Manifesting Shared Affordances in System Development – the System Anatomy

Lars Taxén[a] and Joakim Lilliesköld [b]

[a] Campus Norrköping,
Linköping University
Department of Science and Technology
Norrköping, Sweden
{lars.taxen@telia.com}

[b] Joakim Lilliesköld
The Royal Institute of Technology
Department of Industrial Information and Control Systems
Stockholm, Sweden
{joakiml@ics.kth.se }

Abstract

In complex systems' development, it is necessary to understand how things depend on each other in order to plan and control the development task. Ericsson, a major supplier of telecommunication systems all over the world, has successfully used a construct called the system anatomy for this purpose. The anatomy shows, in a compact way, the crucial functional dependencies in the system. Since the anatomy has had a profound practical impact, it is relevant to analyse how this construct can be grounded also theoretically. In this paper, we present such a grounding in which the anatomy and its associated plans are seen as manifestations of affordances. These affordances enable different groups of actors to reconcile their actions. Besides affordances, the theory is grounded in the Russian theory of activity and the Activity Domain Theory. The findings indicate that the suggested theory is a promising socio-technical approach that may complement existing approaches for development of complex systems.

Keywords: anatomy, affordance categorization, activity theory, the Activity Domain Theory, activity modalities, practical applications, complex systems

1   Introduction

The development of complex systems such as the 3rd generation of mobile telecom systems is usually carried out in global development projects that include many different organizations. The coordination of such projects brings about almost an endless amount of technical, market related and organizational interdependencies. Most often, this requires mutual adjustment across many types of both technical and organizational boundaries (Adler, 1999). Moreover, the management of these projects is also challenged by an ever-increasing pace of technical development, new standards and changing customer demands. This requires flexibility to incorporate new technical solutions or functionalities during the development process. Consequently, new circumstances arise throughout the project that must be dealt with dynamically to meet both fixed and emerging targets.

In order to develop a complex system many actor skills are needed. Such skills evolve in various *workpractices*. By workpractice, we understand a socially organized setting where actors / producers produce an outcome for some clients (e.g. Goldkuhl & Röstlinger, 1999). The actors become proficient in particular areas such as project management, system analysis, design of software or hardware, etc. Each workpractice has its own way of thinking, specific tools and methods, rules, norms, etc. For example, a project manager will be familiar with instruments like work breakdown structure, Gantt diagrams, the MS Project tool, etc., while a software designer may be proficient in using use case diagrams, object oriented design and so on.

Most actions carried out in a workpractice remain local to that particular practice. However, some actions may influence other workpractices. For example, system architects may need to change the architecture of the system. This will affect project management and possibly the customer. Another example is the cancelling of some functions ordered by a customer. This will certainly affect project management and possibly system management. Moreover, a complex system like a telecom system includes many different types of technologies such as software, hardware, radio, mechanical, etc. The workpractices that work with these technologies are interrelated. For example, the hardware of a processor must interact with the microcode of the software. Due to the complexity of the system, it is hard to anticipate the consequences of a certain action on the development task as a whole. An action, which may appear perfectly feasible in a certain workpractice, may result in unmanageable consequences for other workpractices. For example, an interface specification between software and hardware parts may be changed from either side of the interface without notifying the other side.

Thus, in complex systems' development there is a need for instruments by which actions in different workpractices can be reconciled. Such instruments must have at least two qualities. First, they must be meaningful in each workpractice as well as across all workpractices. Second, they should enable the actors to recognize what actions are possible and anticipate the consequences of these actions for other workpractices. Traditional tools and methods do not appear to have theses qualities. To this end Ericsson, a major provider of telecommunication systems around the world, has introduced a construct called the "system anatomy" in their development practice.

The system anatomy, or "anatomy" for short, is a comprehensive picture – on one page – of how the system is working. It shows the functional dependencies in the system from start-up to an operational system. The gist of the anatomy approach is to develop, integrate and verify the system in the same order as it "comes alive". In order to do so, two types of plans are defined based on the anatomy: the increment plan and the integration plan. The increment plan structures the development work in verifiable steps – increments – that can be successively integrated. The integration plan shows sub-project responsibilities and dates for deliveries of increments.

The anatomy approach has had a profound impact in the Ericsson development practice. Since the early 1990s, this approach has been successfully used in more than 250 projects (Lilliesköld et al., 2005). The mere magnitude of this impact makes it interesting to theorize about the anatomy approach. A theoretical grounding may indicate directions in which complementary approaches to system development can be found. Moreover, such a theory may inform the definition and usage of the anatomy in practice.

The purpose of this paper is to suggest a theory that can be used for analytical and constructive purposes regarding instruments such as the anatomy. Such a theory should emphasize the socio-technical nature of the anatomy as well as its capability to signify action possibilities for various actors. The proposed theory is grounded both in existing theories as well as empirically in the Ericsson practice.

The paper is structured as follows. In the next section, we describe the system anatomy and its usage at Ericsson. This is followed by outline of the proposed theory. We depart from the concept of affordances suggested by Gibson (1979). Affordances signify action potentials in the natural environment in a direct and immediate way. In order to include cultural-historical artefacts we make use of the Russian theory of activity (e.g. Bedny et al., 2000). This makes possible a view of affordances as features of human specific "activity systems". The last step in the theory definition is to categorize affordances according to the Activity Domain Theory proposed by Taxén (2004). The purpose of this line of argument is to retain the essential qualities of affordances in such a way that they can be operationalized in system development practices.

The theoretical section is followed by a discussion where we argue that the system anatomy and its associated plans can be seen as various manifestations of affordances. The paper ends with a discussion of possible implications for system development from these findings.

