On Qualitatively Unstable Objects

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Abstract. I present in this paper a certain classification of objects with respect to their qualitative stability, i.e., with respect whether they change their qualities. The resulting classification is a flat typology of objects with two facets and three types in each facet. Assuming this classification the paper is then focused on one of these types: very weakly unstable objects. In particular, I discuss the problem of their persistence and attempt to sketch identity criteria over time.

Keywords. quality, change, persistence, identity

1. Introduction

Suppose that developing a computer system you designed a relational database whose one table looks like table 1 below. That is to say, you ended up with a set of tables and one of them is a table (relation) with just one column (attribute) whose values look as if they were meant to identify certain objects.

Although your table is allowed by most (if not all) database languages and although it does not breach any usual design principle [1], there is something wrong with it: the values in the column do not seem to provide any information, so the table is void of any content although it contains some data.

Identifiers
1
2
...

Table 1. Table

Is there a reasonable scenario when such situation may occur? Well, suppose that the system in question is a historic-geographical system or more specifically that it is designed to gather information about histories of (human) settlements. The design requirements specify that we need to trace the location, name, and the type of such settlements. You know from the SMEs that each settlement may change its location, name, and type in time, so that a settlement may have at time t_1 different location and name, and type than it has at time t_2, i.e., all

[1] In fact, it satisfies the third normal form of E. Codd, because it has only one attribute.

these attributes may change from t_1 to t_2 (cf. [11]). So you need another table for settlement states (or manifestations) at different times – e.g., similar to table 2 below. Now since attribute SettlementIds in this table looks like a foreign key,

Ids	SettlementIds	Locations	Names	Types	Starts	Ends
1	1	N52°99.21′ E18°59.16′	Podgorz	Village	1555	1611
2	1	N52°99.21′ E18°59.16′	Podgorz	City	1612	1833
3	1	N52°99.21′ E18°59.16′	Podgorz	Village	1834	1924
4	1	N52°99.21′ E18°59.16′	Podgorz	City	1925	1938
5	1	N52°99.21′ E18°59.16′	Podgorz	Suburb	1939	2017
...	...	...	...	...	...	...

Table 2. Settlement States Table

you think you need a table where this attribute constitutes a primary key, so you end up with a table whose schema is identical to that of table 1.

Brushing aside the database design issues I claim that the aforementioned scenario concerns objects of an unusual ontological kind. Namely, they exist and change in time, but, given the scope of the presupposed conceptualisation of the domain, neither of these objects is bound to keep any of its characteristics in time, i.e., an object of this kind may change all its properties or qualities in time while maintaining its identity. In this sense they are qualitatively unstable.

2. Types Of Qualitative (Un-)Stability

Now the kind of objects described in the previous section can be defined as a component of the formal framework below. The typology I outline in this section classifies objects with respect to their qualitative stability, i.e., to that how stable their qualities remain in the course of time.

The framework in question is in fact a thin first-order theory of objects or rather of things with qualities.[2] It assumes a multi-sorted language defined as below:

1. four (disjoint) sorts: $S_{object}, S_{quality}, S_{value}, S_{time}$;
2. and their sorted individual variables:
   (a) $x, x_1, x_2, \cdots : S_{object}$
   (b) $q, q_1, q_2, \cdots : S_{quality}$
   (c) $v, v_1, v_2, \cdots : S_{value}$
   (d) $t, t_1, t_2 \cdots : S_{time}$.

The framework takes off with two primitive predicates: $\mathrm{Q}(x, q, v, t)$ and $\mathrm{Exist}(x, t)$, whose informal readings are given in table 3.

The theory in question is philosophically "thin", i.e., it assumes a few basic ontological features of objects, which are described by the following four axioms:

[2] It is not, thus, a theory of qualities in the sense of [5].

