A Neurobiological Foundation for Enterprise Architectures

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Abstract. Enterprise architectures, however conceived, need to consider the centrality of the individual in organizations. Without individuals, organizations would not exist. To this end, a novel perspective on organizations as an array of interdependent *activity domains* is proposed. The activity domain denotes activity as grounded in our neurobiological faculties for acting in the world. These faculties are conceived as the *activity modalities* objectivation, contextualization, spatialization, temporalization, stabilization, and transition, which are derived from long-term observations of coordinating complex system development projects in industry. Since our neurobiological constitution is indifferent between activities, the activity domain provides a generic and recurrent Unit of Analysis for organizational inquires. This enables enterprise architectures to be modeled as *organizational anatomies*, and visualized as dependencies between organizational capabilities. The activity domain represents a paradigmatic shift in thinking about organizations, which may provide new ways of approaching enterprise architectures.

Keywords: enterprise architecture · EA · activity modalities · activity domain · coordination · neurobiology · organizational anatomy· IT artefacts · enterprise systems· ERP

1 Introduction

In order to manage change, organizations need to harmonize IT-resources and business strategies. This has led to an increasing interest in both academia and business of enterprise architectures (EA); i.e., some kind of an operative description of the organization. How such architectures should be conceived has been called “the issue of the century” by one of the pioneers in EA, John Zachman [1].

In spite of extensive efforts, however, the EA discipline is beset by problems. One of the most severe ones is the deficiency to articulate the core element in EA – the organization. A number of different Unit of Analysis (UoA) for organizations have been suggested, such as “individual act” [2], “organizational field” [3], “practice” [4], “organizational routines” [5], “transaction” [6], “activity” [7], “social actor” [8], “work teams” [9], and “work system” [10].

Harmonizing efforts are further aggravated by the controversy over the nature of information systems (ISs) and the IT-artefact. This issue has been intensely debated in the IS community without reaching closure (see e.g. [11], [12], [13]). Part of the problem concerns the fundament of IS related research:

“To its detriment, past research in information systems … has taken for granted many of its own key concepts, including ‘information,’ ‘theory,’ ‘system,’ ‘organization,’ and ‘relevance.’” [14, p. 336].

I suggest that this unfortunate state of play in EA can be derived from a superficial conceptualization of the individual; the *fons et origo* of organizations. Without individuals, organizations would not exist. To this end, a novel perspective on organizations as an array of interdependent *activity domains* is proposed.

The activity domain denotes activity as grounded in our neurobiological faculties for acting in the world. These faculties are conceived as the *activity modalities* objectivation, contextualization, spatialization, temporalization, stabilization, and transition, which are derived from long-term observations of complex system development projects in industry [15]. Since our neurobiological constitution is indifferent between activities, the activity domain provides a generic and recurrent UoA for organizational inquires. This enables enterprise architectures to be modeled as *organizational anatomies*, which can be visualized as dependencies between organizational capabilities. The activity domain represents a paradigmatic shift in thinking about organizations, which may provide new ways of approaching enterprise architectures[1].

2 A neurobiological perspective on organizations

Imagine that you can travel some 30,000 years back in time, and that you are a member of an “organization” specialized in exploiting mammoths for the benefit of your tribe. The activity of one “business unit” in this organization is illustrated in Fig. 1 – hunting the mammoth. What individual capabilities enable you to participate in this activity?