2   The Anatomy and its Use in Project Management

A commonly used model in the industrial development of products is the *product structure*, which shows the parts a product consists of. The product structure is used to describe the product and manage it during development and maintenance. An example of a product structure is given in Figure 1 (the example is modified after Anderstedt et al., 2002):
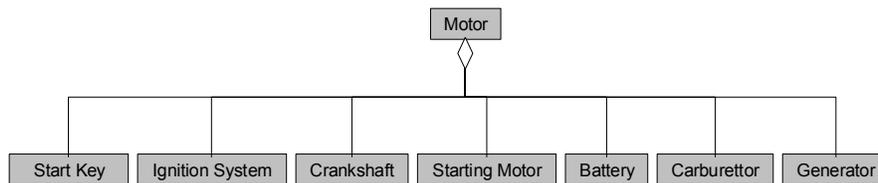

Figure 1 The product structure of an Otto engine.

In complex system development, this type of structure is necessary but not sufficient. The product structure does not capture dependencies between the product parts. For example, there is no indication that the ignition system needs the battery for its function.

The product structure signifies a certain "mind setting" of how the actors "see" the system being developed. In particular, descriptive and management aspects of the systems are emphasized by the product structure. Actions, support systems, methods, rules, etc. will be flavoured by this mind setting.

The anatomy construct is an attempt to model a system from what it offers the end-user. Rather than focusing on product parts, the focus in on what functions these parts provide. In Figure 2, an anatomy of the same Otto engine as in Figure 1 is

shown. The figure illustrates the functional dependencies in the system from start-up to an operational system. Thus, the boxes in the figure should be read as functions or capabilities. An arrow between the boxes indicates a dependency. The mind setting behind the anatomy is how to "breath-life-in-a-system". In order to start the engine a start mechanism and a power source is needed, which could be provided by a start key and a battery. This enables the starting motor functionality, which is to provide torque to the crankshaft. The torque, start and power functionalities enable the ignition functionality, which together with the carburettor functionality enable the motor functionality. This in turn enables other functionalities until the full car functionality is available. As can be seen, the anatomy is completely different from the product structure.
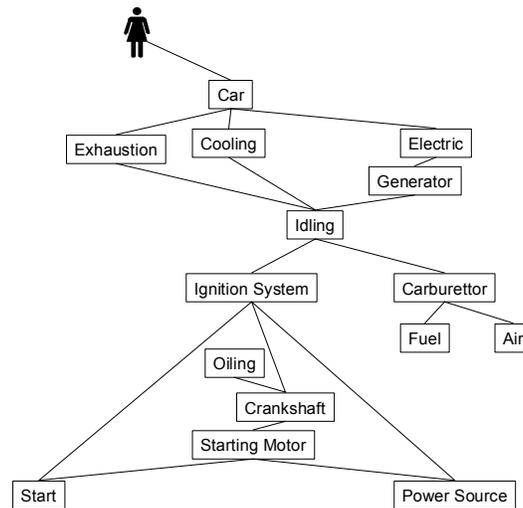

Figure 2: An example of the anatomy of an Otto engine.

It can be noted that the anatomy shown in Figure 2 is to a certain extent arbitrary. Other functionalities might have been included such as steering, breaking, etc. Moreover, the level of detail is more or less arbitrary. This indicates that the anatomy is, as indeed any other model, something that the actors must agree upon. Furthermore, it should be kept in mind that each function must be related to some part in the product structure. The way of naming the functions might be misleading since they often refer to the entity that provides the function, for example, "Starting Motor".

2.1 System development using the anatomy

The central idea behind using the anatomy in system development is to design and test the system *in the same order* as it "comes alive". In order to achieve this, the project is planned in three steps: anatomy definition, increment planning and integration planning. These steps are not sharply separated; rather they should be seen as different foci in the coordination of the development task. In the following sections, we will describe the principles of the planning process using a simplified example from the Ericsson practice: the development of a processor in a telecom system.

2.1.1 Anatomy Definition

The purpose of the anatomy definition step is to achieve a shared understanding about how the system works. The focus is on the major functional dependencies in the system. In Figure 3, the anatomy of the processor is shown. It is outside the scope of this paper to describe the working of the processor in detail. However, the name designation of the major functionalities should indicate the character of these functions.
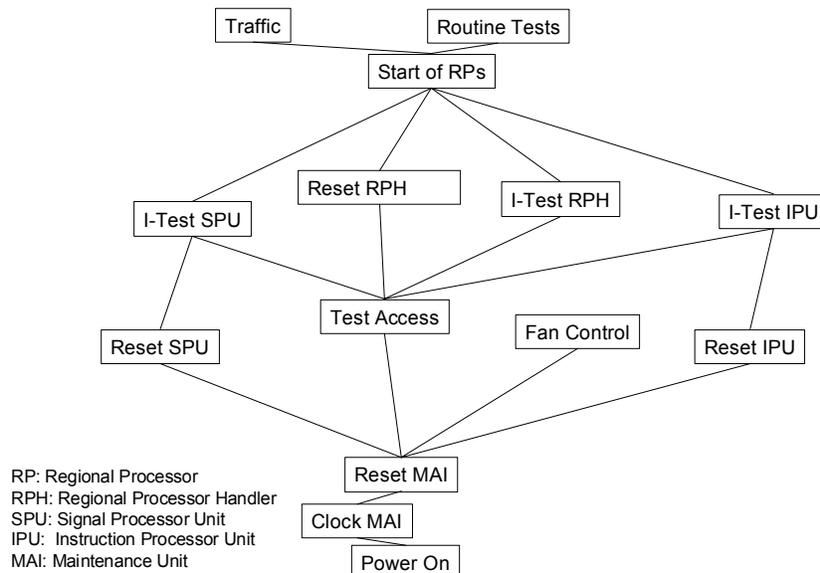

RP: Regional Processor
RPH: Regional Processor Handler
SPU: Signal Processor Unit
IPU: Instruction Processor Unit
MAI: Maintenance Unit

Figure 3: The anatomy of a processor in a telecom system

The anatomy is created in several meetings where the mindset should be: "if you 'power-on' what happen then and then." This question is repeated until you reach the end functionality. Thus, the approach is in essence a bottom-up process rather than top-down (Anderstedt et al., 2002). When deciding which functions should be included, the focus should be on integration and testability since this will be used to plan and monitor the project. This process is usually iterated several times until a working consensus is achieved. The organizers of this activity have to keep in mind that the anatomy can never be complete or "correct" in an absolute sense.

