Towards Measuring the Complexity of Information Systems: A Language-Critique Approach

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ABSTRACT

Organizations increasingly depend on information technology for their operation. Consequently, complexity of information systems becomes an important issue for management. This paper shows how the combination of conceptual modeling with the concept of variety from cybernetics contributes to the measurement of complexity for the analysis and diagnosis of information systems. Building on language critique, we propose that conceptual models are marks of the shared understanding of a language community. Consequently, conceptual models are a means to make the variety of an information system visible. Within an information technology controlling setting, we apply our approach for the diagnosis of a controlling and reporting system used in the German subsidiary of a large European bank. We show how conceptual models can significantly contribute to organizational analysis if used in combination with an established cybernetic theory.

Keywords: Complexity, Variety, Language Critique, Conceptual Modeling.

1. INTRODUCTION

Organizations invest greatly in information technology (IT) and information systems (IS) in order to improve their operational and strategic position (Laudon & Laudon 2005, p. 7). But not all organizations are successful in this (Brynjolfsson 1993). The interaction between IT and organization is complex and influenced by many mediating factors, including the organization's structure, standard operating procedures, politics, culture, environment and management decisions (Laudon & Laudon 2005, p. 77). As a consequence, complexity of IS becomes a subject for IS research.

Complexity is a multi-facetted term which has many possible meanings (Flood & Carson 1993). Since complexity is something subjective (Ashby 1973, p. 1), perceived by an observer, the complexity of the system being observed can be described as a measure of the perceived effort that is required to understand and cope with the system (Backlund 2002, p. 31). This makes the analysis and design of complexity of IS more difficult. Since unnecessarily complex IS seem undesirable, we should find methods to reduce complexity. However, we cannot address this problem unless we have a shared meaning of what comprises the complexity of an IS. Furthermore, it would be desirable to compare several organizations or IS regarding their complexity (Backlund 2002, p. 40). Then, how can we measure the complexity of an IS? Can we categorize the factors for complexity in IS and organizations if complexity depends on the subjective understanding of an observer? Or are we able to deduct a general and intersubjective measurement for complexity?

In this paper, we propose to combine concepts from cybernetics with a language-based approach for conceptual modeling in order to measure the complexity of an IS. In the remainder of the paper we proceed as follows. First, we introduce variety as a measure for complexity. Then, we present our understanding of conceptual models based on language critique. Afterwards, we propose that conceptual models are a means to make variety visible. We apply and test our approach in an action case study.

2. VARIETY AS A MEASURE FOR COMPLEXITY

The cybernetic concept of variety is a measure for complexity, and defines the number of manifestations or patterns of behavior, the possible states of a system (Ashby 1964, p. 126). Variety, in relation to a set of distinguishable elements of a system, means either 1) the number of distinct elements, or 2) the logarithm to the base 2 of this number. Measured in logarithmic form, the unit of variety is the bit. If a situation has a variety of 32, or 5 bits, it will take five "yes/no" decisions to eliminate the uncertainty implicit in that variety – because $32 = 2^5$ (Beer 1981, p. 45). In theory, it is possible to count all possible states. If this is not directly possible, we can make comparisons ("something has more or less variety than another thing") or apply ordinal scaling ("This product has a rank of five"). Consequently, we are able to compare things that are different in nature.

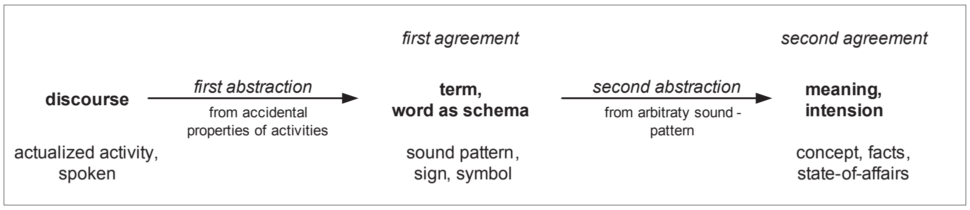
Ashby's *Law of Requisite Variety* is one important driver for the design of complexity reduction: "Only variety can destroy variety" (Ashby 1964, p. 207). This forms a problem because in order to make a system responsive to change, we need to possess as much variety as the system itself exhibits. With systems that exhibit massive variety, such as organizations and IS, only reducing the environmental variety or increasing the manager's own internal variety enables us to cope with this problem (Jackson 2000, p. 73).