Formula	Informal Reading
$\mathrm{Q}(x, q, v, t)$	object x has quality q that has value v at time t
$\mathrm{Exist}(x, t)$	object x exists at time t

Table 3. Primitive Predicates

$$\exists t \mathrm{Exist}(x, t) \tag{1}$$

$$\mathrm{Exist}(x, t) \rightarrow \exists q, v \mathrm{Q}(x, q, v, t) \tag{2}$$

$$\mathrm{Q}(x, q, v, t) \rightarrow \mathrm{Exist}(x, t) \tag{3}$$

$$\mathrm{Q}(x, q, v_1, t) \wedge \mathrm{Q}(x, q, v_2, t) \rightarrow v_1 = v_2 \tag{4}$$

The theory's scope is limited to things with qualities that exist in time, so axiom 1 has it that all objects, and not necessarily the qualities themselves, exist in time.[3] The term "quality" is taken here in a fairly broad sense: qualities are those entities that can be predicated of things or attributed to them because things bear, possess or exemplify them ([8]). Then the main, although modest, ontological assumption is the "quadruple" distinction between objects, their qualities, quality values, and times. In particular, a quality (of a certain object) may have different values at different times at which this object exists, although by axiom 4 no quality (of a given object) can have more than one value at a time. Axiom 2 excludes from this consideration "bare objects", i.e., objects without qualities. Axiom 3 excludes qualities of non-existing objects. All other philosophical controversies about qualities are left open. In particular, I do not make any assumption in this section on the individuation of qualities, their extensionality, etc.

Now within this framework one can define two types of relations between objects and their qualities: weak and strong stability.[4] By definition 6 a quality is *weakly stable* for an object if this object has this quality throughout its lifetime although at different moments in this lifetime its values may differ. By definition 7 a quality is *strongly stable* for an object if this object has this quality all the time (when it exists) and the quality has the same value all the time. An example of an object with a quality that is not even weakly stable might be a lump of bronze that undergoes a phase transition change, say, melting. When in the solid state the lump has the a certain ductility, i.e., it has the ductility quality with a certain value, but this quality is lost when it is in the liquid state since ductility is a property of solid bodies only. The population size of a city may exemplify weakly stable qualities. Finally, the charge of an electron seems to be a strongly stable quality thereof.

[3] That is to say, if there exist atemporal things with qualities, they are not within the scope of this paper.

[4] For the sake of simplicity, no formal definition provided in this paper has any explicit modality. If the reader finds this lack disturbing, he or she may prefix the *definienda* of the respective definition with the necessity operator.

Formula	Informal Reading
$\mathrm{Span}(q, x)$	quality q belongs to the quality span of object x
$\mathrm{SS}(q, x)$	quality q is a strongly stable quality of object x
$\mathrm{WS}(q, x)$	quality q is a weakly stable quality of object x

Table 4. Auxiliary Predicates

Formula	Informal Reading
$\mathrm{FullySS}(x)$	object x is fully strongly stable
$\mathrm{FullyWS}(x)$	object x is fully weakly stable
$\mathrm{PartiallySS}(x)$	object x is partially strongly stable
$\mathrm{PartiallyWS}(x)$	object x is partially weakly stable
$\mathrm{FullyWunS}(x)$	object x is fully weakly unstable
$\mathrm{FullySunS}(x)$	object x is fully strongly unstable
$\mathrm{PartiallyWunS}(x)$	object x is partially weakly unstable
$\mathrm{PartiallySunS}(x)$	object x is partially strongly unstable

Table 5. Types of Qualitative (Un-)Stability

$$\mathrm{Span}(q, x) \triangleq \exists t, v \mathrm{Q}(x, q, v, t) \tag{5}$$

$$\mathrm{WS}(q, x) \triangleq \forall t[\mathrm{Exist}(x, t) \rightarrow \exists v \mathrm{Q}(x, q, v, t)] \tag{6}$$

$$\mathrm{SS}(q, x) \triangleq \exists v \forall t[\mathrm{Exist}(x, t) \rightarrow \mathrm{Q}(x, q, v, t)] \tag{7}$$

Now this distinction may be used to classify all objects with respect to the following eight (basic) types.

