SHAPES 2.0: THE SHAPE OF THINGS

THE BOOK OF ABSTRACTS

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Invited Keynotes

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Blueprint for knot logics

Logic is to natural language what knot theory is to natural knots. Logic explains some cognitive performances; in particular, some natural language inferences are captured by various types of calculi (propositional, predicate, modal, deontic, free, quantum.), which in turn may generate inferences that are arguably beyond natural logic abilities, or non-well synchronized therewith (eg. ex falso quodlibet, material implication). Mathematical knot theory accounts for some abilities - such as recognizing sameness or differences of some knots, and in turn generates a formalism for distinctions that common sense is blind to. Logic has proven useful in linguistics and in accounting for some aspects of reasoning, but which knotting performaces are there, over and beyond some intuitive discriminating abilities, that may require extensions or restrictions of the normative calculus of knots? Are they amenable to mathematical treatment? And what role is played in the game by mental representations? I shall draw from a corpus of techniques and practices to show to what extent compositionality, lexical and normative elements are present in natural knots, thus allowing us to formally explore an area of human competence that interfaces thought, perception and action in a complex fabric.

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Prolegomena to an Ontology of Shape

Influenced by the four-category ontology of Aristotle, many modern ontologies treat shapes as accidental particulars which (a) are specifically dependent on the substantial particulars which act as their bearers, and (b) instantiate accidental universals which are exemplified by those bearers. It is also common to distinguish between, on the one hand, these physical shapes which form part of the empirical world and, on the other, ideal geometrical shapes which belong to the abstract realm of mathematics. Shapes of the former kind are often said to approximate, but never to exactly instantiate, shapes of the latter kind. Following a suggestion of Frege, ideal mathematical shapes can be given precise definitions as equivalence classes under the relation of geometrical similarity. One might, analogously, attempt to define physical shape universals as equivalence classes under a relation of physical similarity, but this fails because physical similarity is not an equivalence relation. In this talk I will examine the implications of this for the ontology of shape and in particular for the relationship between mathematical shapes and the shapes we attribute to physical objects.

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Graph-based pattern recognition and applications

Structural pattern recognition plays a central role in many applications. Recent advances include new theoretical results, methods and successful applications. In the present talk, some recent graph-based methods for shape analysis will be shown. The presented methods include a new representation for graph-matching-based interactive segmentation and models for the analysis of spatial relations between objects. Applications will be presented and discussed.

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Shape, Composition and Juxtaposition in The Painting Fool

The Painting Fool is software that we hope will one day be taken seriously as a creative artist in its own right. To that end, we are giving it abilities to exhibit behaviours which might be called skilful, appreciative and imaginative, as described at www.thepaintingfool.com. At its heart, The Painting Fool is a graphics program which gathers, manipulates and renders shapes for artistic effect. In the talk, I will give details of how the software can invent its own painting styles by invention of schema for segmenting images (from photographs and 3D models, and generated synthetically, for instance by context free design grammars) into shape regions, abstracting the shape outlines, assigning colours from palettes, choosing simulations of natural media such as pencils, paints and pastels, and finally simulating the usage of the media to render the final artworks. As discussed in the talk, this is part of a bigger picture of how The Painting Fool collates and composes source material for collages based on texts, which itself is part of the bigger context of the potential for Computational Creativity research to lead to fully autonomous, creative agents.

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Lines, Shapes, and Meaning

Lines are the paths we walk in the world, the inscriptions we put on a page, the gestures we draw in the air, the contours the eye discerns. Lines form patterns and make shapes. Lines are the paths we take in life, the connections we make in the mind, the social relations we form. Lines, like the shapes and patterns they form, make meaning.

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Sketch Learning by Analogy

Sketches are shapes that represent objects, scenes, or ideas by depicting relevant parts and their spatial arrangements. While humans are quite efficient in understanding and using sketch drawings, those are largely inaccessible to computers. We argue that this is due to a specific shape based representation by humans and hence the use of cognitively inspired representation and reasoning techniques could lead to more proficient sketch processing. We also propose a three-level system for sketch learning and recognition that builds on concepts from cognitive science, especially from analogy research, to map and generalize sketches.

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The Shape of Empty Space

We propose a human-centred model for abstraction, modelling and computing in function-driven spatial design for architecture. The primitive entities of our design conception ontology and computing framework are driven by classic notions of 'structure, function, and affordance' in design, and are directly based on the fundamental human perceptual and analytical modalities of visual and locomotive exploration of space. With an emphasis on design semantics, our model for spatial design marks a fundamental shift from contemporary modelling and computational foundations underlying engineering-centred computer aided design systems. We demonstrate the application of our model within a system for human-centred computational design analysis and simulation. We also illustrate the manner in which our design modelling and computing framework seamlessly builds on contemporary industry data modelling standards within the architecture and construction informatics communities.

Keywords: spatial cognition; spatial representation and reasoning; knowledge engineering for design; (analytical) design computing and cognition; computer-aided architecture design

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A new Molyneux's problem: Sounds, shapes and arbitrary crossmodal correspondences

Several studies in cognitive sciences have highlighted the existence of privileged and universal psychological associations between shape attributes, such as angularity, and auditory dimensions, such as pitch. These results add a new puzzle to the list of arbitrary-looking crossmodal matching tendencies whose origin is hard to explain. The puzzle is all the more general in the case of shape that the shapes-sounds correspondences have a wide set of documented effects on perception and behaviour: Sounds can for instance influence the way a certain shape is perceived (Sweeny et al., 2012). In this talk, we suggest that the study of these crossmodal correspondences can be related to the classical cases of crossmodal transfer of shape between vision and touch documented as part of Molyneux's question. In addition, these studies reveal the role that movement plays as an amodal invariant in explaining the variety of multimodal associations around shape.

