Quality Patterns and Conceptual Spaces

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Abstract. In this abstract, we try to build a bridge between Guarino's notion of quality fields/patterns and the Theory of Conceptual Spaces (CS). For that, we employ an extension of CS called Holistic-Structure Spaces.

1. Introduction

In SHAPES 2.0, Guarino [1] presented an initial study about the mereological behaviour of qualities in the context of DOLCE ontology. In brief, he proposed that the qualities of parts of an entity can be aggregated in the whole by means of quality patterns and quality fields. Such constructs would allow one to specify notions such as the shape of the bottom of an ocean, or the colour pattern of an apple. However, Guarino did not elaborate on how such notions connect to quality regions, an intrinsic aspect of qualities in DOLCE. In this short paper, we suggest that Holistic-Structure Spaces, presented by us at the same event in 2014 [2], can serve as a background theory connecting quality patterns and fields to quality structures. Such connection would clarify a bit more the difficult task of representing knowledge about patterns and shapes in computer systems.

2. Quality fields and patterns

DOLCE top-ontology distinguishes between qualities and qualia. Qualities are entities that inhere to other entities and characterize them. For example, the colour of an apple, the mass of my head. Values attributed to qualities are called qualia, which are points in abstract mathematical spaces called Conceptual Spaces (more on that later).

According to Guarino [1], there is a general distinction between *global* and *local qualities*. Global qualities inhere to the whole object, while local qualities inhere to a *part* of the object. For instance, when we say that the Adriatic Sea has a volume, we are referring to a global quality. But given that the sea has many depths, when we say that the Adriatic Sea has a depth, we are referring to a quality inhering in a specific part of the sea (e.g. the deepest part). More importantly, not all qualities of parts of an object are local qualities of the object. For instance, while the many widths of the main body of a vase are local qualities of the vase, the many widths of its handle are not local qualities of the vase itself. Guarino argues that there is probably a "simple cognitive mechanism" that divides the vase in *canonical parts*, "whose width count as local widths of the vase".

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Guarino goes further, proposing the notions of *quality fields* and *quality patterns* as distinguished ontological categories. A quality field is the mereological sum of all local qualities of a given entity. Whereas local qualities inhere in parts of an entity, a quality field inheres in the actual entity. For example, the local qualities of the Adriatic Sea form the depth (quality) field of that sea. Guarino argues that quality fields also help to describe the distinction between *variation* and *change*. Variation would be explained as a process of change in the focus of attention along different parts of a quality field. For instance, there is a variation in the depth of the Adriatic Sea from the east part to the depth at the west part. The variation occurs as attention shifts from one part to the other.

Quality patterns refer to an individual distribution of qualia in a quality field. For instance, the depth quality field of the Adriatic Sea had a specific qualia distribution at the Roman ages, which is different of the distribution present today. Guarino describes quality patterns as constituted by a part of a quality field. The difference between quality fields and patterns is that the precise qualia distribution is essential to a quality pattern, whereas it is not essential to a quality field. [1] does not make it clear whether quality fields inhere in other entities.

3. Holistic and Structure Spaces

In [3,2], we proposed an extension to Conceptual Spaces Theory (CS) called Holistic-Structure Spaces. A conceptual space is a mathematical space in which objects and concepts can be represented according to their similarity. Objects are points in this space, while concepts are (sets of) convex regions. Similar objects are close together in a CS. The dimensions of a CS are called quality dimensions and provide the metric to measure similarity. The typical example of CS is the HSL colour space (also known as colour spindle). Each point in the spindle represent a specific colour shade. Regions of points represent named colours (i.e. the concept of red). Complex concepts (e.g. car) would involve a set of regions in colour space, shape space, weight space and so on. Spaces which have inseparable dimensions (such as colour and shape space) are called quality domains. Therefore, complex concepts can be represented as sets of regions in different quality domains, effectively being embedded in a Cartesian product of these domains. Gardenfors was able to associate different aspects of CSs (e.g. prototypes, similarity, betweeness, convexity) to cognitive phenomena related to how humans deal with concepts.

In its original form, CS does not elaborate much on how one can represent relations between concepts. With our Holistic-Structure Spaces, we proposed an extension to CST that could allow one to represent part whole relations based on similarity. The general idea is that a complex object (e.g. say, a car) is a point in a conceptual space formed by a cartesian product of a subspace W composed by quality domains representing qualities about *the whole* object, a subspace P of quality domains representing qualities *of parts* of the object, and a subspace S of quality domains characterizing how each part compose the whole, which we call structure domains. We call subspace W *holistic* space and $P \times S$, *structure spaces*. We call this conceptual space *holistic-structure space*. A complex concept C is a set of regions in the conceptual space formed by holistic and structure spaces, such that $C \subset W \times P \times S$.

