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TOWARDS A UNIFIED THEORY OF PROPERTIES IN ENGINEERING DESIGN SCIENCE

Seppo SUISTORANTA
Wartsila Finland Oy, Finland

ABSTRACT

This study deals with the current theories of properties that are introduced and presented in the literature of engineering design science. Based on the findings, the paper addresses four fundamental theses, which are separately discussed and commented.

Our sole research question aims at amending the basics of the property theory in EDS. The main outcome of this paper is as follows:

- Definition of the property should be specified and expanded. It should be unambiguous at all abstraction levels of a technical system.
- Terminology of properties, especially the naming of ontologically important property classes, should be agreed on.
- The theory should not be limited only to a particular system model but should rather apply to the whole world. It should also address the properties related to the observer and environment, and they should together make a unified and unambiguous system.

These amendments will help the theory work in its principal tasks, which are explaining, describing, and evaluating objects and events. Further studies are needed. Likewise, the outcome of this paper should undergo exhaustive discussion within the community of engineering design science.

Keywords: design theory, properties, ontologies, requirements, life phase systems

Contact:
Dr. Seppo Suistoranta
Wartsila Finland Oy
Ship Power
Turku
20810
Finland
seppo.suistoranta@wartsila.com

1 INTRODUCTION

The theory of properties plays the central role in the Theory of Technical Systems (TTS). Many authors within the field of engineering design science (EDS) have introduced accounts of properties, with varying content. The literature study shows that they basically share the same framework but they also have clear differences in their conception and terminology.

We need a comprehensive and consistent theory of properties for two main reasons. First, it should provide a solid basis for scientific research and discussion within the community of EDS, especially related to TTS. This objective will serve, in the first place, the researchers and academia without forgetting the students.

Second, the theory is needed in order to support the developers of design tools, which essentially make use of properties as information carriers, such as DFX and QFD.

In this literature study we discuss the scientifically relevant differences found in various theories of properties. At the end, we conclude the findings and give our comments for further studies.

2 BACKGROUND

The problems in the current theories of properties within EDS start from the very basics: What is a property? There is a lot of fuzziness in this subject matter. The current theories put little focus on the ontological aspects of properties, such as existence and identity conditions, requirements for and constraints on the proper use of properties. These topics, despite their fundamental importance, are far too challenging to be treated in this paper; therefore, they will be addressed in future studies.

2.1 Motivation

We need properties in EDS in order to describe, explain, and evaluate objects and events, such as technical systems (hereinafter referred to as “TS”), processes (especially life cycle processes), and phenomena. From the ontological point of view, the theory of properties should be rich and powerful enough to fulfill these tasks, maintaining the epistemic security at the same time. This calls for a consistent conception of properties, with clear and unequivocal terminology, taxonomy, and rules.

The current literature of EDS puts forth several theses for a property theory. Nevertheless, they are not fully compatible. In order to contribute to the development of a unified theory we undertook the effort of analyzing and discussing the main findings from the literature. The outcome of this discussion can hopefully serve as a reference for further studies.

2.2 Research question

Within the scope of this study we ask only one research question: What has to be amended in the basics of property theory in EDS?

2.3 Research methods

In order for us to conduct this research we have studied the subject matter found in the EDS literature. We have selected the main findings and sorted them into four fundamental sub-topics, which we call *theses*. They are related to the main interest areas listed in (Hubka and Eder, 1996): Classes and categories, relationships among properties, design characteristics, determination (measurement) of properties, evaluation of the technical system, and optimization.

Our approach assumes that the theses are hypothetical propositions, which are put forth without proof. This is justified by the fact that EDS is not interested in *being qua being* as such but strives to find theories that can be used in engineering sciences, in the first place.

Each thesis has been discussed and commented on. Finally, the outcome has been concluded.

2.4 Scope of the study

This study concentrates on topics that are metaphysically important. This is also reflected in the selection of theses. We intentionally omit a rigorous analysis of taxonomies and naming conventions and content ourselves only with highlighting some special observations thereof.