2.1.2 Increment planning

In the second step, the focus is to establish a shared view of how to develop the system. The functions are grouped into integration steps — increments — in such a way that the resulting functionality after each added increment can be verified. The intention is to parallelize design and testing as much as possible. The increment plan describes in what order increments need to be completed to ensure smooth progress. The structure of the plan is determined by a number of circumstances such as available resources, customer feedback, complicated or simple functions, geographical proximity between resources, functions that can be tested jointly, etc., (Anderstedt et al., 2002). In Figure 4, a possible increment plan of the processor is shown.
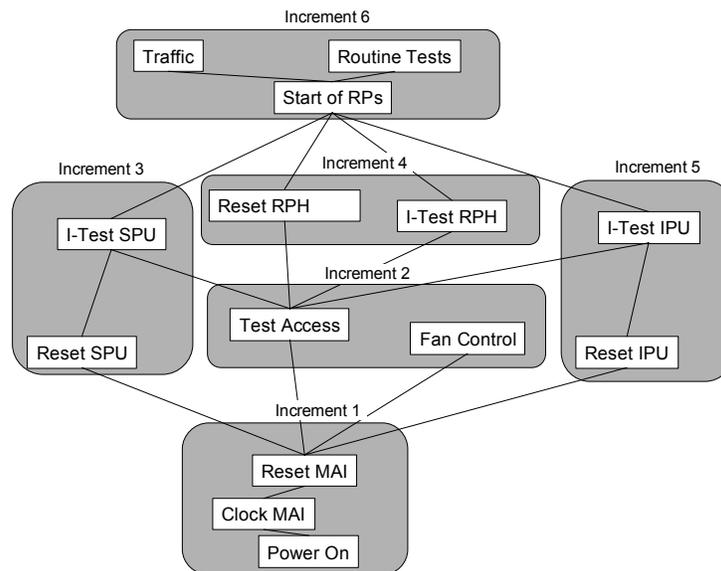
Figure 4: Increment plan of the processor.

2.1.3   Integration planning

In the third step, the purpose is to divide the work between the actors and establish a shared commitment about what is delivered, from whom and when. This implies hat resources are assigned and dates for deliveries of the increments are negotiated. For each increment, traditional time and resource plans are made as well. In Figure 5, an integration plan of the processor is shown.
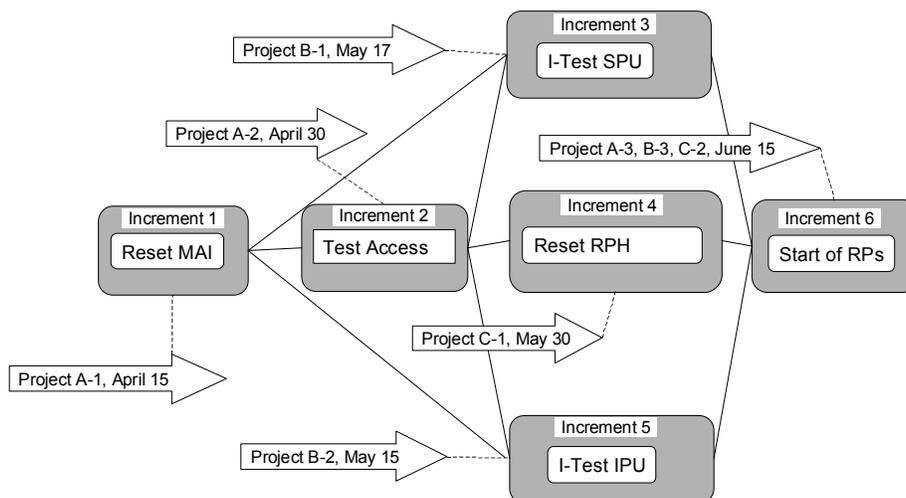

Figure 5: Integration plan of the processor

The integration plan focuses on the dependencies between subprojects. It clearly shows the impact of delaying a certain delivery. Thus, it provides early warnings of

delays that give the project management time to correct them. During the project, the integration plan is used as an instrument for controlling the progress of the project. The state of each increment may be associated with traffic-light colours such as Green – On Plan, Yellow – Warning, Red – Off Track, etc.