1 The terms “enterprise” and “organization” are used interchangeably in the paper.

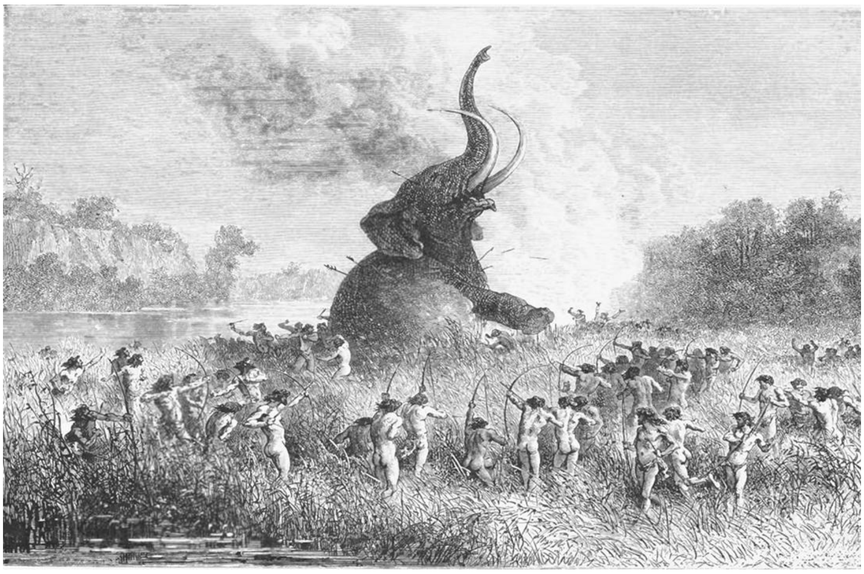

Fig. 1. Illustration of a mammoth hunt. Source: Original wood engraving by E Bayard; in [17].

2.1 The activity modalities

First, you need to *contextualize* the situation. You have to grasp what is relevant for the hunt, and disregard the rest. For example, hunters, bows, arrows, actions, shouts, gestures, and other hunters are certainly relevant, while the beetles and other insects in the trees in the background can safely be ignored.

Second, you must focus on *the object* for the activity, the mammoth. Object orientation is fundamental for carrying out any kind of action: "Human beings live in a world or environment of objects, and their activities are formed around objects" [18, p. 68].

Third, you need to orient yourself *spatially* in the context. You must recognize how relevant things, such as how the mammoth, river, trees, and hunters are positioned in relation to your own position.

Fourth, you must acquire a sense for how actions should be carried out in a certain order, which is a *temporalization* capability. For example, shooting an arrow involves the steps of grasping the arrow, placing it on the bow, stretching the bow, aiming at the target, and releasing the arrow.

Fifth, you cannot shoot your arrows in any way you like. Shooting in a wrong direction may result in other hunters being hit rather than the mammoth. You must learn how to perform appropriate mammoth hunting; something that will be accrued after participating in many successful, and, presumably, some less successful, mammoth hunts. Eventually, this habituation lends a sense of *stability* to your actions, which need not be questioned as long as it works.

Sixth, an activity is typically related to other activities. For example, the prey will most likely be cut into pieces and prepared to eat in another "business unit" – the cooking activity. This has its own motive, to satisfy hunger, and object, which happens to be the same as for the hunting activity, the mammoth. However, here other aspects of the mammoth are contextualized as relevant, such as which parts of the mammoth are edible. In order to conceive of other activities, you must be capable of *refocusing* your attention from one activity to another, and understand how they are related.

The six dimensions outlined above – *contextualization*, *objectivation*, *spatialization*, *temporalization*, *stabilization*, and *transition* between activities – are denoted *activity modalities*. The modalities, which were instigated from my work with coordinating complex development projects [15], should be regarded as a-priori categories brought about by the evolution of humankind; as modes of making sense of external reality for acting in a coordinated manner [20]. Each modality is realized by systems of concertedly working zones in the brain, "which may be located in completely different and often far distant areas of the brain" [21, p. 31]. A lesion in a particular zone in the brain may destroy any of the modalities, and consequently the ability to act [22]. For example, the entorhinal cortex has a crucial role in spatial representation and navigation [36]. If this area is affected, the spatialization modality is demolished.