3 FINDINGS FOR A FRAMEWORK OF PROPERTY THEORY

In order to consolidate the conception of property in EDS, we first need to clarify the ontological foundation to the relevant extent. This can be done within the six interest areas (Hubka and Eder, 1996), which we have slightly developed in order to form our four theses. They are:

- Definition - What the property is,
- Origination - How the property comes into being,
- Ontological classes – What the fundamental dichotomy within the properties is,
- Relationships - What structural relationships properties constitute within the object (TS) and with its environment.

The main findings from the studied literature that address definition, origination, ontological classes, and relationships are quoted below in 10 clauses. The numbering serves as reference in the later chapters.

Definition:

1. "A property is any characteristic or quality that is possessed by an arbitrary object, and that describes and characterizes that object." (Hubka and Eder, 1988), p. 247
2. "Properties (attributes) of the technical systems are all those features which belong substantially to the object --- the object owns the property (it is proper to the object)." (Hubka and Eder, 1996), p. 108.
3. "A property is anything that is possessed (owned) by an object (a TS). Each constructional structure (or TS [sic]) is the carrier of properties or property classes." (Eder and Hosnedl, 2008), p. 309.

Ontological classes:

4. "For an existing or finally designed TS, the primary classes of properties are external properties and internal properties. External properties are derived from the tangible part of the TS-life cycle and the five operators of each of these life cycle stages. --- Internal properties can be axiomatically defined." (Eder and Hosnedl, 2008), p. 312.
5. The ontological entities that we generally call properties are separated into two main classes: properties that define the object and properties that describe the object. The designer can directly influence the former, whereas his influence on the latter is indirect. Weber (2008), Andreasen et al. (2008) + post-conference discussions.

Origination:

6. "Designers establish the individual structures of technical systems. These structures become carriers of the necessary and desired properties of the future real products." (Hubka and Eder, 1996), p. 139
7. "The internal properties are created by the engineering designer, using design characteristics, general design properties, and elemental design properties." (Eder and Hosnedl, 2008), p. 319

Relationships:

8. "In a particular technical system, the properties appear in definite manifestations, and with appropriate qualitative or quantitative values (measures, magnitudes)." (Eder and Hosnedl, 2008), p. 321.
9. Properties can assume various types of relationships with each other. In particular, the "elements of a more abstract (higher) structure can be mapped to a more concrete structure." (Hubka and Eder, 1996), p. 111.
10. The life cycle of a technical system is a continuum of its interactions with operators of specific transformation systems. These interactions bring about the properties that are attributable to the decisions made by the designer. (Olesen, 1992), (Suistoranta, 2007).

We discuss each thesis separately in Sections 4 through 8.

4 DEFINITION

Clauses 1 through 3 are formal definitions for a property in the account of Hubka et al. They address the three main aspects for a definition: what a property is, what it does, and how it works.

Clause 1 explicates the property with "any characteristic or quality". Instead, Clause 2 identifies properties with "attributes" and, explicates the properties with "features". In naturalistic ontology, properties *include* attributes, qualities, features, and characteristics. Clauses 1 and 2 are not explicit definitions in that regard.

Clause 1 also mentions "describing or characterizing the object", which is fundamental and will be discussed in connection with thesis 2, ontological classes.

Clause 2 says that "the object owns the property." This definition is close to what a metaphysical nominalist might use: the object *has* the properties (Loux, 2006), instead of exemplifying them.

Clause 2 also uses the expression 'belong to'. But what kind of relation is it? This two-place relation can be formally written as "P belongs to O", in which P stands for property and O for object. It is not symmetric and it involves two types of entities, objects (particulars) and properties (universals). This definition calls for an object in order to be meaningful. If the object (a TS) does not exist we cannot tell anything about its properties. At first sight this seems less important but becomes relevant when speaking about designing new TS.
The formal definition of Clause 3 introduces the term "constructional structure". As such, the term does not tell much about the object; except that it distinguishes the object having a structure from an "amorphous blob". But even an amorphous blob has properties, at least 'being an amorphous blob' or 'structure-less', which by definition do not require structures as property carriers. 'Constructional' obviously refers to the fact that the object is implicitly thought to be *built* or constructed into being, so the term possibly leaves out the spontaneous origination (which could be possible in some natural systems).