2.2   A realistic example

One of the first projects to use the anatomy approach was conducted between 1995 and 1999 (Lilliesköld et al., 2005). The goal of the project was to develop a new central processor for the main Ericsson switching system, the AXE System. The project faced disorder, bordering to chaos. This in turn, was due to a number of factors such as new technology, many sub-projects distributed around the world, new customer relations, cultural differences, different experiences among the project participants, newly appointed managers, etc. In order to manage these circumstances it was decided to use the anatomy. In Figure 6, the anatomy of the processor is shown. Again, it is outside the scope of this paper to describe the detailed working of the central processor. The purpose of including this example is to convey a sense for the complexity inherent in these kinds of systems.
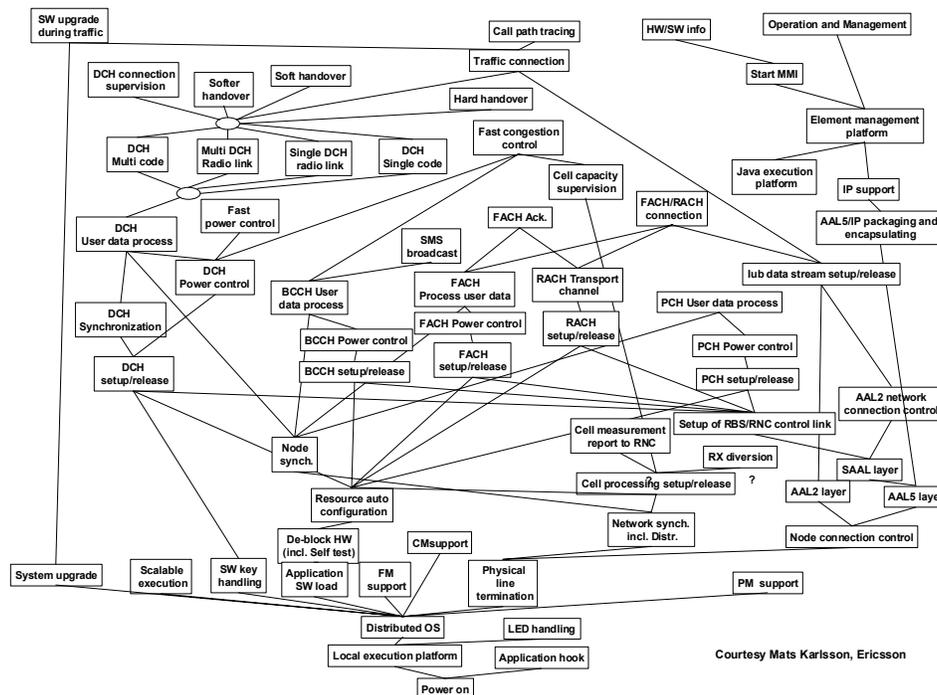

Figure 6: The anatomy of the central processor

Several effects of the anatomy approach have been observed (ibid.). One type of effects concerns overview and understanding. Everyone's part is visible and the same information is provided to everyone at the same time. This makes the actors understand the project/system and helps them to anticipate the consequences of their actions.

Another type of effects is related to the planning of the project. The anatomy provides an ability to put many design and verification activities in parallel with control. It enables early integration of functions and early start of production if needed. The margins in the project can be controlled, something that is more difficult if all the integrations are done towards the end of the project. It becomes easier to identify critical paths.

A third group of effects has to do with monitoring the progress of the project. The anatomy provides a Push and Pull concept where you have a receiver for every delivery in the project. It is easy to identify critical problems that might jeopardize the project. The progress of the project can be easily made visible by "traffic light" cues.

In addition to these positive effects, there are also a number of problems associated with the anatomy approach. These problems are mainly of a socio-technical nature. Defining the anatomy is often difficult. The actors may disagree about what to include in the anatomy and the level of detail in it. Sometimes there are also opposing views of how the system actually works. Other problems are related to the established ways of working. The anatomy approach enforces a new mind setting which is not accepted by all actors.

3   An operational theory of affordances

In this section, we will outline a theoretical perspective in which the system anatomy may be grounded. In the literature there are numerous suggestion of how to model a system, for example ER-diagrams (e.g. Chen, 1976), UML (Universal Modelling Language, e.g. Jacobson et al., 1992), State Charts (e.g. Harel, 1987), Petri Nets (e.g. Reisig, 1985), Data Flow Diagrams (e.g. Marca, 1988) to mention but a few. So why introduce yet another modelling approach? The experiences from Ericsson are unambiguous: the anatomy provides something that the other formalisms cannot offer (Lilliesköld et al., 2005). We claim that this something is related to the actions taken by the actors. Thus, the anatomy is faced towards the social aspects of system development rather than towards the system as the other models are. This means that the theoretical perspective concerning the anatomy should have action as a fundamental construct.

The perspective we propose takes its point of departure in the concept of *affordances* suggested by Gibson (1979). In spite of the ample time passed since Gibson introduced this concept, there is still an ongoing discussion about the nature of affordances (e.g. Jones, 2003). In our characterization of affordances, we will mainly make use of sources in the literature. However, the characterization of affordance dimensions is our own theoretical contribution to this discourse (see Section 3.3).

3.1   Characteristics of affordances

In conventional psychological understanding, perception is understood as a passive sensing of an image on the retina. Contrary to this, Gibson meant that perception is an act in which invariants in the ambient optical array are directly picked up. The affordances of an environment are "… what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill." (Gibson, 1979:127). This definition indicates that affordances enable organisms to devise their actions and evaluate the consequences of these actions. The affordance is "… a characteristic (or a set of characteristics) of an object, which offers a potential for action." (Goldkuhl, 2002:4). Thus, a fundamental

aspect of affordances is activity. The environment becomes meaningful by acting in it.

An affordance is inherently relational in character: it "cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behaviour. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and the observer." (Gibson, 1979:129). This rather nebulous characterization is elaborated by Chemero, which states that "affordances […] *are relations* [our emphasis] between abilities of the organism and features of the environment." (Chemero, 2003:189).

Affordances are contextually conditioned: "The fact that a stone is a missile does not imply that it cannot be other things as well. It can be a paperweight, a bookend, a hammer, or a pendulum bob. It can be piled on another rock to make a cairn or a stone wall. These affordances are all consistent with one another." (Gibson, ibid.:134). Affordances become effective in meaningful contexts.

Some affordances may be valid for several individuals of a species: "I have described the invariants that enable […] two children to perceive the common affordance of [a] solid shape despite the different perspectives, the affordance of a toy, for example. Only when each child perceives the values of things for others as well as for herself does she begin to be socialized." (Gibson, ibid.:141). Coordinated actions presume shared meaning about the action possibilities.