It follows that the brain is capable of perceiving, processing, and integrating multimodal sensory impressions into an action capability in the form of the activity modalities and their interdependencies. This capability is the same regardless of whether actions are carried out in solitude or together with other individuals, as in the mammoth hunt example. Moreover, since the human neurobiological constitution has not changed significantly since the emergence of early hominids some 3.5 million years ago, the same activity modalities are at play today when we try to make sense of and manage modern organizations. We still need to contextualize situations, focus on the target, orient ourselves spatially, plan for actions, learn to distinguish purposeful actions from aimless ones, and refocus our attention to other situations.

2.2 Functional organs and equipments

Before you can participate in the hunt, you need master various means such as bows, arrows, hunt-specific language, gestures, etc. This can be seen as an encounter between phylogenetically evolved morphological features of the brain, and the ontogenetic development of the individual in a particular cultural and historical situation. How to understand this encounter was in focus for such eminent scholars as Lev Vygotsky, Aleksei Leontiev, and Alexander Luria. A common tenet in their thinking is that the socio-historical environment plays a decisive role in the formation of higher mental functions. The brain is formed "under the influence of people's concrete activity in the process of their communication with each other" [19, p. 6]. External, historically formed artefacts such as tools, symbols, or objects, among others "tie new knots in the activity of man's brain, and it is the presence of these functional knots, or, as some people call them 'new functional organs' […] that is one of the most important features distinguishing the functional organization of the human brain from an animal's brain" [ibid.].

From the moment you start engaging with an artefact, functional connections between individual parts of the brain are gradually established, which means that “areas of the brain, which previously were independent, become the components of a single functional system” [21, p. 31]. This can be seen as an *equipment* constructing process, where the artefact passes from a state of being *present-at-hand* to *ready-at-hand* [23]. Equipment is encountered in terms of its use in practices rather than in terms of its properties: “our concern subordinates itself to the ‘in-order-to’ which is constitutive for the equipment we are employing at the time” [23, p. 98]. In this process, the artefact itself may or may not be modified, but for the actor, the tool recedes, as it were, from “thingness” into equipment, when the in-order-to aspect – what the tool can be used for – takes precedence. A nice example of this process originates from the cellist Mstislav Rostropovich:

“There no longer exist relations between us. Some time ago I lost my sense of the border between us…. I experience no difficulty in playing sounds…. The cello is my tool no more” (cited in [24, p. 295]).

2.3 Joint action

When several individuals coordinate their actions in order to achieve a common goal, they are engaged in “joint action” according to Blumer [18]. This term refers to the “larger collective form of action that is constituted by the fitting together of the lines of behavior of the separate participants” [ibid., p. 70]. Since each actor occupies a different position in space and “acts from that position in a separate and distinctive act” [ibid., p. 70], joint action cannot be interpreted as participants forming identical functional organs and equipments. Rather, individual equipments need to be fitted together by external artefacts, which provide guidance in directing individual acts so as “to fit into the acts of the others” [ibid., p. 71]. Such artefacts are called “common identifiers” by Blumer. Joint action is, according to Blumer, a fundamental aspect of a society: “To be understood, a society must be seen ... in terms of the joint action into which the separate lines of action fit and merge [ibid., p. 71].

2.4 The activity domain

If we put together the notions of activity modalities, functional organs, equipments, and joint action, the contours of a neurobiological conceptualization of activity begin to materialize. As individuals, we are endowed with certain neural faculties for coordinating actions, which we call activity modalities. We employ the very same faculties in every situation we encounter; it could not possibly be otherwise. When acting, we may use various artifacts such as tools or other means. These we learn to use in an equipment forming process, which “tie new knots” in our brains – functional organs.

At the same time as we are all unique individuals, we are also inherently social beings. From the moment we are born, we enter into a specific cultural and historical situation. In pursuit of fulfilling common social needs, we coordinate our own actions with others in joint action, which requires recognizable and meaningful external expressions – the common identifiers.

In order to conveniently theorize about activities thus conceptualized, Taxén has proposed the term *activity domain* [15]. Thus, the activity domain comprises both tangible elements – manifestations of the activity modalities – and intangible ones – the functional organs "manifested" in the brains of each individual participating in the domain[2].