$$\mathrm{FullySS}(x) \triangleq \forall q[\mathrm{Span}(q, x) \rightarrow \mathrm{SS}(q, x)] \tag{8}$$

$$\mathrm{FullyWS}(x) \triangleq \forall q[\mathrm{Span}(q, x) \rightarrow \mathrm{WS}(q, x)] \tag{9}$$

$$\mathrm{PartiallySS}(x) \triangleq \neg \mathrm{FullySS}(x) \wedge \exists q \mathrm{SS}(q, x) \tag{10}$$

$$\mathrm{PartiallyWS}(x) \triangleq \neg \mathrm{FullyWS}(x) \wedge \exists q \mathrm{WS}(q, x) \tag{11}$$

$$\mathrm{FullySunS}(x) \triangleq \forall q[\mathrm{Span}(q, x) \rightarrow \neg \mathrm{WS}(q, x)] \tag{12}$$

$$\mathrm{FullyWunS}(x) \triangleq \forall q[\mathrm{Span}(q, x) \rightarrow \neg \mathrm{SS}(q, x)] \tag{13}$$

$$\mathrm{PartiallySunS}(x) \triangleq \neg \mathrm{FullySunS}(x) \wedge \exists q[\mathrm{Span}(q, x) \wedge \neg \mathrm{WS}(q, x)] \tag{14}$$

$$\mathrm{PartiallyWunS}(x) \triangleq \neg \mathrm{FullyWunS}(x) \wedge \exists q[\mathrm{Span}(q, x) \wedge \neg \mathrm{SS}(q, x)] \tag{15}$$

The corollaries below show the basic set-theoretical relationships between these types:

$$\text{FullySS}(x) \rightarrow \text{FullyWS}(x) \tag{16}$$

$$\text{PartiallySS}(x) \rightarrow \text{PartiallyWS}(x) \tag{17}$$

$$\text{PartiallySS}(x) \equiv \text{PartiallyWunS}(x) \tag{18}$$

$$\text{PartiallyWS}(x) \equiv \text{PartiallySunS}(x) \tag{19}$$

$$\text{PartiallySunS}(x) \rightarrow \text{PartiallyWunS}(x) \tag{20}$$

$$\text{FullySunS}(x) \rightarrow \text{FullyWunS}(x) \tag{21}$$

$$\text{FullySS}(x) \vee \text{PartiallySS}(x) \vee \text{FullyWunS}(x) \tag{22}$$

$$\text{FullyWS}(x) \vee \text{PartiallyWS}(x) \vee \text{FullySunS}(x) \tag{23}$$

The resulting typology of objects has thus two overlapping facets, which are determined by two types of quality stability: 6 and 7. Each facet contains, effectively, three types:

1. strong stability facet: FullySS PartiallySS, and FullyWunS;
2. weak stability facet: FullyWS, PartiallyWS and FullySunS.

Combining the types from the two facets, we can get six new types, which are the intersections of the original ones. These intersections are shown in cells of table 6, where the column and row headings are the intersecting types. These "combined" types are pairwise disjoint and collectively exhaustive.

	FullySS	PartiallySS	FullyWunS
FullyWS	Strongly Stable	Weakly Stable	Very Weakly Unstable
PartiallyWS	$\emptyset$	Partially (Un-)Stable	Weakly Unstable
FullySunS	$\emptyset$	$\emptyset$	Strongly Unstable

Table 6. Combined Types of Qualitative (Un-)Stability

Now let me say a few words about the resulting typology. First, it is obvious that whether a certain object belongs to a certain type depends, among other things, on a scope of qualities under consideration. So two different sets of qualities may give rise to two different classifications of the same object. For this reason the above framework should be taken as relative to or parameterised with a set of qualities.[5] This relativisation may pose a problem for philosophy where some search for the ultimate conceptualisation, but in the engineering context of applied ontology it is more acceptable, perhaps even justifiable, if one is ready to embrace such meta-principles as perspectivalism ([1, p. 44-45]).