Gibson focused mainly on the perceptual side of affordances and left the activity of the organism as a more or less implicit precondition (Bærentsen &Trettvik, 2002:1). For lower organisms, affordances are provided by the natural environment only. This is of course valid for humans as well. However, human activity is also mediated by symbolic and technological artefacts that develop historically in the particular culture in which they emerge. This makes it a non-trivial task to include cultural-historical affordances in the theory development. Bærentsen &Trettvik (2002) suggest that the concept of *activity* found in the Russian theory of activity (e.g. Bedny et al., 2000) is a useful framework for approaching this task. This enables the view of affordances as features of "activity systems" which include both the physical and cultural environment. This means that affordances for humans develop in bounded activity areas such as organizations, practices, cultures, etc. "The development of capacities for directly picking up information about [cultural – historical] forms of affordances takes place by the inclusion of individuals' activities in adequate forms of societal praxis." (Bærentsen &Trettvik, 2002:4). In the following, we shall consider affordances in this more elaborate sense.

3.2   Manifesting affordances

By acting in the world, an organism learns its action potentials by the "adaptation of pre-wired systems during ontogenesis, i.e. training of sensory-motor systems 'designed' by evolution." (Bærentsen &Trettvik, 2002:8). In principle, there is no difference between natural and cultural-historical affordances. "In both cases the basis for direct perception of the relevant affordance is the performance of an adequate activity that reveals the relationship between needs and capabilities of the organism and the characteristics of objects and processes in the environment." (ibid.: 8). Thus, once learnt, affordances of cultural origin offer direct action possibilities as well. For example, a mailbox offers the direct action possibility of "letter-mailing to letter-writing human in a community with a postal system." (Gibson, 1979:139).

The relational character of affordances means that these are manifested in two realms: in the human cognitive systems, and in societal praxis. In praxis, man transforms the world into artefacts such as tools, institutions, organizations, etc. This form of objectivizing is *objectification* ("Vergegenständlichung") (Kosík, 1976). In order to relate to these artefacts, individuals have to appropriate their meaning:

> "In order to enter the species-specific *historically developing mode of existence*, the most significant capacities are the ability to objectify insight and knowledge in complex objects, and the ability to appropriate these objects as extensions of the body. […]The objectification-appropriation cycle constitutes a significant ingredient in the context of the abilities to maintain these objects and disseminate their use in the social community, communicate about them, and transmit them from one generation to the next." (Bærentsen, 2000:44)

The result of the objectification – appropriation process is the formation of what Activity Theory calls a "functional organ", that is, a "combination of natural human abilities with the capacities of external components – tools – to perform a new function or to perform an existing one more efficiently." (Kaptelinin, 1996:109). However, in societal praxis, individual appropriation of artefacts is not enough. The individual needs to cooperate with other individuals. In order to do so, she needs to be integrated in a trans-individual whole as one of its elements. This incorporation transforms the subject: "The subject abstracts from his subjectivity and becomes an object and an element of the system." (Kosík, 1976:50). This form of objectivizing is *objectivation* ("Objektivierung") (ibid.: 131).

A central aspect of the objectification – objectivation process concerns the issue of meaning. According to Bedny & Karwowski (2004), it is important to distinguish between meaning and sense. Meaning has an objective character and is referred to as "objective meaning" while sense has an individual, subjective character, referred to as "subjective sense". Objective meaning is a *shared* meaning concerning the objectified elements at a particular moment in the socio-cultural development of the activity system. Objective meaning, which is necessary to perform coordinated actions, is a result of objectivation and has an external manifestation outside the heads of the individual actors.

The concepts discussed above may seem abstract and hard to grasp. Nevertheless, we claim that they are fundamental for theorizing about human activity. To this end, we will briefly illustrate them by a concrete example: the activity of playing a string quartet. First, there are obvious objectified elements / artefacts involved like the instruments and the musical score. Each individual actor / player has to appropriate her instrument by a long and intense interaction with it. Technical and musical abilities must be learned. Moreover, she has to appropriate the (objective) meaning of the score. The meaning of notes, their significance of time and space, etc., has to make sense to each individual player. However, in order to bring forth music the players cannot act by themselves. They have to be integrated in a trans-individual whole where they start play at the same time; they use the same phrasing and dynamics, etc. Without going through this objectivation process, they cannot coordinate their actions.

The essence of this reasoning is that invariant, objectified elements in societal praxis are congruent with invariant, objectivated elements in the brain. In this understanding, affordances are apprehended as relations that relate these two forms of objectivizing.

3.3   Dimensions of affordances

In the previous sections, we have given a general characterization of affordances. In this section, we will articulate this characterization further in order to make it operational.

The characterization of affordances has been discussed by, for example, Zhang (1999) and Albrechtsen et al. (2001). Zhang suggests a typology of affordances consisting of biological, physical, perceptual, cognitive and "mixed" affordances. Albrechtsen et al. propose structuring affordances along a means-ends model which have five levels, ranging from physical properties to high level goals and intensions (ibid.:25). However, neither of these proposals appears to render themselves easily operational.

To begin with, the notion of activity systems needs to be more precise. In the Activity Domain Theory (Taxén, 2004) it is suggested that activity systems should be structured as *activity domains*. An activity domain may be regarded as particular perspective of a workpractice where coordinating aspects are emphasized. In this domain, the objectification - objectivation process develops along certain dimensions which we will call *activity modalities* (modality: "a modal relation or quality; a mode or point of view under which an object presents itself to the mind.", Webster's 1913 Dictionary).

