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Simpler, Better, Faster, Cheaper, Contextual: Requirements Analysis for a Methodological Approach to Interaction Systems Development

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Abstract: **In the Cyberspace context Information Systems become Interaction Systems, effective mediators of the activities performed. Our goal is to consider the challenges of such a scenario and analyse the requirements for a methodological approach to the development of Interaction Systems. To that aim, the authors resort to the Activity Theory as an analytic tool and establish general and specific requirements for such an approach.**

I. INTRODUCTION

From the introduction to the ECIS 2000 Track - Information Systems Development:

"Information systems (IS) have a life cycle. The IS development life cycle is a process by which an IS comes to life and maintains its usefulness to a business as it moves from inception to replacement. IS development is considered a complex engineering process that encompasses various stages, including planning, analysis, design, construction, and implementation. The process involves professional developers (e.g., systems analysts, designers, programmers), users (including management) and software engineering methods.

The use of the term "software engineering" is meant to emphasise that the IS development process ought to be conducted as in other engineering disciplines, using well defined, precise and reliable methods and techniques. These methods and techniques are generally termed "methodologies", and the software tools that support them are termed CASE (Computer Aided Software Engineering) tools.

IS development methodologies are aimed at improving the management and control of the development process, structuring it, reducing its complexity, and standardising both the process and resulting product. Hundreds of diverse development methodologies have been developed over the years, some from practice and some from theory. Methodologies differ from each other in various ways. Variations among methodologies are manifested in their underlying ontology, the life-cycle development stages they cover, modes of presentation, supported environments, techniques and application domains, degree of formality as well as the managerial and control mechanisms they provide.

In spite of promises and expectations, difficulties of various sources often hinder the effective use of IS development methodologies and their supporting CASE tools, and their contribution to achieving the above mentioned objectives is barely evident. In fact, many organisations are unable to utilise, and avoid adopting development methodologies. A major source of difficulties in using methodologies is rapid changes in software technology. For example, the transition that has taken place in the last decade from structured, process-oriented to object-oriented programming languages has caused an analogous shift in the orientation of analysis and design methodologies. This transition is not yet complete, and most emerging methodologies are still not mature.

There is no consensus regarding the usefulness of existing methodologies in today's environment. Past research has focused on the development of new methodologies and frameworks for their selection and evaluation, not on their evaluation or use in practice. The bottom line in practice and research is that there is no generally accepted theory of IS development, nor a systematic investigation of advantages and shortcomings of methodologies in use. More research is needed in the field in order to provide a sound foundation for IS development methodologies of the next century."

We subscribe to this introduction and it is our goal in this paper to shed some light on the problem of methodological fitness for the context of Interaction Systems Development. We begin by presenting some key ideas of Activity Theory, with roots in Russian psychology, with the activity, the minimal meaningful context, as its unit of analysis.

Building on the concept of Activity System and the cycle of expansive learning, as proposed by Engestrom [1], we proceed arguing that the object of the Interaction Systems Design Activity is an evolving target, and that designing artefacts (such as methodological frameworks for the analysis and design of IS or the IS themselves) is inseparable from designing the context or activity of use.

We proceed by eliciting a working set of requirements for a methodological framework to be used in the context of IS development. Through this, we aim to contribute to a systematic study of Interaction Systems development.

A. The notion of Interaction Systems

By Interaction Systems we mean those that effectively mediate the human activity, be it in work settings or otherwise. This corresponds to a change in perspective over Information Systems, to consider them as effective expressions and conveyors of action in an organisation. We intentionally abandon a perspective of Information Systems as strictly (or mainly) systems about action, i.e.,

devoted to the management of information about the activities, towards a supportive perspective, where the system plays a part as mediator of the actions themselves, i.e., activities develop through the system.

Our analysis of the IS perspective is based on the Activity Theory framework, which is based on the idea that all human activity is mediated, as originally proposed by the Russian psychologist Vygotsky [10][11], and subsequently developed by others (Leontiev [5], Luria). Their work has been further developed by Yjro Engestrom [1][2] that introduced the expansive learning cycle and the Activity System notions.

The Interaction Systems perspective considered here is by no means farfetched. It is already a reality in many organisations and can be conceived as the basis for virtual organisations, understood as those that exist, fundamentally, through mediated interactions, as opposed to typical localised or face-to-face interactions. Our goal is thus to search for an adequate methodological framework to develop and maintain these systems in a way that is best suited for the challenges posed by those contexts.