In this paper, we follow Backlund's call to explore the usefulness of variety as a measure when applied to organizations and IS (Backlund 2002, p. 40). But several charges have been put forward against the use of variety (Jackson 2000, pp. 172-177, 207). Most severe seems to be Ulrich's attack (Ulrich 1981). Ulrich argues that variety operates only at the syntactic level, which is solely concerned with whether a message is well formed or not, in the sense of readability. Consequently, according to Ulrich, variety ignores the meaning and significance of messages for the receiver (semantics and pragmatics). This argument falls short considering our approach based on language critique.

Language critique, a branch of constructive philosophy known as the "Erlangen School" of Kamlah and Lorenzen (Kamlah & Lorenzen 1984, Lorenzen 1987), provides useful insights and backup for our understanding. By separating *language* (as a schema which one knows how to speak) and *discourse* (as linguistic action and activities), Kamlah and Lorenzen separate concepts from their linguistic usage (Kamlah & Lorenzen 1984, p. 41). Discourse means the repeatedly actualized usage of concepts in changing combination and variation. Thus, discourse is an actualized activity, whereas language comprises potential activities, or activity-schema (Kamlah & Lorenzen 1984, p. 45). The transition from an actualized activity to its activity-schema is called an *abstraction*. Terms are syntactical representations used in discourse with fixed conventions (*first abstraction*), whereas in order to get concepts, we abstract from the phonetic form of terms (*second abstraction*), see Figure 1 (Lorenzen 1987, pp. 115-118).

The question of how the conventions that align syntax, semantics and pragmatics of symbols are formed can be answered using the construct of a *language community*. Kamlah and Lorenzen argue that language as a system of signs promotes mutual understanding as "a 'know-how' held in common, the possession of a 'language community'." (Kamlah & Lorenzen 1984, p. 47). A new term is introduced by *explicit agreement* between language users with respect to its usage (*first agreement*) and meaning (*second agreement*) (Kamlah & Lorenzen 1984, p. 57). This agreement leads to a relation of concept and term, and is shared by a language

Figure 1. Agreements and abstractions in language critique (Holten 2003a, Holten et al. 2005)



community as the knowledge of using this term. Accordingly, if members of a group of people communicate, and each has an aligned semantic and pragmatic dimension of a symbol (or term) in mind, then this group of people forms a language community. The implications for our work are that the semantic and pragmatic dimensions of symbols need to be introduced together. If a language community has been created, based on a language (re)construction of a domain, the members of this language community share the pragmatic dimension of a symbol.

Usually, conceptual models are understood as part of a method, a planned and systematic approach (Braun et al. 2005). Conceptual modeling deals with the process of building or interpreting a conceptual model whereby the stakeholders reason and communicate about a domain in order to improve their common understanding of it (Gemino & Wand 2004, p. 80). According to our understanding, conceptual models play a significant role in making language communities explicit: conceptual models are designed through linguistic actions of a language community. Therefore, they are an expression of a shared language understanding, so-called *marks* (Kamlah & Lorenzen 1984, p. 46, Holten 2003a, pp. 33-91). Marks are written-down or printed writing-signs (Kamlah & Lorenzen 1984, p. 51). They are actualized as activities by the one who produces the marks in *writing* them, and again actualized by the one who *reads* them (Kamlah & Lorenzen 1984, p. 46). Models as marks create persistent things. Like road signs or written words, models are solidified activities which stay put and can be read.

Following this, conceptual models can be used as a formalized way of stating the intersubjective consensus of a language community. Then, truth or correctness of statements depends on the consensus of the group of people that constructed the conceptual models (Kamlah & Lorenzen 1984, pp. 101-111). For example, in IS development, mere understanding of the syntax or even the specific semantics of a specialized modeling language or grammar is not the most crucial factor. Of far greater significance are the pragmatics, the unstated assumptions that reflect the shared (common sense) knowledge of people familiar with the social, business and technical contexts within which the proposed system will operate (Ryan 1993, p. 240). Therefore, conceptual models are intensively used in requirements engineering to facilitate the process of creating a language community.