Secondly, let me risk providing some instances of the "combined" types. Strongly stable objects are fairly exceptional as they are objects that exist in time, but do not change in time. So the least controversial cases thereof are instantaneous objects, i.e., objects that exists only at one time, e.g., events. Weakly stable objects are more frequent – in fact such ontologies as Dolce [6] seem to postulate that all objects are fully weakly stable, so probably some kinds of animals, e.g.,

[5] Formally, we could add an additional axiom schema like "$Q_i(q)$", whose semantic interpretations may express this parametrisation.

birds, may by weakly stable. An example of a partially (un-)stable object might our lump of bronze (with the melting temperature point as a stable property). If the case described in the introduction is accurate, than human settlements may constitute a class of very weakly unstable objects provided that they do not gain or lose any quality during their existence. The type of weakly unstable objects is tricky as it contains those things whose all qualities change in time and in addition which may gain or lose some qualities. The question whether this category is empty or not is left open here. Strongly unstable objects are relatively rare either. In fact one can argue that this class is empty if we assume that each object that exists in time has at every time it exists a certain location and that this location is among its qualities. Then all objects will be (at least) partially weakly stable. On the other hand if you think that certain temporal objects have no spatial location, e.g., events, then weird mereological fusions of such objects and other, spatially determined, objects may fall into this category. For instance, the mereological fusion of the Big Bang event and the village of Podgorz may be a strongly unstable object.

Finally, the above framework implies that all these types are rigid, i.e., that whether an object belongs to a certain type or not is not accidental. So any object begins its existence, persists, and ceases to exist belonging to the same type. In this sense they are ontological types, although I envisage that their application may be more valuable on the meta-ontological level where we may mark up ontological categories with these types respective to the types of objects falling under these categories.

3. On Very Weakly Unstable Objects

Let me restate that an object is very weakly unstable if all its qualities may change their values during its lifetime but it cannot gain or lose any of these qualities. As such very weakly unstable objects present a particular challenge for ontological engineering as their identity does not seem to be grounded, at least not intrinsically. That is to say, these objects persist in time, but they lack grounds for this persistence because their qualities are in constant flux. The rationale for this claim is the intuition that if the ground for its persistence was internal to an object, e.g., it was grounded in its mereological structure, then this fact would entail that some of its qualities would be strongly stable. Obviously, not every strongly stable quality of an object has to do with its identity, but if the object persists in time its identity cannot be grounded in qualities that are not strongly stable.

So if there is a ground for the fact that a certain very weakly unstable object maintains its identity, then this ground must be external to the object, i.e., it might be a certain relation that this object keeps to some other entity during the lifetime of the former. Again, it must be an external relation, i.e., it must not depend on the qualities of the object. But then the object turns out to be ontologically volatile since its identity is grounded in something else than itself. And there are ontological viewpoints which would explicitly disqualify such entity because its putative existence would violate the so-called 'The Only X and Y'

principle [7]: whether x is identical to y can depend only on facts about x and y and the relationships between them.

This is not to say that all aspects of very weakly unstable objects are accidental to them. Consider the category of human settlements and one of its members, say, the (contemporary) suburb of Podgorz. Now it is possible that Podgorz will become a city (or even a capitol) or a village in the future (in fact it was a village and a city in the past – see table 2), but it is unlikely that it will become a river or a car. So it seems that the category of settlements is rigid (in the sense of [4]) and that its members are necessarily settlements, i.e., metaphorically speaking, they are born and they die as settlements. So weakly stable objects may have some necessary or essential aspects although these aspects do not individuate them sufficiently enough to ground their identity over time.[6]

This theoretical problem is accompanied by more practical issues. Let us go back to the database mentioned in Introduction. Suppose that you finalised the design of the table for settlement states and started filling it up with the data. After some time its content looks like in table 7. Now the question arises whether

Ids	**SettlementIds**	**Locations**	**Names**	**Types**	**Starts**	**Ends**
1	1	Loc1	Name1	Type1	t1	t2
2	2	Loc1	Name1	Type1	t1	t2
3	2	Loc1	Name2	Type1	t2	t3
...	...	...	...	...	...	...
999	2	Loc2	Name2	Type2	t999	t1000

Table 7. Settlement Identity Issues

this body of data is correct or even consistent. In the first interval, i.e., from time t1 to t2, the table has it that there are two settlements with the same location, name, and type. Is it possible that there are two different settlements located at same time in the same place, having then the same names and types? Comparing the second and the first interval, one can ask whether it is possible that a single settlement may change its name? Finally, records id=3 and id=999 imply there is a settlement that changed its location and type in a long period of time. Is this possible?