Moreover, the Interaction Systems perspective proposed here proves to be a valuable first step towards a possible shift in the way we conceive Information Systems in general and their development. A shift towards a contextual approach, embracing the context of use as integral part of IS design, constitutes a significantly different object of study, albeit still included in the general framework of Information Systems design.

II. Background on Activity Theory

As personal computing gives way into interpersonal computing, information and communication technologies present new challenges to both IS theory and practice in organisations. New approaches are needed to understand the role of technologies in practice. As a social psychological theory focusing in the dynamics of human activity, rooted in dialectical materialism whose basic idea states that things be studied as process in motion and change [10], Activity Theory seems to provide appropriate abstractions and concepts to analyse, among others, the IS design activity.

A. All Human Activity is Mediated

Activity Theory has its origins in the work of Lev Vygotsky, a Russian psychologist that worked in the 1920s. Vygotsky's colleagues further developed his work, but only recently (1979) has it gained acceptance and recognition in the English-speaking world. Nowadays, Activity Theory has gained a multidisciplinary community concerned with the research of activity and its implications in several areas (such as Education, HCI and IS).

Intended by Vygotsky to be an unifying framework for the study of human as a subject acting in a cultural-historical context, Activity Theory is a cross-scientific theory whose central tenet is the idea of a dialectical process between human and artefacts, shaping and being shaped by both the natural and socio-cultural environment [7].

The purpose of Activity Theory is to understand the unity of consciousness and activity, incorporating strong notions of mediation (activities are mediated by artefacts, both internal and external), history (activity changes and develops so a historical analysis is often needed in order to understand current state) and collaboration (an activity is carried by an individual, in order to accomplish some desired result, within a community of other individuals, conducted according to a set of rules and subject to time and access conditions of the object).

B. Structure of Activity

Vygotsky [10] extends the basic concept of mediation in human-environment interaction, rooted in the Engels concept of "tool", to the use of signs as well as tools, thus establishing that an activity always has artefacts, whose essential feature is that they have a mediating role. Fig. 1 intends to depict that the relation between the subject and object of an activity is always mediated by some sort of artefact (or artefacts).

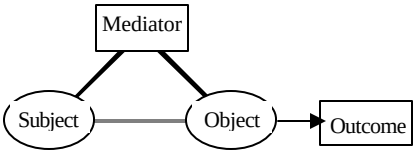

Fig. 1. Mediated Activity

According to Vygotsky, a person's actions, language and learning (and ultimately, higher mental processes) are located in everyday practice and can only be understood as part of a broader social matrix, embedded in social environments of people and artefacts. Thus, the structure in Fig. 1 is too simple to fulfil other considerations of systemic relations of the subject to her/his environment.

The structure of an activity, as presented by Engestrom [1] and schematically shown in Fig. 2, contains three relations between the three main components: subject, object and community. Each relation is mediated.

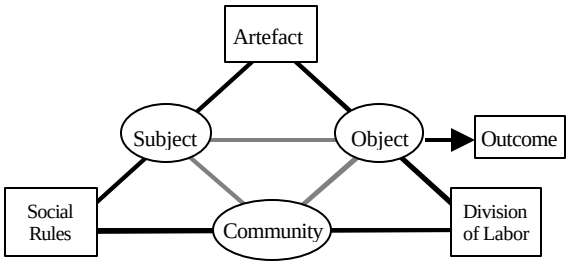

Fig. 2 – Structure of Activity, as proposed by Engestrom.

An activity is carried out by a *subject,* that can be an individual or a group. An activity is a form of doing,

directed to an *object*, and activities are distinguished from each other according to their object. The purpose of the activity is to transform the object into a desired outcome. By considering the third component, the *community,* Engestrom introduces the relations between the subject and the environment in an activity. Those who share the object belong to the community.

The relation between the subject and the object is mediated by one or several *artefacts*. An artefact can be anything used in transforming the object into the outcome. They can be tangible or intangible, but must be shared by the community, and used in some way. They can be both external (physical tools) or internal (mental tools).

The relation between subject and community is mediated by *social rules*, and the relationship between object and community is mediated by the *division of labor*. Each of the mediators (artefacts, social rules and working rules) carry with them the history of the relation, past changes and older developments [4]. Describing the elements of the activity describes the context.

Leont'ev, one of the first developers of activity theory, introduces a notion of contextual decomposition within the Activity Theory framework by pointing out that just as the concept of "action" brings coherence to related "operations", the concept of "activity" brings coherence to a set of related "actions".