5 ONTOLOGICAL CLASSES

5.1 Internal properties

Clause 4 claims that internal properties can be axiomatically defined. What it means here is slightly obscure. Does it mean that the internal properties are introduced without their existence being proven? Or does it mean that they are introduced without an explicit definition? One interpretation could be that since internal properties are basic entities for defining the object (ref. to Clause 5) they form a language with an axiomatic syntax. Be that as it may; thesis 2 conveys the important message that internal properties have a fundamental role in the theory of properties and consequentially in the design process.
(Hubka and Eder, 1988) defines the internal properties by deriving them from the "principles of systems". Based on this view, the internal properties consist of (a) relationships between the elements of the system, and (b) the properties of those elements. This definition does not specify what the system elements are but we can assume that in the material world they are micro-structural entities, such as grains, or construction elements, such as parts and components. This would, however, suggest that any property on the higher level of system is compounded of the properties from the lower levels. In certain cases this can easily lead to a paradox: If a mechanical system has a spherical part and a cubical part, what would be the shape expressed on a higher level of system?
The internal properties are also loosely characterized as not being visible to a non-technical person or as being measurable only by an expert. This characterization leaves too much latitude. Who then can be considered a non-technical person or an expert?
To capture the idea that (Hubka and Eder, 1988, 1996) pursue the internal properties can be regarded as objective features of the world; i.e., they are fundamental in the sense that they explain why things have the other properties that they do.

5.2 External properties

Clause 4 speaks about two primary classes of properties, external and internal, and Clause 5 about defining and describing classes. Basically this is a convention-based distinction of the classes. (Hubka and Eder, 1988) introduces seven categories or classes of properties. The categories 'external' and 'internal' are based on the way of *observing* the TS and they are ontologically the most fundamental.
For defining the external properties Hubka et al. speak about the "tangible part of the TS-life cycle and the five operators of each of these life cycle stages" and "derivation". The definition implies that TS' external properties are a consequence of its continuous subjection to the various phenomena in the material world and that the properties somehow depend on this.
Clauses 4 and 5 imply further that the external properties, as derived from the TS-life cycle, cannot be defined independently from the context where the TS subsist. In other words, the external properties are not monadic properties *of the TS* but rather *relations* between the TS and its life-cycle context. (Hubka and Eder, 1988) captures the idea by stating that "external properties are the relationships of the TS to its environment".
Clause 4 calls for "existing" or "finally designed" TS but it leaves open, or unknown, the details of the life cycle stages that the TS will undergo during their lifetime. The expression "tangible part of the TS-

life cycle" probably refers to the life phase systems that exist in the material world and that have physical operators.

5.3 Dichotomy of properties

Two ontological categories

Among the categories of properties concerned in EDS, the ones that thesis 2 (Clauses 4 and 5) postulates are the most fundamental. This is a principal finding in all accounts. Roughly speaking, the claim goes that the properties of any object can be divided according to their ontological role into two main classes, which in EDS are called *defining* and *describing* properties.

The ontological relationship between these property classes is supervenience; the describing properties supervene on the defining properties. In practice, this means that changing the defining properties will pass to the describing properties. In EDS this dichotomy of properties has a major pragmatic content. The engineering designer can directly influence the defining properties only, whereas the describing properties are somehow consequential thereof. This is probably what Hubka et al. means by saying that "designing can be seen as a search for suitable design properties", in which they take design properties for defining properties.

Authors within EDS have adopted various names to denote the two main classes of properties. This also provides an example for the need of alignment in terminology:

- Defining and describing properties, (Andreasen et al.)
- Internal and external properties, (Hubka, Eder, Hosnedl)
- Characteristics and properties (*simpliciter*), (Andreasen, Weber)
- Merkmale and Eigenschaften (Andreasen, Weber)

The dichotomy is not absolute. We can find properties that fall into both categories. For example, the property 'spherical' both defines and describes the object. This is due to the fact that the sphere's definition implicitly describes its shape (this is called an analytic truth).