Although variety – like complexity – is an inherently subjective concept, it becomes intersubjective for the members of a language community as soon as the language community is created. A member of the language community is able to distinguish between data (syntax and semantics, term) and information (pragmatics, meaning) and to relate the two. Once a language community has been created, variety as a measure of complexity for the used terms considers pragmatics and semantics respectively. As a result, Ulrich's argument falls short considering language critique. Language restricts the possibilities to communicate the possible states of a system (Daft & Wiginton 1979). Variety is a measure of the number of possible states of a system. Based on the conceptual models as marks of the shared understanding of a language community, we are able to measure this variety. In the next section, we use an action case to show how the variety of an IS can be made visible by conceptual models.

3. VARIETY IN IT CONTROLLING: AN ACTION CASE

3.1 Research Methodology & Action Case Description

Every research approach is based on fundamental philosophical assumptions (Myers 1997, Lee 2004). We believe that a *constructive philosophy* (Lorenzen 1987) which integrates interpretive and positivist approaches is required. Consequently, we assume that an objective world exists (*ontological realism*), but that our cognition of this world is subjective or private (*epistemological subjectivism*) (Holten et al. 2005, p. 177). We argue that due to this subjectivity, cognition relies upon the (re)construction of reality through linguistic action. After having created a subjective understanding of everyday meanings within the observed organization, which provides the basis for the interpretive understanding, we create a positivist understanding in order to explain the empirical reality – the explanation being a scientific theory which can be tested against the subjective meaning as recorded in the interpretive understanding (Lee 1991, pp. 351-354). Following this, we apply our understanding of variety and conceptual models within an action case study (Hughes & Wood-Harper 1999).

The action case domain concerns IT controlling at FSB AG, a German subsidiary company of the FSB banking group[1]. The FSB Group is among the leading asset managers and financial service providers throughout Europe (as measured by managed capital). Within the FSB Group all operative tasks concerning IT are delegated to FSB IT, a wholly owned subsidiary of FSB Group. For example, this includes the development and maintenance of networks, mainframes, host systems, databases, servers and user support (e. g. helpdesk). FSB IT Development (FSB ITD) is a department of FSB AG that conducts development and controlling of IS for the German business units. FSB ITD develops and supports IS (*development functions*). Additionally, FSB ITD plans and controls both self-developed IS as well as IS developed by FSB IT in order to make the IT usage transparent for the German business units and divisional management (*controlling functions*). A management IS (based on a data warehouse solution using an Oracle database) is used for reporting and controlling in general. The management of FSB ITD approached our research group, voicing difficulties in their IT controlling processes. Especially the reporting was mentioned as an area of concern, creating frustration amongst the business units.

3.2 Data Collection & Interpretation

The action case study lasted from November 2004 to August 2005. We conducted a series of initial semi-structured interviews with different stakeholders. The interviews focused on the IT controlling process and on the roles within it. They were of variable length, ranging from 30 minutes to 90 minutes. The stakeholders selected for the interviews were head of IT controlling at FSB ITD, IT controlling staff, system developers, head of business unit and service staff (from business units). Additionally, we had full access to the MIS and to the created reports. The transcripts and notes from our interviews, administrative documents and printouts of the generated reports were collected in a project diary. The diary served as the main source of data for the following interpretation.

We used conceptual models for the interpretation of the reports, choosing MetaMIS as a modelling language. MetaMIS has been originally developed for the specification of management views on business processes (Holten 2003b, Holten et al. 2005). The approach has been previously applied in similar contexts (e. g. Holten et al. 2002, Holten & Laumann 2004).