Needless to say, to provide non-arbitrary answers to such questions one needs some theoretical principles that have to do with the nature of settlements, their persistence, etc. One possibility is to establish settlement identity criteria – in both versions: synchronic and diachronic (cf. [3]). As the reader may expect very weakly unstable objects pose a special challenge for those who search for the former. It is not an obvious matter under what conditions (very weakly unstable) object x_1 is identical to (very weakly unstable) object x_2 when x_1 exists at time t_1 and x_2 exists at time t_2 ($t_1 \neq t_2$).

The problems with identity criteria are notorious ([2]) and the fact that we deal with very weakly unstable objects does not help. Nonetheless I will attempt to sketch a certain theoretical proposal on how to arrive at such criteria. The

[6] One could probably say that such objects have general, but not individual, essences in the sense of [9].

proposal below was coined to fit the case of settlements, but it aspires to provide a general solution for all very weakly unstable objects. Since very weakly unstable objects are rather irregular types of entities, the proposal has largely stipulative nature. Let me summarise it before a more detailed exposition is provided. First, I assume that there exists such *synchronic* criterion of identity for (a certain kind of) very weakly unstable objects that entails that there is a set of qualities such that objects indiscernible with respect to these qualities are identical. Secondly, I claim that a very weakly unstable object maintains its identity throughout certain changes such that each change affects no more than one of such qualities.

So suppose that we deal with a class (type) X of very weakly unstable objects, e.g., let X be the class of settlements. The proposal in question presupposes that we are able to formulate a synchronic criterion of identity for X that is equivalent or entails the following principle:

$$X(x) \wedge X(y) \wedge$$
$$[\mathrm{Q}(x, q_1, v_1, t) \wedge \mathrm{Q}(y, q_1, v_1, t)] \wedge \cdots \wedge [\mathrm{Q}(x, q_n, v_n, t) \wedge \mathrm{Q}(y, q_n, v_n, t)] \rightarrow$$
$$x = y. \tag{24}$$

That is to say, I take it for granted that there are qualities $q_1, q_2, \ldots, q_n$ such that no two X-objects can have the same values of these qualities at any time.For instance, if X is the category of settlements, [11] has it that this set includes names, locations, and types.[7]

Secondly, let me define the notion of qualitative transformation for very weakly unstable objects. Suppose that x and y are very weakly unstable objects (possibly $x = y$). Let then p be a process that starts at time t_1 and terminates at time t_2. Object y will be called a *p-transformant* of object x at time t with respect to quality q from set of qualities $Q = \{q, q_1, q_2, \ldots, q_n\}$ if all below conditions are met:

1. $t_1 < t \leq t_2$;
2. x participates at t_1 in p and its qualities $q, q_1, q_2, \ldots, q_n$ have at that time values $v, v_1, v_2, \ldots, v_n$;
3. y participates at t in p and its qualities $q, q_1, q_2, \ldots, q_n$ have at that time values $v', v_1, v_2, \ldots, v_n$ (possibly $v' = v$);
4. there is no other (than x and y) object z such that z participates at t in p and its qualities $q, q_1, q_2, \ldots, q_n$ have at that time values $v'', v_1, v_2, \ldots, v_n$, where $v'' \neq v$.[8]

[7] Interestingly enough, some studies suggest that there are very rare cases of settlements that at some point in their existence share the name, location, and type, so the list in the main text may be too short. For instance, [10, p. 34] gives three examples of such "duplicated" villages: there were two villages of Mikuszowice, two villages of Biertoltowice, and two of Komorowice at the same location in the end of the XVI century. The quality (if this is a quality) that made them different is their different administrative affiliation: one village of Mikuszowice belonged to the Kingdom of Poland and the other belonged to the Kingdom of Silesia. If this finding is accurate, the list given in the main text needs to be extended or modified.

[8] For the sake of simplicity, some parts of the phrases of the form "p-transformant of object x at time t with respect to quality q from set of qualities $Q = \{q, q_1, q_2, \ldots, q_n\}$" will be dropped in what follows provided that the context where these phrases occur make it obvious what exactly was dropped.