Requirement vs. property

Properties are often contrasted with requirements. This suggests that certain properties are expected or wished to be found in the TS. In an existing TS the properties *conform* to the requirements, at least to some extent – the degree of conformance might be called 'goodness' or 'quality' of that TS.

(Eder and Hosnedl, 2008) explain the term 'requirement' by means of relations between: (a) constructional entities, (b) properties, and (c) internal and cross-boundary relationships of the TS. Ontologically, the internal and cross-boundary relationship between any two entities make a two-place relation, which infers that this relationship is a sort of dyadic property.

We can conclude that in the design process, 'requirements' approach the 'degree of conformance', and maintain the ontological balance between the defining properties and the describing properties. Together, these two groups of properties explain the current state of TS being designed.

In the design process the describing properties assume two statuses, which are *as is* and *to be*. The latter status of describing properties can also be called 'requirements'. The design process, in general, incorporates iteration and navigation, which can be illustrated as follows: "Describing properties *as is*" ↔ "Defining properties" ↔ "Describing properties *to be*". This suggests that the defining properties are also evolving in the process. Weber (2008) describes this as alternating cycles of analysis and synthesis.

To extend their model to also include the designing of a *new* TS, (Eder and Hosnedl, 2008) add three new relations to compensate for the "describing properties *to be*", which in this design situation have become 'requirements'.

Behavior vs. property

Literature in EDS presents various conceptions of TS' behavior. But is behavior a property; and if yes, is it a defining or a describing property?

(Hubka and Eder, 1988) state that the "behavior of the system is determined by its structure [--]". This suggests that behavior supervenes on the structural properties of TS. Thus, behavior would be an internal property that the designer can directly influence. This interpretation places behavior in the category of defining properties.

Weber (2008) places behavior in the category of 'Eigenschaften' (i.e., not to the defining properties), which he calls collectively 'behavior describing data'. This suggests that 'behavior' is some kind of compound property or a total description of the system.
Hosnedl et al. (2008) says "TS behavior is a response of a TS constructional structure on (external or internal) stimulus." (Eder and Hosnedl, 2008) says the same thing in a slightly different way: "Behavior is the succession of states that the TS assume in response to a stimulus." Both interpretations involve a two-place relation, say, 'response of S on T'. It would suggest that the structure possesses behavior only if a stimulus is present, which leads to the conclusion that behavior cannot be a defining property.

6 ORIGINATION

Thesis 3 passes over the axiomatic definition for internal properties, and postulates that the designer establishes (Clause 6) or *creates* (Clause 7) them. Creating means bringing into being. Naturally this must be understood in the way that the designer sets numerical or qualitative values and/or dimensions for properties that are elemental to the TS being designed. At this stage of its life cycle the TS is only a set of representations, such as drawings, parts lists, and the like, and the internal property must, therefore, be understood as a kind of description without materialization.
Clause 7 introduces three groups of properties, viz. design characteristics, general design properties, and elemental design properties, jointly called *design properties*. Eder (2008) slightly modifies these names but for the sake of consistency we use the old naming.
(Eder and Hosnedl, 2008) put the elemental design properties to a fundamental position. They claim that the existing general design properties, design characteristics, and all the external properties are *causally dependent* on the elemental design properties. This suggests that the elemental design properties, such as the derivatives of 'structure' and 'elements', which they mention in the same context, have causal power on the other properties. This may not be understood that a property causes or brings about another property; what makes the things happen is not the property *per se* but the *object* (or event) with properties. How the object affects things depends on what properties the object has.
In the early stages of the design process, the elemental design properties have no materialization. Here, the causality could refer to a special relation, at the designer's thinking, between an idea and action, where the idea matures into a particular decision, and this decision will then materialize in a form of other design properties.

7 RELATIONSHIPS

Thesis 4 speaks about the mutual relationships of properties. (Hubka and Eder, 1988) says: "Properties and their general relationships are treated in various fields of natural science and engineering, and relationships expressed either in equations (or inequalities) or words." Indeed, many properties are understood or defined in terms of other properties, and properties also play an important role in many accounts of natural laws; Swoyer et al. (2011).