Initially, we constructed conceptual models based on our understanding of the reports, which were refined by insights gained from the interviews and observation of controller activities. Afterwards, all project participants at FSB AG were made familiar with the MetaMIS approach, which resulted in a common language to discuss the conceptual models. Repeatedly, the models were refined together with all participants. This resulted in a common presentation of facts about the IT controlling and reporting system in such way that all participants could understand it and relate it to their objectives. Additionally, the conceptual models ensured that we as researchers understood what is really happening in IT controlling at FSB AG. Consequently, we engaged into a language (re)construction, using the conceptual models as marks of the pragmatic dimension of the domain in focus in order to create a mutual understanding and a language community.

3.3 IT Controlling at FSB AG

FSB ITD in its controlling function creates detailed reports of IT usage. An in-depth analysis of the constructed models revealed that the reporting is purely cost-based. The costs for the IT supplied by FSB IT are based on internal transfer prices for IT items which usually are used for the chargeback of IT costs. These prices are negotiated between the divisional management of the German business units and FSB IT's management. The chargeback structure is initially applied for the resource bargaining during periodical budgeting negotiations between FSB IT and the business units. As a result, the charged items are extremely resource-oriented (e. g. measured as "costs per CPU second"). The created models are extremely large and intricate, mirroring this phenomenon (see Figure 2).

The models show that the variety of this item catalogue is very high: it lists over 550 single items, grouped according to 85 services. Each of these items is used in several IS, for which both price negotiation and controlling are undertaken. Usually, a management decision is the selection of one possible state from all the others. In our case, there are approximately 550 items in total – each with a price accuracy down to Euro and cent. The average IS includes about 150 items. FSB AG has approximately 150 IS in total for which IT chargeback and reporting are conducted. Additional complexity arises because even these items are not constant over time, but change between and during budget periods. In the example of a document management system, the models revealed that nearly two-thirds of the charged items for this system changed between two budgeting periods.

The *potential* variety of the IT controlling and reporting system, as revealed by the conceptual models, and reflected in the item catalogue, appears as approximately

$$V \approx \text{number of IS} \times \text{set of possible combinations using 150 items} = 150 \times 2^{150} \approx 157 \text{ bits}$$

Note that we did not consider the additional variety that results from the changing item structure. In order to identify a particular item – an item for an IS – we need to select one out of that total variety. Even with grouping, constraints and categorization of items, which leads to a reduction of numbers (and which is a rather fruitless task since the item structure is constantly changing), a decision for an IS is a matter of selecting "yes/no" answers for more than 150 items on an average. Consequently, the numbers involved in calculating variety for IT controlling are enormous.

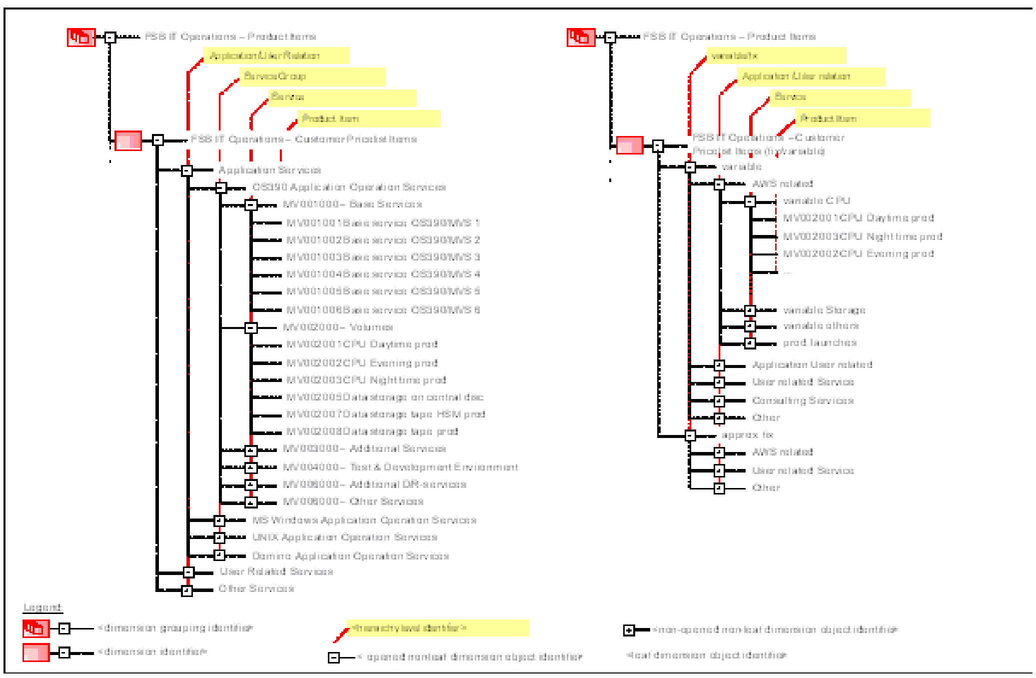
The models point to a high variety within the coordinatory function of FSB ITD: the item structure used for IT controlling 1) has many items, and 2) is changing often. The change of the item structure during and between budgeting periods even makes things more complex.