3 Enterprise Architectures as organizational anatomies

As long as our phylogenetically evolved constitution remains unchanged, the activity modalities, functional organs, equipment, and joint action will be the same, regardless of time and place. This indicates that the activity domain is a strong candidate for the UoA in organizational science and EA, which means that we conceive the organization as an array of *mutually interdependent activity domains*. Examples of such domains in product development organizations are marketing, sales, research & development, production, after sales support, and the like. Moreover, the organization itself is conceived as an activity domain. In each of these domains, actions are supported by, among other things, IT-based artefacts, which in turn require an IT infrastructure.

Since each domain provides some capability that the organization needs, it is close at hand to devise EAs from a capability point of departure. In the 1990s, the telecom company Ericsson was trying to find some way of managing extremely complex projects in developing mobile systems to Japanese markets. To this end, a common identifier was gradually conceived, which subsequently was coined "the system anatomy" [25]. The anatomy is a simple image of the system, illustrating dependencies between capabilities in a bottom-up manner. It is constructed in such a way that it is easy to apprehend by all stakeholders, while simultaneously enabling the management of dependencies – the most important thing when working with complex systems.

Since the system anatomy turned out to be a tremendously efficient instrument in system development, it is near at hand to model EAs in the same manner. In Fig. 2, an example of such an *organizational anatomy* is shown. The illustration should be read from the bottom up. At the very top, the capabilities offered to customers are shown. In addition, certain states are shown, indicating that a particular result has been achieved. Each item in Fig. 2 provides a capability that the organization needs. Lines indicate dependencies between capabilities. So, for example, if the capabilities provided by the IT infrastructure are inactivated by a power failure, every capability above is affected. Most likely, the entire organization will be unable to function at all, unless back-up power is available.

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[2] However, with the advent of brain imaging tools such as fMRI etc., the possibilities to investigate which cortical zones are involved in a certain mental function, have increased substantially (see e.g.[16])