The term "activity modality" is deliberately coined to resonate with the concept "sensory modality". From a cognitive point of view, subjective sense and objective meaning is forged by impressions received through different sensory modalities such as seeing, hearing, etc.:

> "Our perception of the world is not only based on vision, but on complex sensory syntheses drawing on all sensory modalities (vision, audition, taste, smell, the haptic sense, and proprioception [the ability to sense the position and location and orientation and movement of the body and its parts – authors' remark]" (Bærentsen, 2000:43)

The crucial step in our theory building is to identify which activity modalities are relevant in the activity domain. Any suggestion should be grounded in both theory and social praxis. Empirically, the Activity Domain Theory is grounded in the author's experiences from the practice of complex systems development (Taxén, 2003). Based on these experiences, the following activity modalities are proposed as particularly important for the coordination of human activity:

- *Stabilization*: This modality is manifested as a common ideology in the activity domain. By ideology, we simply understand any wide-ranging systems of beliefs or ways of thought.

- *Spatialization*: This modality is manifested as elements that enable the actors to orient themselves spatially. This orientation concerns which phenomena actors perceive as relevant, how these are related and in what state or condition they are.

- *Temporalization*: This modality is manifested as elements that enable the actors to orient themselves temporarily. This orientation concerns the dependencies between the activities in the domain.

- *Contextualization*: This modality is manifested as a context dependency. In the activity domain, the actions are focused and situated in space and time. This

means, for example, that a particular phenomenon will be apprehended and characterized differently depending on the context in which it is considered relevant. Contextualization influence which phenomena actors perceive as relevant, how these are related, in what state or condition they are and during which time span they are relevant.

- *Transition*: This modality is manifested as elements that enable activity domains to interact with each other. The outcome of one domain may be the prerequisite of other domains. Since the stabilization brings about different domain ideologies, the outcome may be characterized differently. If so, there is a need for a translation and interpretation of the outcome in the transition between the domains.

- *Communication*: This modality is manifested as elements emanating from various communicative acts such as agreements, commitments, responsibilities, etc.

- *Instrumentation*: This modality is manifested as instruments that mediate actions. Such elements can be essentially material or symbolic in character, like a hammer or a bank note.

The theoretical grounding of these modalities comes from different areas such as cognitive sciences (e.g. Gärdenfors, 2000), linguistics (e.g. Vološinov, 1986/1929), speech act theory (e.g. Austin, 1962; Searle, 1969), etc. A detailed account is given in Taxén (2003).

The results of objectivation – meaning – is hard to observe in contrast to the results of objectification. We should expect to find objectified elements in activity domains that can be classified according to the activity modalities. Such elements do indeed exist. Here are some examples: Stabilization is manifested in product development organizations as rules for how to identify articles. Information models are manifestation of spatialization. Process models are manifestations of temporalization. Organizational boundaries are manifestations of contextualization. Translation of article identifications between two cooperating organizations is a manifestation of transition. Information systems are manifestations of instrumentation.

This brings us to the central tenet of the proposed theory: *affordances in activity domains emerge along the dimensions given by the activity modalities*, regardless of whether these affordances are natural or cultural-historical in origin. This should be understood in the following way: In societal praxis, affordances provide direct action possibilities once they are manifested in the activity domain. This implies both an objectification process resulting in artefacts and an objectivation process resulting in an appropriation of the meaning of these artefacts. The manifestations may take different forms depending on which activity modality is emphasized. However, the affordance concept is regarded as a coherent whole, which means that manifestations resulting from different modalities are always interdependent.

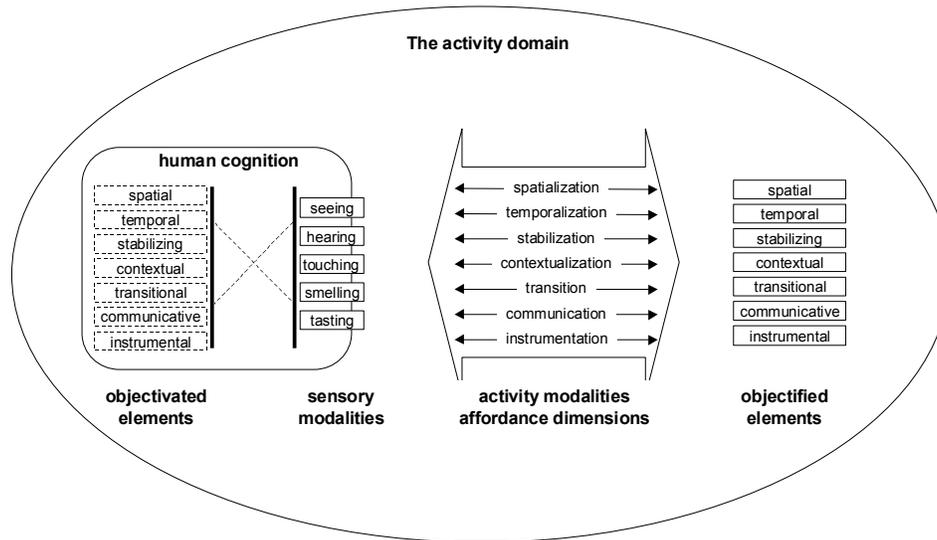In Figure 7 the objectivation – objectification process is illustrated:

Figure 7: The objectivation – objectification process

4 Discussion

In the previous sections, we have described the anatomy approach and presented a theoretical articulation of affordances. In this section, we shall discuss the anatomy approach in the light of the proposed theory.

4.1 Affordance indications

What indications are there that the anatomy and its associated plans can be regarded as shared affordances? As stated in the introduction, an important aspect of complex systems' development is that actors can conceive of action possibilities and anticipate their consequences. The essence of affordances is that they signify such possibilities in a direct way without necessarily articulating these explicitly. Thus, it can be expected that manifestations of affordances would emphasize understanding at the expense of formality and rigor. There are several observations supporting this conjecture:

- Even if all elements in the anatomy are functions, their denotations are ambiguous. In Figure 6, for example, we find names indicating functions ("Node connection control"), activities ("Power on"), parts providing functions ("Local execution platform"), etc. Moreover, the whole illustration gives a rather messy and confusing impression. Thus, rigorous formality is obviously not important in defining the anatomy.