4.4 Matching with Theory: Hypothesizing on the Establishment of Requisite Variety

The IT controlling and reporting system exhibits a proliferating variety. We gained this insight by analyzing the conceptual models as marks of the language community in focus. The conceptual models enabled us to make that variety visible. According to Ashby's Law, varieties tend to equate naturally (only variety absorbs variety). Consequently, the proliferating variety will be compensated by other means. The *actual* variety must be less enormous than the potential variety. As a result, we hypothesized that in order to establish requisite variety, either 1) *attenuation* on the side of the business units reduces the external variety, or 2) *amplification* on the side of the business units increases the internal variety (Beer 1979, pp. 89-93). Both types of adjustment establish requisite variety and should be detectable accordingly. In order to corroborate or falsify this hypothesis about the establishment of requisite variety, we subsequently conducted a second set of unstructured interviews. The questions for these informal interviews were derived from our application of Ashby's Law. In addition, we used the conceptual models as a starting point for discussions.

Following our analysis, it is not surprising that our hypothesis about the establishment of requisite variety was corroborated. To summarize our results, people from FSB AG's business units have difficulties to understand the IT controlling reports. They are not "written in business language" and "not related to the daily affairs". In addition, the pure number of the provided information generates a feeling of information flooding. In order to cope with these problems, the business units have developed various strategies. For example, one business unit appointed two people with a background in IT that are responsible for the analysis of the IT reports and for the understanding of the item catalogue. Accordingly, this business

Figure 2. Excerpt of MetaMIS model (item catalogue)



unit establishes the missing internal variety by amplification. In addition, other amplifiers and attenuators have been identified, e. g. most prominent the complete disregard of the reports delivered by the IT controlling and reporting system.

4. DISCUSSION & CONCLUSION

According to our findings, the implemented IT controlling and reporting system at FSB AG is not designed with regard to requisite variety. It is quite clear by the different strategies employed by different business units that the existing IT controlling system fails to deliver meaningful information, i. e. information that makes the usage of IT transparent to the business units. For example, this leads to the need of people with expert knowledge in order to establish requisite variety for divisional management, and consequently to a misuse of resources (time, people and/or money). As a practical recommendation, the system should be redesigned in order to fulfill its cybernetic role as a regulator. We propose that this problem could be solved by a reduced item catalogue, made up of terms that are understandable by both business units and IT departments (Zarnekow & Brenner 2003, Nolan 1977).

In this paper, we showed how conceptual modeling and cybernetics can be combined in order to measure complexity. By using language critique as a means to understand conceptual models as marks of a language community, we were able to construct models in order to generate an interpretive understanding of the IS in focus, and to use variety as a measure for the complexity of this IS. Next, we confronted Ashby's Law as a theory with our interpreted observations. Based on Ashby's Law, we generated the hypothesis that due to the failed design of the IT controlling and reporting system, requisite variety asserts itself in other ways. Consequently, we generalized from the interpreted observations to a theory. Using the concept of variety and Ashby's Law as a theory in order to test our hypotheses, we make certain that our research approach is both rigorous and relevant. Our understanding based on language critique shows how conceptual modeling can be applied as a tool for diagnosis.

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ENDNOTE

1 Real name withheld for reasons of anonymity.

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