7.1 Mapping

As an important example of a relationship, (Hubka and Eder, 1996) highlight the *mapping* between a more abstract (higher) structure to a more concrete structure. In their context the "more abstract structure" means a particular order of function elements and the "more concrete structure" means the order of organ elements and/or component elements. Mapping is the relationship that ordains the order of elements between the levels of abstraction.
From the systemic point of view, this mapping is a one-to-many relationship, which means that it does not fix any lower level structures: The same function or systemic behavior can be reached by various component structures, (Hansen, 1974).

7.2 Supervenience

But what does mapping mean in terms of properties? From the ontological point of view it is a question of *supervening* properties; the properties on the lower levels of abstraction determine those that are on the higher levels. Generally, supervenience means a relationship between pairs of *families of properties*.

7.3 Manifestation of properties

(Eder and Hosnedl, 2008) introduces the term 'manifestation' by which they probably mean the same as 'exemplification' or 'instantiation' in metaphysical realism. If so, it makes an interesting juxtaposition with Clause 2, which refers to "owning a property". In any case, it can be argued whether manifestation is a relation between the object and its property or not. However, this consideration would take us too far away from the subject matter.

Appearance

Clause 8 uses the word "appear", which means coming into sight or becoming visible. This suggests that the manifestation (of a property) is something that is perceived or experienced. Consequently, a manifestation is subject to the observer and his or her way or means of sensing. For example, the property 'color' has different manifestations depending on whether the object is being observed, say, in daylight or in a room, which is illuminated with a light of special tone. Of course the TS can be specified (e.g., in terms of wavelengths of light and roughness of outer surface) and built with a particular color (manifestation). However, if the TS are kept in a dark room, the manifestation of color tells nothing about the TS to the observer. This is the trivial reason as to why we have to switch on the light when fetching a particular garment from the walk-in closet.

Qualitative properties

Clause 8 speaks also about the "appropriate qualitative or quantitative values". 'Quantitative' refers to some kind of measurability by definition. However, (Eder and Hosnedl, 2008) state that for many properties "quantification is not possible, and even qualitative statements may be questionable". As examples they mention appearance, safety, and suitability for manufacture.

But why is this so? Let us consider the property 'suitability for manufacture'. As the phrase suggests, it consists of two parts, which are 'suitability' or 'being suitable for' and 'manufacture'. Indeed, being suitable does not characterize the object in any specific way. Perhaps 'suitability' can be decomposed into context-dependent, quantitative sub-properties (this suggests that a 'property' is of higher order than a 'sub-property', which is not self-evidently true).

Also the word 'manufacture' is obscure as such. As a general term it can include all operations made and events that happen when the TS is being manufactured. As a simple example, consider a shaft journal (S). Being suitable for manufacture could be represented with the following relation R_n, which gets more general as *n* increases (the relata separated with '–'):

- R_1 = S – The machine (M) being used for turning S
- R_2 = S – M – The workshop (W) where S is manufactured, including also other Ms and Os
- R_3 = S – M – W – The operators (O) who operate M
- R_4 = S – M – W – O – Industrial company (C) that runs W
- R_5 = S – M – W – O – C – Society (Y) and environment (E).

We may conclude that 'suitability for manufacture' incorporates an *n*-place relation R_n, which ties up the relata S, M, W, O, C, Y, and E. It is noteworthy that 'suitability for manufacture' presented in this form is not only a relation of the shaft journal and the tool that is machining it but also involves the machine tool's relation(s) to its surroundings.

Here, again, the manifestation (of this relation) depends on the observer and his or her particular interest area or own preferences. Even if the relation R_n were developed into a matrix of quantifiable, actually measured values, it still leaves much room for interpretation about what the numbers really tell.

The relation R_n illustrates, *mutatis mutandis*, the conception of "Design for Manufacture" as presented by Hubka et al., in their general systematics of "Design for X" classes. Instead of relations and relata, they use their customary names for the operator systems: O $\rightarrow$ Humans, teams; M and W $\rightarrow$ Working means, tools; C $\rightarrow$ Leadership, management; W and S and E $\rightarrow$ Surroundings, environment.