- Usually, names are not assigned to the dependencies. Just indicating the dependency appears to be enough.

- Easy-to-apprehend traffic light cues are used for controlling the progress of the project.

- The integration plan is 'tilted' in order to signify a time line.

The most conspicuous feature, however, is that the anatomy is adjusted to fit onto a single page. It is displayed as a coherent entity. There is no moving up or down between levels or browsing between lots of pages. This makes it possible to put the illustration up on a wall, thus enabling different groups of actors to see the same anatomy simultaneously. Actions suggested by some actor may be discussed, approved or rejected immediately. In these discussions, a shared meaning concerning the system and its development is gradually emerging.

Moreover, the anatomy, the increment plan and the integration plans are defined in collaboration between various groups of actors. This learning process can be apprehended as an objectification – objectivation process in which the affordances emerge.

To summarize, we argue that that the observations above are strong indications of the affordance character of the anatomy approach.

4.2 Activity modalities

What activity modalities are involved in the anatomy approach? First, if we consider the anatomy, it can be interpreted as a manifestation of the spatialization modality. The anatomy shows spatial dependencies between functions. As such, it indicates action possibilities for mainly system architects and actors active in technology specific workpractices. When defining the anatomy, the consequences of choosing various alternative architectures and technologies can be discussed and evaluated.

The increment plan shows which activity domains (increments) must be coordinated during the development. Thus, the increment plan can be interpreted as a manifestation of the transition modality since this plan focus on the outcomes and results passed between the different increments. Above all, this plan is an instrument for the total project manager in structuring the project.

The integration plan is similar to the increment plan with the addition that sub-projects and milestones are defined. With the help of this plan, commitments and responsibilities of sub-project managers are decided. This means that the main modalities manifested as the integration plan are temporalization and communication.

Thus, the anatomy and its associated plans may be regarded as affordances manifested from different activity modalities. Each affordance affects a main actor even if other groups of actors are also involved. It is also clear that the various modalities are interdependent. For example, if the anatomy is changed, then the increment and integration plans must also be changed.

We have argued that the anatomy and its associated plans can be used to reconcile the actions of the actors. A striking example of this is given by the following statement (the acronyms CPG and RPH are Ericsson internal names of two of the sub-projects in the total project mentioned in Section 2.2):

> "PM (Project Manager, CPG project): Before we did the integration plan we thought that RPH was delayed. But then we saw that we did not need their stuff until late, in fact they were perfectly on time. I (Interviewer): You had a different opinion about the dependencies in the project? PM: Exactly, it was the micro programming which was wrong, totally wrong. They didn't even have the resources in the project at that point in time. So they had to re-schedule everything they had to do. I: This is an obvious effect of the anatomy work? PM: Absolutely, it wasn't until then we saw how late we were. When doing the anatomy we realized that we would be late anyhow."

Another example concerns the control of the progress of the project: "Without the integration plan that was created after the anatomy plan, we would never have obtained this much control over the project." (Project manager, CPG project). However, this was not always appreciated:

> "When you did progress control based on the anatomy it became very clear who is slacking, which is not very popular by many people. It becomes so evident on the map and that gives you hell. But that was really the truth. But as soon as one part became marked in red, some people thought that something was wrong. 'That is not correct'." (Project manager, CPG project)

4.3   Shared meaning construction

In general, models like the anatomy are regarded as more or less "true" abstractions or views of "reality": "The anatomy shall be as close to the truth as possible, and this is something you work out in a number of meetings, it's a process which leads to the anatomy." (Project manager, CPG project). This indicates that the design work is apprehended as a sort of treasure hunt in which the "real" anatomy is found in the end.

In contrast to this, the affordance perspective emphasizes the mutuality of the actors and the system. During the development the actors, the anatomy and the gradually emerging system influence each other in a dialectical process where the construction of objective or shared meaning is a fundamental element. This process may be arduous: "Some kept on for two months drawing the anatomy. […] it is still difficult for people to agree even if they have been sitting in the same corridor for 20 years" (Project manager, CPG project).

Consequently, sense making should be more emphasized in the development process. This implies several things. First, the correspondence view of reality cannot be upheld. It is necessary to change this mind setting towards a perspective where the system is seen as interrelated to the actors and their interpretation of the system. This is a similar approach as taken in the FRISCO study (Verrijn-Stuart, 2001):

> "The key to understanding the system concept is to realise that a system is not an absolute or objective phenomenon. Systems are not a priori given. […] It is important, that there is a system viewer who can see a purpose in regarding something as a system." (Verrijn-Stuart, 2001:29).

Second, the construction of the anatomy should be done iteratively throughout the development. Action possibilities should be tried out and evaluated as early as possible. This should be regarded as a learning process in which experiences influence further actions.

Third, a new way of thinking must be established among designers. The principle of developing systems in the same order as it "comes alive" was hard to accept for some designers: "I'll design this function in the end; I'll start with the most difficult ones first." Furthermore, some actors experienced the anatomy as a threat against their professional knowledge: "It can't be this bloody easy; I'm actually doing more difficult stuff". Thus, it is important to convey the message that the complexity of the system does not go away with the introduction of the anatomy. The anatomy should be seen as a complementary instrument that enables all actors, including designers, to manage the complexity.

4.4   Consequences for system development

If the anatomy can be apprehended as a shared affordance for various groups of actors, what implications might that have for system development in general?

4.4.1   IS development

In IS design, the affordance concept has in general been applied in the interaction between the user and the IS (e.g. Norman, 1988; Bærentsen, 2000; McGrenere & Ho, 2000; Goldkuhl, 2002). This is natural since the end-user is in focus. There has also been a surging interest in using Activity Theory as a theoretical framework in the HCI (Human-Computer Interaction) area (Nardi, 1996; Bærentsen, 2000).

