Part-whole Relations in Conceptual Spaces

Sandro Rama Fiorini[1,2], Peter Gärdenfors[2], Mara Abel[1]

[1] Federal University of Rio Grande Do Sul | [2] Lund University

Introduction

Part-whole relations are essential components of concept representation. Their meaning is grounded in **cognition**, and how humans deal with parts and wholes.

We propose a representation scheme for part-whole relations that takes into account two important characteristics of human cognition: **similarity** and **prototypes**.

Mereology, prototypes and similarity

We focus on how the notion of prototypes is reflected in parts and wholes of objects and object categories. Prototypes are not much considered in the literature of mereology. However, it seems natural to think about a prototypical *pen* with its typical part configuration. The degree of typicality of other pens can be measured by their similarity to the prototype.

Mereological similarity between wholes takes into account which parts are similar and how parts are structured. While some experiments have indicated prototype effects in part-whole relations,[1] the specific role of prototype effects in such relations is yet to be investigated. There is direct and indirect evidence that mereological similarity plays a role in object recognition and concept learning[2,3].

[1] Chaffin, R., Herrmann, D.J. & Winston, M., 1988. *An empirical taxonomy of part-whole relations.* DOI: 10.1080/01690968808402080

[2] Mash, C., 2006. *Multidimensional shape similarity in the development of visual object classification.* DOI: 10.1016/j.jecp.2006.04.002

[3] Wu, R., Mareschal, D. & Rakison, D.H., 2010. *Attention to Multiple Cues During Spontaneous Object Labeling.* DOI: 10.1111/j.1532-7078.2010.00061.x

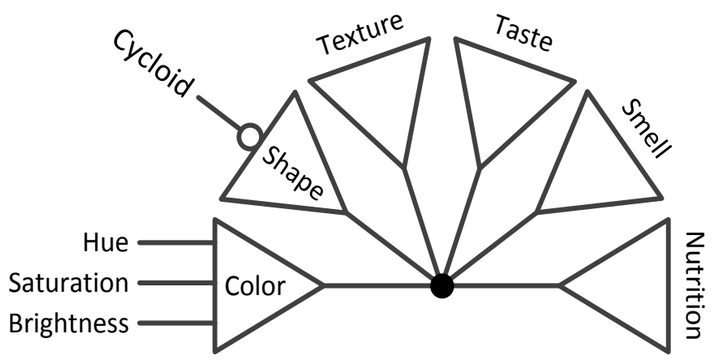
Conceptual Spaces

The proposed framework is founded on conceptual spaces (CS), a geometrical approach to represent concepts.

Concepts are represented as a **convex regions** in a space formed by **quality dimensions** representing qualities. Points represent individuals. For instance, the concepts of *red* and yellow are convex regions in the colour space formed by the quality *dimensions hue*, *saturation* and *brightness*. Points within the concept yellow denote particular shades of yellow.