C. Activity is Context

Some psychological theories focus on the isolated human action as their unit of analysis, much because of the easier that is to design and carry out experiments and tests in laboratory (e.g usability tests of computer systems).

User models, considering the human alone, separated from a social group and featuring no associated artefacts, can no longer be used to fully understand what goes on in real world situations (such as learning or working), because actions outside the controlled lab environment are always situated in a context and without this context, they would be impossible to understand (see [8][9]). Indeed, some more recent approaches to systems development begun considering social approaches to user modelling.

Activity theory offers a solution by considering activity the minimal meaningful context for individual actions [4], preserving the link between mind and society and the coherence of a set of individual actions.

Also, as a subject can (and usually does) participate in several activities, and the outcome of an activity can easily constitute an object or artefact of other activity, considering activity as the minimal context enables the understanding of a broader Activity System constituted by several interacting activities, that evolve together.

D. The notion of Activity System

In order to study change and learning Engestrom [1] considers a set of interacting activities with interrelated outcomes, i.e. an activity's outcome may be another's artefact, subject, object, etc..

Although the term Activity System is frequently used to refer to the context of a single activity (one triangle) we will use it in this paper to refer to the set of these interacting, neighbouring interrelated activities and maintain the reference to a single activity as simply "activity".

By considering this set of activities, Engestrom explains that activities change as an expression of learning, through a cycle of expansive learning that usually begins with a primary contradiction in the central activity. The concept of contradiction in this model arises from the dialectical materialism that is subjacent to the theory.

Fig. 3 depicts an Activity System and the relations between neighbouring activities by types of contradictions.

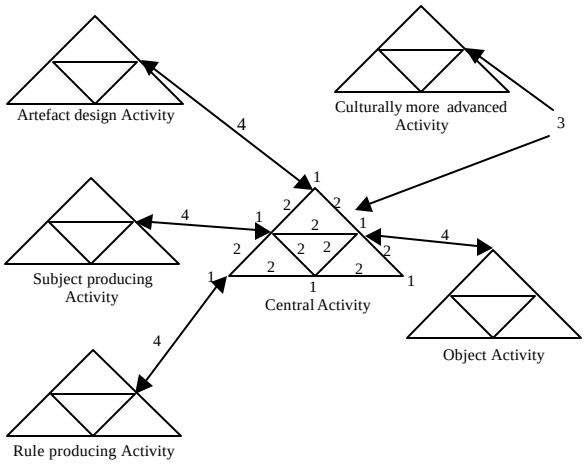

Fig. 3. An Activity System – a set of interrelated activities. Also shown their relation in terms of contradictions (1 – primary, 2 – secondary, 3 – tertiary and 4 – quaternary).

Contradictions may be classified in four types: a) primary contradiction, meaning a contradiction within an activity between an activity element and its exchange value, e.g. the perceived cost of using an artefact is greater than the valued result; b) secondary contradiction, between elements of an activity, e.g. the skills required for the use of an artefact are not mastered by the subject or the artefact does not relate adequately to the object; c) tertiary contradiction, between the current activity and an activity that is perceived as a more advanced substitute; d) quaternary contradiction, occurring between the activity and one of its neighbouring activities, e.g. one that "uses" its result, or activities contributing to the elements of this activity, e.g. producing artefacts, teaching the subjects skills, formulating rules, etc.

E. The Expansive Learning Cycle

The cycle of expansive learning model consists, succinctly, of a sequence of steps that begins with a contradiction in the activity system and proceeds towards the resolution of that contradiction, through the successive adaptation of the conditions and elements that originated it.

According to Engestrom [1], the cycle of expansive learning would describe a journey through the zone of proximal development, in five stages.

The starting point is a state of need in the central activity that in general would have its origin in a primary contradiction between use and exchange value. In the second phase, the central activity is faced with dilemmas caused by a secondary contradiction between elements of the activity, possibly by the introduction of new corner elements. In a third phase, motive or object construction begins with the search for new artefacts and the reformulation of the activity. New artefacts and actions are modelled for the new activity. In the fourth phase, the application and generalisation, the new artefacts are confronted with the old activity; precursors of the expected new and the old activity conflict and disturb each other (tertiary contradiction), and a new activity is born in forms not anticipated in earlier phases. In the fifth phase, the new activity is consolidated through a set of steps where: a) new artefacts are systematic applied in a repetitive and explicit way; b) the use of artefacts varies and the new activity gets adjusted to the activity system; c) the new activity takes effect in the relation to neighbour activities in the activity system, possibly resolving or generating new quaternary contradictions. “The new central activity has to compete with and adjust to the dynamics of the neighbouring activities" [1].