The practical experiences from the anatomy approach are so far collected from the development of telecommunication systems. However, the approach is not limited to that particular type of systems. An IS is in itself a complex system which is realized through a number of interrelated system parts implemented in software and hardware. Thus, the anatomy approach should be applicable in principle to IS design as well. However, this is a topic for further research.

Another issue concerns the scope of the IS design task. In order for affordances to become manifested, objectified as well as objectivated elements must emerge. This indicates that objective meaning construction is a major concern in IS design. Taxén has suggested (Taxén, 2004c) that IS design should benefit from moving the focus from the IS to the entire activity domain in which the IS is immersed. IS design should rather be regarded as domain construction in which the objectivation process is emphasized. In the Activity Domain Theory, this is process operationalized as a *domain construction strategy* (Taxén, 2004b) based on experiential learning (Kolb, 1984). The purpose of this strategy is to advance the objectification – objectivation process in all the activity modalities.

4.4.2   Affordances and use cases

A commonly used technique in software design is use case modelling (e.g. Jacobson et al., 1992). A relevant question to ask is how affordances are related to use cases and whether in fact they are the same phenomenon. There are several definitions of use cases. Cockburn (1997, 1997b) has encountered over 18 different ones. The bottom line seems to be that use cases imply "the way in which a user uses a system". A more detailed definition is the following: "A use case is a collection of possible sequences of interactions between the system under discussion and its external actors, related to a particular goal." (Cockburn, 1997:36).

It is clear that affordances and use cases are indeed related. However, use cases appear to be directed towards technical implementation of the system. For example, the affordance "transportation" of a car may be implemented as a sequence of actions like "lock up car door", "enter car", "press clutch", "turn start key", "put in gear", etc. This interaction between the driver and the car may well be described by a use-case.

The action character inherent in affordances is not emphasized in use case modelling. This indicates that affordances and use cases may complement each other in a productive way. In short, the anatomy of affordances would provide the "big picture" where activity, overview, action alternatives, division of work, development management, etc. are in focus while use cases provide technical implementation methods and supporting tools. It is also interesting to hypothesize that the enormous popularity

use cases have gained is related to its affinity to the affordance concept. This is, however, also an issue for further research.

4.4.3   Interaction between modalities

The theoretical approach suggested opens up interesting perspectives for the development of complex systems. These perspectives would emphasize the reconciliation of actions through affordances manifested along the modalities suggested. In some situations, the transitional dimension of affordances would be preferred, while in other situations other dimensions would be more expressive. However, these dimensions of affordances are always interrelated. This suggests a development strategy where a focal change is performed between various dimensions of affordances, each expressing a certain perspective on complex systems development. Such a strategy would not replace existing, more technically oriented development strategies but rather complement these. For example, it might be advantageous to design the system architecture in such a way that increment assignment and integration of the system is facilitated.

4.5   Mediation

In Activity Theory, the concept of mediation plays a key role. Human activity is directed towards an object and mediated by signs (semiotic activity) and tools (instrumental activity) (e.g. Engeström, 1999:23 ff.). However, the distinction between semiotic and instrumental activity is problematic (Bødker & Bøgh Andersen, 2004). Even if these two types of activities differ with respect to their material and social effects they should not be regarded as belonging to different realms of reality (ibid.:6). Bødker and Bøgh Andersen propose a model in which the semiotic triangle is combined with the Activity Theoretic triangle into a combined model where "… instrumental and semiotic activities are variants of the same pattern but with different kinds of emphasis. This predicts a smooth transition between the two." (ibid.:10).

The position of Bødker and Bøgh Andersen aligns well with the affordance perspective. From an action potential point of view is the difference between semiotic and instrumental activity is beside the point. A bank note and a hammer offer different action possibilities, and the meaning of both must be learnt before they can be effectuated in action. Thus, the notion of affordance may be a way to reconcile the problematic semiotic – instrumental partition.

4.6   Limitations

In this paper, we have proposed a theoretical articulation of affordances based on activity modalities. The theory is at this stage at most preliminary. So far, it has been grounded in one setting only, that of developing telecommunication systems at Ericsson. However, there are some interesting results reported elsewhere which indicate that our results may be transferable to other settings. For example, Eriksson et al. (2002) describes a "dependency diagram" which is used to reconcile the action of various actors in a large, multi-organisational project developing electrical power equipments. The dependency diagram is used in the same manner as the anatomy. However, it differs from the anatomy in the sense that it has a distinct temporal characteristic. A similar construct called Information Flow Diagrams is reported in Taxén & Svensson (2004).

5   Conclusions

In complex systems' development, it is essential to understand how things depend on each other in order to plan and control the development task. This is necessary in order to reconcile actions performed by actors working in different workpractices. Due to the complexity, seemingly harmless actions in one workpractice may have devastating consequences in other workpractices if it is unclear which action possibilities are at hand in a certain situation. The system anatomy developed in the Ericsson practice is a result of the insight that traditional system development approaches are inadequate for this purpose.

The theory proposed in this paper suggests that the concept of affordances may be a beneficial way to approach this problem. This emphasizes the immediate and direct apprehension of action possibilities without necessarily articulating these in a formal and logically consistent manner. By augmenting the affordance theory of Gibson with the Russian theory of activity and the Activity Domain Theory, it is possible to articulate affordances in such a way that they can be made operational in system development.

The analysis of the system anatomy, using this theoretical framework, reveals that the anatomy and its associated increment and integration plans can be seen as manifestations of various dimensions of affordances. Thus, the findings open up for theoretical and practical advances in system development where established development strategies are complemented with an affordance perspective.

Acknowledgement

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