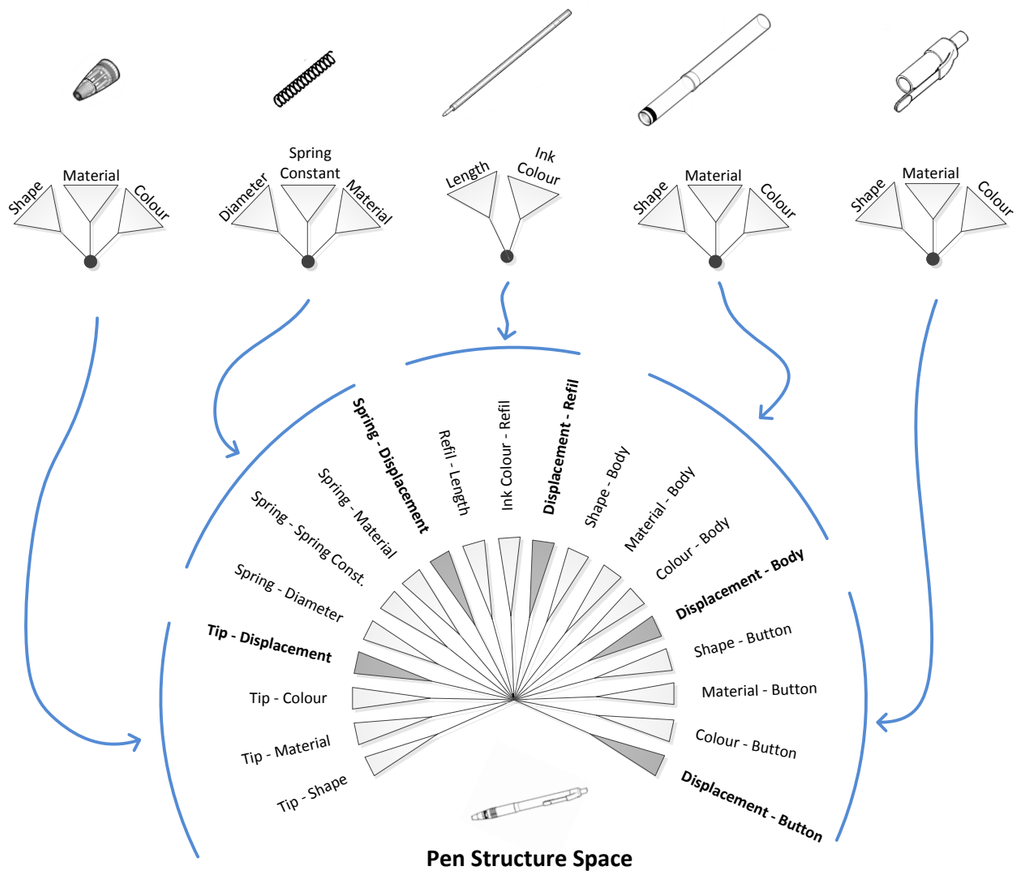
It is possible to measure similarity between individuals in a CS. If one assumes that concepts are represented by one (or more) prototypical individuals, it is possible to infer inclusion by measuring the distance of each particular instance to the concept prototypes.

Non-dissociable dimensions form **quality domains** ( ). Complex concepts span regions in many domains. Below, a schematic example of the multi-dimensional space for the concept *apple* is presented.



Structure Space

Part-whole relations can be represented in CS through the notion of **structure space.** It is a high-dimensional space which supports mereological comparisons (of similarity) between wholes. The structure space of a whole is composed by the sum of the quality domains of all its parts, added of **structure domains** ( ) for each part.



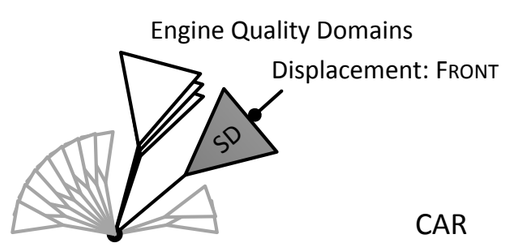
Pen Structure Space

Points in the structure space denote specific **part configurations** for wholes. Typical part arrangements can be seen as prototypes in the structure space. From them it is possible to define concept regions, which complement the definition of wholes with different **categories of part configuration**.

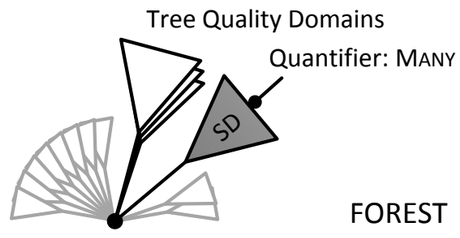
Part-whole relation types

The notion of structure space can explain the diverse ways in which parts can form wholes.[4] Different structure domains reflect the distinct roles that parts play within the whole.

COMPLEX: Parts play a specific role within the whole. In this case, the structure domain contains configuration information, such as relative displacement, e.g. "*a car has an engine at the front*".



COLLECTIVE: Parts do not have a specific role. The structure domain represents how instances of the same kind are aggregated, such as general or specific quantifiers; e.g. "*a forest has many trees*".



[4] Gerstl, P. & Pribbenow, S., 1995. *Midwinters, end games, and body parts.* DOI: 10.1006/ijhc.1995.1079

Contact: srfiorini@inf.ufrgs.br