The resulting activity is not a finite state and development will continue through recurring cycles of expansion. This perpetual motion and adaptation within the Activity System is a fundamental property of the model, and has specific consequences to the Interaction Systems Design activity.

III. Theorising the Interaction System Design Activity

A. Organisations as Activity Systems

Subsequently, we will explore some consequences of considering the introduced Activity Theory principles and models as lenses for an interpretative discussion of the activity of Systems (Analysis and) Design. To this purpose we consider the previously proposed perspective of Interaction Systems.

If we interpret an organisation through the lens of Activity Theory it appears as an Activity System, a system of interacting activities that evolve together through expansive learning. This means that the analysis of learning in an Activity System can be used as a model for the analysis of change in organisations, being change a product of organisational learning.

As an organisation adapts that is reflected in the model as an Activity System development. We can identify two strategies that relate organisational change to mediating artefacts: an artefact *follow up strategy* that consists in the definition of new activities that require new systems or the adaptation of existing ones; an *hopeful strategy* that considers systems as enablers of new activities that rearrange around them. These are two faces of the same coin. Two interpretations of the same reality: that activity and artefact co-evolve.

Whatever the strategy, there is always a target activity, an idealised order to be formed around the developed system. This target activity is the context for the Interaction System Design activity. In fact, this implies that the design of the systems is not independent from the design of the activity meant to be its context. Taken in the broader context of the Activity System representing the whole organisation, the design of Interaction Systems is co-determined by the design of the Activity System. This is a fundamental result that argues for the importance of appropriately considering context in the design activity.

B. Organisational learning and systems development: a moving target?

Still using the organisation as Activity System interpretative model, combined with the cycle of expansive learning as a model for organisational change, we verify that, after new motives and instruments are modelled, comes the application phase where the new artefacts are confronted with the old activity. This generates a contradiction between the new and old activity (tertiary contradiction), that must be resolved within the context of the activity system.

At this point we step into the consolidation of the new activity phase, where: a) new artefacts are systematic applied in a repetitive and explicit way; b) the use of artefacts varies and the new activity gets adjusted to the activity system; c) the new activity takes effect in the relation to neighbour activities in the activity system, possibly resolving or generating new quaternary contradictions. "The new central activity has to compete with and adjust to the dynamics of the neighbouring activities"[1].

The resulting activity is not a finite state and development will continue through recurring cycles of expansion. The perpetual motion and adaptation within the Activity System is a fundamental property of this model. Thus, we have to conclude that the Design of Interaction Systems is an activity struggling to assert its objective, as the target context adapts. If the new central activity is not final the same happens to the target context of the systems design activity.

Still using the cycle of expansive learning model, whenever an activity in the organisation gets adapted or evolves through the cycle of expansive learning other activities interacting with this one may have to be reformulated. This means that whenever design for a specific activity takes place, the impact on neighbouring activities should be considered. And thus, the design context for the artefact should be expanded to include

not only the targeted central activity but "expected" interacting activities.

An Interaction System as mediator of an Activity System must satisfy the need of each subject in relation to the object of his/her activity. But as part of a system of activities, each activity is subject to change or evolution with respective consequences for the design of the artefacts that mediate it. Thus, we are compelled to conclude that, in a fast moving context, (business or otherwise,) the Interaction System Design activity is aiming at a moving target, possibly incompatible with a system life-cycle management using current methods and with current software development rhythms and cost.

If the Interaction System is meant to be the mediator (or the ordered collection of mediators) of the activities in a corresponding Activity System, co-evolving with them, as the organisation changes, then its design must be faced as a work in progress. Consequently, systematic methods, as instruments for that design activity must support iterative, incremental and refinement approach qualities, with modelling of the context of use as the central guiding concern.

IV. Requirements for a Methodological Approach to Interaction System Development

Following, we will provide our contribution to the analysis of the requirements for a methodological approach to Interaction Systems development activity.

A. Simpler

Simpler, as a general requirement is valid for any methodological artefact, and is especially important if our context is one of rapid change, either in technology or use. The desired effects of simplicity are ease of use and learn, translated in the time required to achieve different levels of mastery and proficiency. A simpler artefact is one that enables fast learning and low overhead on use, when perceived by users against a non-systematic approach.

B. Better

A better methodological artefact is necessarily a quality consideration of subjective nature. We should differentiate between the notions of intrinsic vs. extrinsic value. A better artefact may be intrinsically better, meaning that it is considered that way by the designers or, extrinsically better, e.g. because designers have produced better results with it, from the point of view of the users of the Interaction Systems developed.