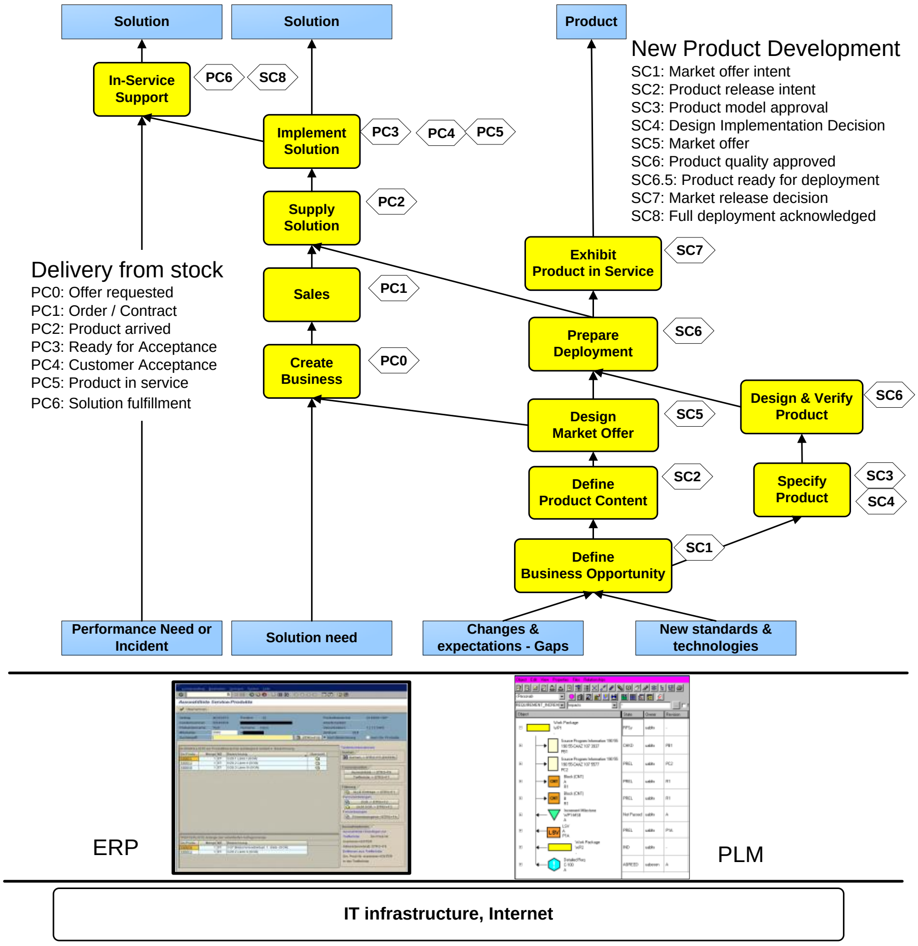

Fig. 2. An organizational anatomy from the telecom company Ericsson around year 2000

With the IT infrastructure in place, IT-systems can be actuated. In product development organizations, two main types are usually employed: Enterprise Resource Management (ERP) systems, and Product Live-cycle Management (PLM) systems. ERP systems support delivery from stock to customers, while PLM systems support new product development.

The activity domains depending on the IT-systems are depicted above each system, as well as the dependencies between them. In each of these domains, the IT-system will be contextualized as more or less relevant, and characterized accordingly. Each individual user in a certain domain needs to experience the IT-artefact as equipment; taking it from a state of being *present-at-hand* to *ready-at-hand*.

By illustrating EAs as organizational anatomies, a compact, yet comprehensive common identifier of the organization is achieved, which is ultimately grounded in individual neurobiological faculties for coordinating actions.

4 Implications

By taking the activity domain as the UoA, a firm theoretical ground is laid for the EA area and organizational science. Some issues that can be addressed from this perspective are as follows.

4.1 EA Models

There exist a large number of architecture frameworks for enterprises [26]. From the perspective presented here, most (if not all) have the following critical weaknesses:

- They are overly complex, which impedes the development of a common understanding about the enterprise. Common identifiers, such as the Zachman framework [27], are abstract and vague on operational guidelines. As a consequence, a number of unfavorable side-effects result, such as fragmented views of the enterprise, ill-informed decisions, onerous implementations of changes, and more.
- They lack a generic structure, which precludes the possibility to model various organizational units (individual, team, group, division, company, etc.) in the same way.
- Humans are modeled as homogeneous ideal type that can be analyzed and manipulated as any other, non-human element. Thus, our biological capabilities and limitations for acting are left unattended, which often result in chimerical conceptualizations without contact with the *sine qua non* of human existence.

The purpose of modelling EAs as organizational anatomies, is to mitigate these deficiencies. Complexity is reduced by focusing on the single most important aspect – dependencies between capabilities needed in the organization. The activity domain is a generic structure, derived from a neurobiological perspective, and which can be applied to any organizational unit.

With the activity domain as the organizational UoA, other types of models can be positioned in a coherent way to each other. For example, process models are seen as manifestations of temporalization. In the same manner, information models are seen as manifestations of the spatialization modality, business rules as manifestations of stabilization, and collaboration agreements between activity domains as manifestations of transition.

4.2 Strategy planning

The activity domain and the organizational anatomy are powerful instruments for strategic purposes. Since the anatomy is focused on dependencies between capabilities, it provides a resource-based view on the organization [28]. Some aspects of strategy planning and alignment from the activity domain perspective are as follows:

- *Capability-based planning of single domains*: Each domain provides a certain capability needed by the organization. This capability is dependent on all aspects of the domain – equipment formation, common identifiers, IT-support, and so on. By examining these aspects, plans can be made to improve the capability of the domain.

