity of the design problem necessitates some adaptations to the approach, especially in what concerns deepening the activity breakdown analysis to consider hierarchical relationships between actors.

6 Conclusion

In this paper, a method for initiation of new concept generation was presented that is based on considering human activity goals and instruments, as well as person and context information, structured according to activity theory, rather than only establishing a "tout court" requirements list specification followed by abstraction of the main problem. It is aimed at combining a technical approach with a creativity stimulation approach, which is based on considering and visualizing the activity in context. "How can this human activity be enhanced, supported or enabled by an artifact?" is the core question. The method is based on searching for answers to this question, once the activity has been characterized and analyzed using the activity framework. It thus entails the potential to trigger the generation of concepts beyond existing solutions. This trigger also aims at pushing the envelope of creativity beyond the mere upgrade of existing concepts. Afterwards, systematic procedures are used to evaluate and improve the initial concepts and guide their development.

The concept generation method presented may be applied to support paradigm shift in activities with a larger scope. Some adaptations were proposed to apply the concept generation method to a larger scope of analysis, such as in a systems design level. Adaptations suggested to support application concerning CSCW at systems design level, in particular, include adopting a hierarchical view, and establishing several individual frames of analysis, considering the broken-down activity of both human and artificial actors. The similarities and differences in rationale between the proposed method, and the methods applied in systems design, were emphasized, based on two examples. This suggests that concept generation in systems design is bounded by a series of constraints that strongly oppose paradigm shift in activities with a systems scope. This may represent the most important factor dictating fundamental differences between the activity based design methods for systems and for products.

Activity theory is a powerful framework that can be applied in many engineering domains, to foster meaningful and efficient solutions to problems in several fields of human action. In what follows, some specific studies and projects, whose development is underway, or that have recently been presented, are used to draw examples of areas that could benefit from the deployment of an approach to organize the solution of the problem, and in a way that is based on activity theory. Sancin et al.'s [26] study of the development of an intelligent advisory system with integrated modules for specific design aspects is one of such examples, which gives rise to suggest in particular that knowledge based engineering could benefit from the insight given by an activity theory based framework.

From yet a different perspective, while concept generation is aided by activity theory in the present paper, an activity theory based framework is also suggested as a means of enabling structuring to support the identification of underlying concepts across collections of works of art, artifacts, or architectural sites. An example of suggested tentative application would be a study in the lines of the one presented by Burley and Loures [27], on identifying and unveiling the underlying design concepts to historical landmark sites.

As a final example for yet another suggested application domain for an activity theory developed framework, the field of distance learning using Information and Communication Tools is emphasized. According to Despotopoulos et al. [28], despite developments in technology and sciences, education does not seem to readily benefit from such developments in terms of improving its instruction methodologies. These authors admit that using ICT for learning purposes is more fun, challenging and inspiring than traditional means. However, since distance education changes the way by which work is carried out in the sector of education, it can function as a tool by which modern society will be able to handle the new challenges to better pursue its educational goals [28]. Activity theory may also have an important role to play in the field of distance learning with ICT, making this possibility a reality through the analysis of the structure of user goals, instrumental conditions and operations.

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