7.4 Dispositions, meetings, and life phase systems

Theory of dispositions

(Olesen, 1992) has extensively researched the interplay between the product and manufacturing system. His *theory of dispositions* introduces an entity, the disposition, which seems to have influencing power over various functional areas in the context of industrial company. The theory can

be generalized and extended to apply technical systems and their life phase systems, (Suistoranta, 2007).
The disposition is a secondary outcome of any decision, which is made under a particular state of affairs, like in a design situation. It can be understood as a package of rules and knowledge that contributes – intentionally or unintentionally – to the TS' behavior in various places and situations. For every property of the TS there is a corresponding property or properties in its subsequent life phase systems. Thus, the TS' life cycle properties are instantiations that are brought about by its *meeting* with a future life phase system.
Olesen's theory suggests that the interplay in the meeting can be expressed as a set of parameter relationships, which can also serve as carriers of dispositions. 'Parameters', in this context, probably mean the combination of design properties that are needed to determine the technical system's response in its meeting with a particular life phase system.

External properties revisited

The conception of external property, as understood in Clause 4, can be reformulated with the help of Clause 10. The life phase systems form a continuum. The extended theory of Olesen explains that the life phase system can be constructed according to the model of a transformation system in which its operators can adopt different constitutions and forms. Hubka et al. call these operators 'human systems, technical systems, management systems, information systems and active environment'. In each stage where the TS and life phase system meet (as termed by Olesen) we can derive (as termed by Hubka et al.) operator-specific and/or operator-related properties. This derivation is based on the assumption that the life phase system's operators are active or reactive at the operator-operand interface.

8 COMMENTS

Next, we comment on the basic findings from the current theories of properties in EDS, in light of the four theses discussed above.

8.1 Thesis 1: Definition

The formal definition given in thesis 1, "the object owns the property", needs further clarification. Considering the relation "A owns B" the definition gives reason for thinking that the property is in some way "inside" the object, isolated of the world. This suggests that it applies, de facto, only to 'defining properties', in the sense that Clause 5 suggested.
To extend the definition to also include the 'describing properties', we could make use of the outcome of Clause 4, complementing it with Olesen's theory about the object's meeting with its life phase system. This would formalize the concept of 'describing property', taking it as a relation, which in naturalistic ontology could be considered an n-place *property*, in this case between the object (TS) and an event (life phase system, at a given time).

8.2 Thesis 2: Ontological classes

The most fundamental distinction of properties is made between the defining and describing properties, as discussed in thesis 2. These two categories provide the building blocks for designing the TS. This topic is addressed in all the works studied for this paper.

Derivation of external properties

Clause 4 says "External properties are derived from the tangible part of the TS-life cycle and the five operators of each of these life cycle stages." This sentence refers to the transformation system model (Hubka and Eder, 1988) where all the external properties are derived from. It remains unclear if we can explicate with these derived properties anything that is external to the model itself.

Terminology and taxonomy

There are various proposals for the terminology. As Andreasen et al. (2008) point out, it seems that the English language makes it difficult to convey the core meaning of the categories' names. Defining and describing properties correspond to 'characteristics' and 'properties' (simpliciter), respectively. Since these English words are more or less synonymous, it might make sense to introduce new terms derived from, say, Latin.

Another important question is the taxonomy of property classes. As mentioned earlier in the discussion of thesis 2 there are several ways to classify the properties. Consequently, constructing a uniform taxonomy calls for consensus.
It seems that the current property theories in EDS consider the properties being entities within objects and the related systems only. This approach leaves out the transcendental relations between the object and the observer, such as 'believes in', 'thinks about', and the like. Professor Andreasen highlights some examples in the post-conference discussions of Andreasen et al. (2008), proposing such categories as 'allocated' and 'ascribed' properties. All in all, a clear taxonomy should reflect the reality, making use of the ontological relations between the objects.