While the first notion may depend on individual subjective appreciation of relative pleasure in working with a specific tool the second notion is more apt to a classification obtained by collective evaluation of results (that may be made on more objective terms, such as fitness to desired requirements). Nevertheless, in this second approach may still be difficult to isolate relative influence of subjects experience with the domain of use, with the technology and with the degree of mastery of the methodological artefact.

Both considerations, intrinsic and extrinsic, are valuable and ultimately influence the subjects' proficiency with the methodological tool.

C. Faster

An artefact that produces results faster is of major importance in fast changing context as the one of Interaction Systems development. A combination of fast prototyping with software life cycle management of more resilient components is a necessity in current organisations. An artefact that produces results faster contributes towards enabling frequent iterations and the incremental development of systems as opposed to medium to long development projects without intermediate deliveries. Short iterations with incremental results enable early usability testing and continuous contextual feedback. Of faster tools we expect also low overhead as compared to a non-systematic approach.

D. Cheaper

A dual contribution to this requirement may be elicited: cost to implement the methodology (given by additional human effort necessary to enact specific methodological procedures or other needed resources) and cost of producing specific solutions. A differentiation between short term and long term costs must also be taken into consideration. A cheaper methodology would enable the development of subsequent versions of an artefact to build on previous investment as opposed to starting all over. An iterative methodological tool should enable refinement of previous solutions and work with components. A cheaper methodological approach is also an attractive one to those management-oriented and an indispensable property to enable a frequent and iterative approach to systems development.

No one would consider re-cycling an expensive development process to make "minor adjustments" or optimisation, only to make major changes. And that would make the approach lean to a "traditional" medium to long term process with sparser releases.

E. Contextual

That enables design driven in a contextual way, that is, that explicitly enables the design of context as well as the design of the artefacts. As argued earlier, the context of Interaction Systems development calls for a permanent management of contextual information as a critical part in system development. That will be the only way to enable the designer to explicitly attempt to determine co-evolution of activities (or context) and artefacts, instead of relying on a blind *hopeful strategy* that if (s)he designs a certain artefact people will hopefully organise their activity around it, or, relying on the *follow up strategy* and design for an activity that is predefined and not expected to change. **A contextual approach would offer tools for the concurrent and proactive design of context and artefact.**

The practice of Information Systems development is full of cases where at some point in the project, whatever the methodological tools involved, someone invokes the "running (or floating) specifications" problem. This

usually means that either technology is changing, or the customer is changing his/her mind as the development progresses, or the context of use is changing or a combination of the previous. Indeed, the authors' experience corroborates that common observation. Why is that so frequent? When we consider the diversity of factors influencing Information System development we should be surprised if that did not happen. Being such a natural and recurrent scenario we have to ask: why is that so frequently considered as a problem instead of as a feature of the IS development process?

A possible answer is that IS design professionals are trained to focus on the invariance of the design context as reinforced by the methodological artefacts they use (method and representations). In addition, they are concerned with quickly defining a frontier for the problem to be addressed as they see that as the main source of trouble in runaway projects. This poses a conflicting problem in the social dynamics of IS design since the customer has just now begin to think about what (s)he wants to be doing with the system, (s)he will continue to think about it through analysis sessions, and designers ideas will only be confronted with the users mindset at the first usability session. So, we should prototype. Eventually in a participatory way involving the user in the design decisions from the early stages. But prototypes are not final systems, and especially, they are not systems in use. And even if they were, their use would yet have to evolve until the activities affected by the system begun reflecting that use on adjacent activities, in the broader Activity System. So, the only way out we see at this point is to consider both the artefacts and the context to be works in progress and embrace that change as part of the development process.

V. Conclusions and Further Work

We propose an Activity Theoretical approach to what we termed as Interaction Systems, defined as a perspective on Information Systems that considers them as mediators of activity. We proceed by arguing that organisations, when viewed through the lenses of the Activity Theory models, pose specific challenges to Interaction Systems design. Namely, that the design activity is directed at the development of artefacts to be used within the context of an idealised activity in a broader Activity System. Moreover, we argue that activity has yet to be realised may change with the introduction of the artefact as well as by adaptation to the interacting neighbouring activities.

Within this framework we elicit a first set of requirements for a methodological approach to be used in such a context. As future work we envision the selection from available methodological artefacts of candidates for usability testing against these requirements as well as the possible development of complementary tools, or new uses of available ones, to respond to the problem of contextual design.

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