As an example, consider the concept of apple and concepts related to its parts (seed, stem, fruit flesh, fruit skin). In our scheme, each concept is a set of regions in specific

CSs (apple space, seed space, and so on), with their pertinent domains. Consider also that just a subset of each part concept is relevant to apple; i.e. only a subset of stems are apple stems. The concept of apple A is then a subset of a holistic-structure space structured $W_a \times P_a \times S_a$, where W_a is a space formed colour, shape and taste domains representing the holistic (i.e. whole) aspects of the apple; P_a is a space formed by a cartesian products of projections of conceptual spaces of seed, stem, fruit flesh and fruit skin, such that these projections include only apple-specific, local quality domains; and S_a is a space composed by structure domains positioning each part within the whole (e.g. locating the stem on the top of the apple). Each point in $A \subset W_a \times P_a \times S_a$ describes the holistic and structural aspects of a particular apple. We assume that certain whole and parts subspaces are correlated. For example, as an apple get older and its overall colour and shape change, it translates in W_a. In such case, a correspondent translation should also happen in $P_a \times S_a$, reflecting changes in its parts.

4. Quality Patterns as Structure Spaces

Contrary to earlier work on qualities, Guarino [1] does not provide much details on how quality fields and patterns are related to regions in Conceptual Spaces. We believe holistic-structure spaces can provide conceptual grounding and justification to some of Guarino's decisions. Here, we will try to sketch how the relationship can be drawn.

The coordinates of a single point in a holistic-structure space form a pattern of global *and* local properties related to a particular object; i.e. it represents a distribution of qualia related to local and global attributes of that object. Global qualities refer to the holistic projection of that point, while local qualities refer to the structure projection. Guarino recognizes that there is a correlation between values of certain global qualities and the same qualities in the parts. This correlation is encoded in the correlations between quality domains and dimensions that form a particular holistic-structure space.

Based in this simple analysis, we can specify the relationship between the two frameworks. We define that (a) *a quality pattern of an object is a projection of the point that defines such object in a structure space*. The coordinate values of this projection form the quality pattern. This projection captures the relevant dimensions/domains from parts of the object. For instance, consider the depth field of the Adriatic Sea. It maps to a single quality pattern at any instant in time, which represents the pattern of local depth qualities of its parts. We propose that this values that compose this pattern is a projection of the point that represent the Adriatic Sea in a holistic-structure space. More specifically, it is a projection of the structure space. Such projection selects all the depth values in depth domains describing parts of the Sea.

Even though definition (a) is useful, structure spaces include further conceptual mechanisms that allows us to generalize it a bit more. Conceptual spaces can be (re)contextualized. Simply put, by giving more weight to certain dimensions in a conceptual space, it is possible to modify the similarity relationships that define the space. For example, it is possible to contextualize the conceptual space of apple by giving more weight to colour domain, thus making colour a more contrasting feature when distinguishing apples. Based on that, we can rewrite (a) by stating that (b) *a quality pattern of an object is a contextualized version of a point that defines such object in a structure space*. In this case, a quality pattern would be seen as a particular context of a structure

space that selects the same quality domain in many parts composing the structure. If the Adriatic Sea corresponds to a point in a holistic-structure space, then by giving greater weight to the depth domains of its parts (i.e., shifting the context) we are effectively representing a depth quality pattern, i.e. we are isolating the qualia that refers to depths of parts of the sea. This definition generalizes the definition (a) above, as the projection can be carried out by simply creating a context with zero weight in irrelevant dimensions.

We can push structure spaces a bit further. Guarino posits that it is possible to observe *variations* in a quality field as one changes the focus of attention from a part to another. Such process can be seen as a change in the contextualization of its structure space, giving more weight to qualities of parts current in focus. For instance, as one observes the variation of the Adriatic Sea's depth field from east to west, we just varying the weights for local depth quality domains from parts in east to parts in the west.

Finally, as with quality types in DOLCE, it is possible to relate types of quality patterns to *regions* in structure spaces.

5. Conclusion

This is just an ketch of how both theories could come together. In order to become a full theory, more analysis is needed regarding formalization and more specific details of holistic-structure spaces, such as the role of specific types of structure domains.

References

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