The designer's viewpoint: naming of properties

In addition, the naming of properties and property classes are widely discussed in the EDS literature. It is generally agreed that there is an infinite number of properties, and what is more, many of them overlap each other.
To reach unambiguousness and clarity the names should be understood in the same way in all cultures within the EDS community. An attempt in this direction is to use a standardized format for drawings, parts lists, and the like. However, there seem to be no rules for the natural language, which in any case is the main way of communication. Can we be sure that a word denotes the same thing in the numerous languages spoken by the practitioners? And how well does the property's name capture its meaning or semantic value? One solution might be to give up the property names and simply consider each property a *predication,* i.e. being something that is said or claimed truthfully about the thing.

8.3 Thesis 3: Origination

Thesis 3 addresses the designer's role as a creator. Designing is creative work and the position is clear and generally recognized. However, the designer creates the *object*, the TS, in the first place. Is it formally correct to say that the designer *creates the properties*? Does this mean that, in the beginning, there is only a kind of substratum that the designer starts to "fill in" with properties?
Properties are an irremovable part of the world, the reality. If we believe that the properties exist (which is a fundamental question in metaphysics), then we should accept the fact that the TS' properties are not created; they just subsist.

8.4 Thesis 4: Relationships

Thesis 4 discusses the relationships of properties. This subject matter is also extensively considered in the works of Hubka et al. The theory could be complemented with a discussion of relations between objects in general, and relations between families of properties, in particular. The concept of supervenience would probably extend and deepen the concepts also within EDS.
Clause 8 introduces the term 'manifestation', which is a kind of appearance of properties' materialized values or magnitudes. It remains unclear as to whether manifestation is a relation between the object and its property. However, it can be understood as a relation between the property and the observer. This is also in line with the everyday experience about sensing the properties. To denote that the object exhibits a property without the observer being present, we could maybe favor the terms exemplification or instantiation, which are widely used in metaphysical realism.
Olesen's theory (which was condensed in Clause 10) makes an important contribution to the theory of properties. It explains how the dispositions, which are a secondary outcome of designer's decisions, affect the behavior of the TS in its future life phases.

About dispositions

Olesen's theory suggests that the 'disposition' is an 'impulse' or a 'carrier of consequential effects'. It originates within decision making, and it probably assumes various physical forms, such as data files, drawings, and the like. But clearly its significance is in its power of influencing the decision making and operations in another time and in other places.
It is slightly unclear as to how Olesen chose his word 'disposition'. It has been said that it resulted from Danish into English due to homonymy. Be that as it may, it is extremely important to separate Olesen's disposition from the very same word used in metaphysics, where it refers to a higher-level property that an object possesses, by virtue of that object's possession of lower-level qualitative (categorical) properties.

However, since the disposition in both meanings of the word possesses certain causal power over other entities, we could maybe use it in the same meaning if two relations are joined to make one causal chain, as follows (denoting the relation with '—', properties with Pr, and object with O):

- R_1 = Decision that has been made regarding O — O's property Pr_1 in another time and/or place
- R_2 = O's property Pr_1 — O's property Pr_2 in another time and/or place

Both relations may be called dispositional, R_1 in the way that Olesen (probably) means, and R_2 as understood in metaphysics.

9 CONCLUSIONS

This study deals with the current theories of properties that are introduced and presented in the literature of engineering design science. Based on the findings, the paper addresses four fundamental theses, which form the basis on and framework for a property theory. The theses are separately discussed and commented.

Our sole research question aimed at amending the basics of the property theory in EDS. The answer – i.e., the main outcome of this paper − is as follows:

- Definition of the property should be specified and expanded. It should be unambiguous at all abstraction levels of a technical system.
- Terminology of properties, especially the naming of ontologically important property classes, should be agreed on.
- The theory should not be limited only to a particular system model but should rather apply to the whole world. It should also address the properties related to the observer and environment, and they should together make a unified and unambiguous system.

We believe that these amendments would help the theory work in its principal tasks − explaining, describing, and evaluating – at the same time maintaining the epistemic security.

The outcome of this study is only a small part of the work that should be carried out for creating a unified theory of properties for engineering design science. Further studies are needed. Likewise, the topics and outcome of this paper should undergo exhaustive discussion within the EDS community.

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