- *Capability-based planning of the organization*: With the organizational anatomy as a common identifier for corporate decision-makers, the contribution of each domain can be analyzed. If necessary, plans can be made to change the architecture of the organization. For example, the effect of mergers and acquisitions can be estimated, as well as outsourcing a certain domain or closing down another.

4.3 Aligning IT-resources

IT-system may be included in the organizational anatomy as illustrated in Fig. 2. Depending on the relevance of a particular system in each of the domains, an analysis may be done of how the entire IT-landscape contributes to the organization, and plans may be done to modify this landscape to better fit into the needs of the organization. The alignment issue is described in more detail in [29] and [15].

4.4 Business process management (BPM)

Usually, business processes are defined as having a definite temporal dimension as, for example "a collection of various tasks which produce an output." [30, p. 366]. Thus, the core of BPM is a one-dimensional management approach focusing on the temporalization modality. However, other aspects are often "sneaked in" under the business processes umbrella. For example, Chan states that "IT can be an initiator, a facilitator, and an enabler *in* [emphasis added] a business process." [31, p. 235]. In this way, the term "business processes" becomes more vacuous. In the activity domain perspective, however, the business process will retain its original temporal dimension as one modality among others in the multi-dimensional conceptualization provided by the activity modalities [32].

4.5 Collaboration and sense-making

Collaboration and sense-making mean that individual lines of behavior should be fitted together. In order to be efficient in EA, common identifiers must capture the essence of the organization, and yet be simple and easy to understand. The organizational anatomy has these properties. Visualizations like the one in Fig. 2 can be used for communicating a common image of the organization to various stakeholders.

4.6 System development

As described, the system anatomy models the system as dependencies between capabilities needed for the system to become "up and running" [25]. The development of these capabilities by an organization can be seen as taking place in activity domains, each developing one or several of these capabilities. The organizational anatomy shows how these domains in turn depend on each other. In this way, the activity domains are, so to say, "overlaid" on top of the system anatomy, thus indicating how system development can be related to EA.

4.7 Knowledge management

The activity domain approach implies that knowledge is inherently bound to the individual: "All knowing is personal knowing" [33, p. 44]. The commodity view on knowledge, in which knowledge is seen as a "thing" that can take different forms, be stored in databases, and transferred between individuals, is downright rejected (for a case in point, see [34]). Management of knowledge is seen as providing effective prerequisites for individual equipments and joint action to evolve in pursuing the goal of the activity domain.

4.8 Levels of inquiry

Since the activity domain is a generic construct, any activity, no matter how small or large, in the organization is structured in the same way from the activity modalities. Manifestations of objectivation, spatialization, temporalization, stabilization, and transitions will be found at any "level"; be that individual, group, unit, organization, or the extended enterprise. Thus, a common ground for specific inquiries into different kinds of activities is provided by the activity domain construct.

4.9 Operationalization

Operationalization implies that the theoretical concepts in the activity domain construct can be expressed in elements that can be manipulated, measured or observed in a particular situation in order to influence this situation [35]. This is done by operating on the artifact side of equipments, which are seen as manifestations of the activity modalities. For example, a common identifier of spatialization is usually an information model. This must be expressed in such a way that individual lines of behavior are fitted together as efficiently as possible. A straight-forward principle is to avoid visualizing this model in esoteric forms such as UML, which usually is not accessible to all actors in the domain.

5 Concluding remarks

Much of what is discussed in the paper is no doubt familiar to many readers. The gist of activity domain approach is rather a paradigmatic shift in thinking about things already known in organizations and EA. As such, paraphrasing Albert Szent-Gyorgyi, it "consists of seeing what everybody has seen and thinking what nobody has thought". Since the approach is in an incipient stage, it is certainly open for a multitude of objections. However, the constituents of the approach are well anchored in both the literature and in practice. Whatever will result from this line of thinking, only future research can tell. In conclusion, I claim that the activity domain approach may open up new ways of addressing issued related to enterprise architectures.

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