Moreover, if the value of q at t is the same as it was at t_1, I will also speak about y as a *p-idempotent transformant* of x at t; otherwise, it will be called a *p-proper transformant*. Note that no object can have more than one transformant with respect to any quality, process, or time in a given context. If y is the p-transformant of x at t with respect to q, then process p will be called a *$q-$transformation* of x at t *into* y.

Suppose now that some x from X start its existence at time t_0. Since x is a very weakly unstable object, it has at this and all other times when it exists all qualities from a set $Q = \{q_1, q_2, \ldots, q_n\}$. Suppose also that these qualities have at t_0 certain values, say, respectively: $v_1^{t_0}, v_2^{t_0}, \ldots, v_n^{t_0}$. Let us consider set P_0 of all processes in which x starts to participate at t_0 or, if this set is empty, the set of all processes at a later time when x starts to participate in any process. If there are two processes in P_0 such that one is a proper part of another, we remove the latter from P_0. Let "t_1" denote the time at which the first member of such P_0 ceases to exist, i.e., if $p \in P_0$ dies at time t, then $t_1 \leq t$. There are four pairwise disjoint and collectively exhaustive possibilities now:

1. P_0 has no q_i-transformation of x at t_1 in the context of Q $(1 \leq i \leq n)$;
2. P_0 has such transformations, but all of them are idempotent;
3. P_0 has such transformations, but all of them that are proper are also q_i-transformations for some single quality q_i;
4. P_0 has (at least) two proper transformations: q_i-transformation and q_j-transformation and $q_i \neq q_j$.

If either case 1 or 4 holds, then I claim that x ceases to exist at some time between t_0 and t_1, so x is not identical to any object that exists at t_1 (or at any later time). Otherwise, I claim that x keeps its identity within the $[t_0, t_1]$ interval and is identical with all its p-transformants (where $p \in P_0$).

Consequently, qualitative transformations provide a kind of local criterion of identity for weakly stable objects, i.e., the above procedure establishes a principle that allows us to answer identity questions at the boundaries of the $[t_0, t_1]$ interval. Naturally, the question of identity within this interval remains open.

If you want to get a less local criterion, then if x survived the changes from P_0, you need to repeat the above procedure starting from t_1 instead of t_0, i.e., now you find out that qualities from Q have at time t_1 values, say, respectively: $v_1^{t_1}, v_2^{t_1}, \ldots, v_n^{t_1}$. And you consider set P_1 of all processes in which x participates at t_1. Etc. Assuming that x terminates its existence at some point in time, the procedure I just described will give us a sequence of local criteria of identity. Combining them sequentially will result in a (global), but restricted, criterion of identity for very weakly unstable objects. Namely, we will arrive at a set of times $\{t_0, t_1, \ldots, t_k\}$ such that we can say under which conditions a (very weakly unstable) object x_1 is identical to a (very weakly unstable) object x_2 even if x_1 exists at time t_i and x_2 exists at time t_j $(0 \leq i, j \leq k)$.

4. Conclusions

In my view the main contribution of this paper is a certain perspective on objects that change their qualities over time. Despite the fact that the prospective was

defined outside the usual research agenda of applied ontology, but it may throw new light on some existing problems there. It provides a new typology of such objects and brings to the reader's attention the category of very weakly unstable objects as entities of a peculiar ontological kind. The perspective I sketched here definitely needs further elaboration – in particular my discussion of identity of such objects lacks both formal outlook and some deeper philosophical insight – but may be mature enough to revive discussion on such issues as criteria of identity for less usual ontological kinds. For example, I find the type of weakly unstable objects worth further investigation in this respect.

Still even now one can envisage some applications of this theoretical research. One obvious case that comes to mind is a (meta-)classification of ontological categories (from some given applied ontology) by means of the types described above. This may help in better understanding of the nature of these categories and in ontology alignment, when we try to match categories that belong to different ontologies. I envisage that this application may be more valuable in the case of comparing domain ontologies than in the case of upper-level ontologies whose categories usually include objects from various such types described in this paper.

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