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Ignorance is bliss: sudden appearance of previously unrecognized information and its effect

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Abstract

The Information Axiom in axiomatic design states that minimising information is always desirable. Information in design may be considered to be a form of chaos and therefore is unwanted. Chaos leads to a lack of regularities in the design and unregulated issues tend to behave stochastically. Obviously, it is hard to satisfy the FRs of a design when it behaves stochastically. Following a recently presented and somewhat broader categorization of information, it appears to cause the most complication when information moves from the unrecognised to the recognised. The paper investigates how unrecognised information may be found and if it is found, how it can be addressed. Best practices for these investigations are derived from the Cynefin methodology. The Axiomatic Maturity Diagram is applied to address unrecognised information and to investigate how order can be restored. Two cases are applied as examples to explain the vexatious behaviour of unrecognised information.

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1. Introduction

Since the introduction of Axiomatic Design (AD) in 1978 [1], the Axioms are applied to determine the technological soundness of a design. The initial number of seven axioms relatively soon [2] were brought back to a number of two, the Independence Axiom and the Information Axiom. These two axioms have been very successful; they are broadly applied for over 35 years since.

The Independence Axiom and the Information Axiom may be considered independent from each other [3], however, this is only the case within the definition of information as it applies for AD. 'Information' or 'Entropy' may be considered as chaos in design. Information in AD is derived from the information technology using a logarithmic measure of Boltzmann's entropy according to Hartley [4] and Shannon & Weaver [5]. It states that information is inversely related to the probability of success. Probability is the central theme of AD around which the axioms are carefully wrapped. Knowledge is applied, in good accordance with the nature of the axioms, to maximise the probability of Design Parameters (DPs) satisfying Functional Requirements (FRs). Knowledge is therefore the most important enabler to address information and consecutively increase the probability of a design to function as expected.

Recently, a broader decomposition of information was introduced for AD, that starts with the Information as defined by Boltzmann, Hartley, and Shannon. The decomposition ends at the bottom with three kinds of information that directly influences a product or system design. One of them is 'Axiomatic Information', directly related to the Information Axiom defined by Suh [6]. Two other kinds of information are 'Recognised' and 'Unrecognised information. Recognised information may be addressed by making the design independent. Unrecognised information on the other hand has more mystical traits; it is not known by the designer and as such it is difficult to address. This paper investigates how to deal with unrecognised information: 1. how it may be found and 2. when found, how to address it. Note, when unrecognised information is found, it instantly changes to recognised information. The research questions for this paper are:

- How can unrecognised information be found?
- How can recognised information be addressed?

This paper is organised as follows. Section 2 focuses on the background of information and complexity. Section 3 considers the concept of unrecognised information, how it can be found and how it may be addressed. Section 4 explains a number of

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cases that deal with unrecognised information, and elaborates on the concept. Finally, Section 5 discusses the findings and conclusions are found in Section 6.

2. Background

2.1. Background on Information or Entropy in a Design

Information in Axiomatic Design is derived from the information theory using a measure of Boltzmann entropy according to Shannon & Weaver [5–7]. It uses the logarithmic representation as introduced by Hartley to make information additive instead of multiplicative [4]. According to the information theory, information is inversely related to the probability of success of a goal being met.

Suh describes three types of information in AD, 'Total' information, which consist of 'Useful' and 'Superfluous' information [6]. Useful information is information that affects FRs and their relations to the other domains. Superfluous information does not affect the relation of FRs and the other domains. Therefore, superfluous information is no information from the design perspective. Puik & Ceglarek decomposed information in the axiomatic context as shown in Figure 1 [3]:

- Total information; the total information content or full entropy of the design as defined by Suh [6];
- Useful information; the part of total information that affects the relation between FRs and DPs [6];
- Superfluous information; information that does not affect the relation between FRs and DPs [6];
- Axiomatic information; useful information due to a discrepancy in design ranges and system ranges as will lead to 'Real' complexity[8];
- Unorganised information; useful information that is not recognised as such due to ignorance of the designer [3];
- Unrecognised information; information of which the designer is not aware of yet [9];
- Recognised information; information of which the designer is aware of but is not addressed yet [9];

2.2. Background on Complexity in Axiomatic Design

Complexity in AD is defined as 'A measure of uncertainty in achieving the specified FRs' [10]. The Complexity Axiom advises to 'Reduce the complexity of a system'. The theory defines two kinds of complexity, 'Time-Independent' and 'Time-Dependent Complexity'. In the case of time-independent complexity, the behavior is governed by the given set of FR and DP relationships. Time-dependent complexity depends upon the initial condition with FR and DP relationships, but unless the system goes back to the same set of initial conditions periodically, the distant future behavior is totally unpredictable as the system tends to escalate [11]. Time-dependent complexity is not further investigated in this chapter.

Time-independent complexity consists of two components: 'Real' and 'Imaginary' time-independent complexity, further to

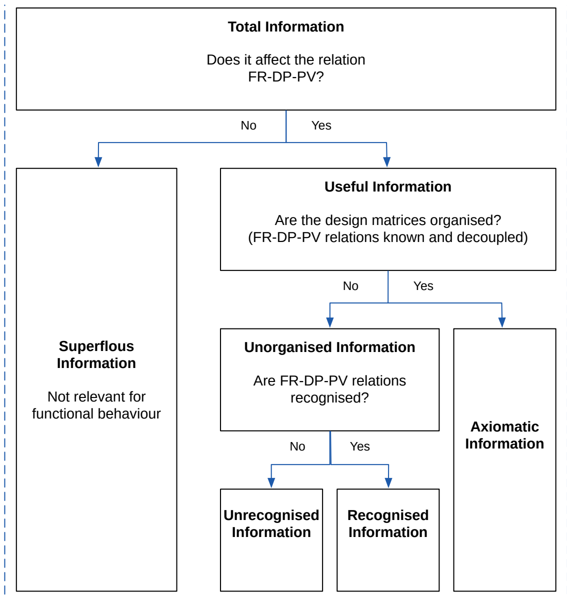

Fig. 1. Overview with types of information and their relations

be referred to as real complexity and imaginary complexity (C_R and C_{Im}). Real complexity is inversely related to the probability of success that the associated FRs are satisfied according to one of the following relations

$$C_R = -\sum_{i=1}^{m} \log_b P_i \tag{1}$$

$$C_R = -\sum_{i=1}^{m} \log_b P_{i|\{j\}} \qquad \text{for } \{j\} = \{1, 2, \ldots, i-1\} \tag{2}$$

depending if the system is uncoupled (Equation 1) or decoupled (Equation 2). Relation 1 is under the reservation that the total probability P_i is the 'joint probability of processes that are statistically independent'. Relation 2, for decoupled systems, is modified to correct for dependencies in the probabilistic function [10]. b Is in both cases the base of the logarithm, usually in bits or nats depending of the preferred definition. Given 1 and 2, real complexity can be related to the information content in AD, which was defined in terms of the probability of success of achieving the desired set of FRs[6], as

$$C_R = I \tag{3}$$

in which C_R is real complexity and I is information as defined in Section 2.1. Imaginary complexity is defined as complexity that exists due to 'a lack of understanding about the system design, system architecture or system behavior' [11]. It is caused by the absence of essential knowledge of the system. The designer cannot solve the problems in a structured manner and therefore is forced to apply trial-and-error. Imaginary complexity exists until understanding of the problem is acquired; it instantly and permanently disappears when the knowledge be-