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Structure, Similarity and Spaces

Much of the discussion about shape representation during the last two decades is fundamentally related to questions about the representation of parts. Inspired by the cognitive processes governing how people represent and think about parts, we provide a brief summary of our framework for representing part structures. It extends the Theory of Conceptual Spaces, where concepts are represented by regions in a mathematical space. We propose a special kind of conceptual space that can represent the part structure of a concept. The structure space of a whole is formed by the product of its parts. In this space, structural similarity judgements between concepts and between objects is reduced to distance measurements; i.e. objects that share a similar part structure are more close together in the space. We are still developing a more formal theory around these notions and we expect to be able to apply it in some real-world problems, particularly in object recognition.

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Local Qualities, Quality Fields, and Quality Patterns

When we describe the shape of certain entities, like a vase or a river, we refer to their qualities in different ways. A river has (more or less) a definite length, but its width varies with the distance from the source, typically getting higher towards the end. Similarly, a vase has a definite height, but its width may vary, reflecting a certain pattern that often marks a particular style. So, at least for certain entities, quality kinds such as length, height and width don't behave in the same way: length or height just inhere to these objects with no need of further qualification, while width requires a spatial localisation in order to be determined. We shall say that length and height, in these examples, are global qualities, while width is a local quality. Note that a local quality of a certain object does actually inhere to a part of that object, but, despite this fact, we tend to consider it, from the cognitive point of view, as a quality of the whole object: so, we rarely say "the width of this river stretch is 100 meters", but we prefer to say "the river's width is 100 meters here". Analogously, we say "the depth of the Adriatic Sea is much higher along the Croatian coast than along the Italian coast", referring to "the river's width" or "the sea's depth" as one single entity, although, so to speak, spread out in space. In many simple cases, this the way we describe the shape of a certain object in terms of the behaviour of a local quality along a spatial dimension. In this paper I would like to explore the way qualities of things behave with respect to the parts of such things. Building on the notion of individual quality introduced in the DOLCE ontology, I will introduce the new notions of local quality, quality field and quality pattern, stressing their cognitive role in many practical situations. I will first discuss Johansson's distinction between inclusive and exclusive properties, which I will take as a basis for my distinction between global and local individual qualities. Basically, the idea is that, given a certain individual quality q of kind Q with a value v inhering to a thing x, q is a global individual quality of x iff, necessarily, there exists a proper part y of x such that Q of y has a value w different from v. q will be a local individual quality of x otherwise. I will then introduce the notion of a quality field as the mereological sum of all local qualities of a certain kind inhering to some thing (endurant or perdurant). I will argue that an expression like "the river's width" or "the depth of the sea" actually refers to a quality field, and not to an individual quality. Quality fields will be used to introduce the further notion of quality pattern, and to analyse the distinction between variation and change. Consider for instance the Adriatic Sea, whose depth changed in the last 2000 years. At the Roman age, this field exhibited local variations corresponding a certain pattern, which is different from the pattern we observe today. The whole quality field did genuinely change in time, keeping its identity, while some of its individual qualities changed their value. So a quality pattern is different from a quality field, since its actual value distribution is essential to it, and not essential for the quality field.

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Shape Perception in Chemistry

Organic chemists make extensive use of a diagrammatic language for designing, exchanging and analysing the features of chemicals. In this language, chemicals are represented on a flat (2D) plane following standard stylistic conventions. In the search for novel drugs and therapeutic agents, vast quantities of chemical data are generated and subjected to virtual screening procedures that harness algorithmic features and complex statistical models. However, in silico approaches do not yet compare to the abilities of experienced chemists in detecting more subtle features relevant for evaluating how likely a molecule is to be suitable to a given purpose. Our hypothesis is that one reason for this discrepancy is that human perceptual capabilities, particularly that of 'gestalt' shape perception, make additional information available to our reasoning processes that are not available to in silico processes. This contribution investigates this hypothesis.
Algorithmic and logic-based approaches to representation and automated reasoning with chemical structures are able to efficiently compute certain features, such as detecting presence of specific functional groups. To investigate the specific differences between human and machine capabilities, we focus here on those tasks and chemicals for which humans reliably outperform computers: the detection of the overall shape and parts with specific diagrammatic features, in molecules that are large and composed of relatively homogeneous part types with many cycles. We conduct a study in which we vary the diagrammatic representation from the canonical diagrammatic standard of the chemicals, and evaluate speed of human determination of chemical class. We find that human performance varies with the quality of the pictorial representation, rather than the size of the molecule. This can be contrasted with the fact that machine performance varies with the size of the molecule, and is absolutely impervious to the quality of diagrammatic representation.
This result has implications for the design of hybrid algorithms that take features of the overall diagrammatic aspects of the molecule as input into the feature detection and automated reasoning over chemical structure. It also has the potential to inform the design of interactive systems at the interface between human experts and machines.

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Shapes as property restrictions and property-based similarity

Varied approaches to the categorization of shapes and forms, as well as their mutual similarity and connectedness, are of great importance for the development of many scientific fields. In different contexts, domain knowledge can be represented semantically using ontologies expressed in OWL, where domain concepts are organized hierarchically and have their features defined as properties. Properties are used in OWL for defining classes with property restrictions, using *value constraints* and *cardinality constraints*.

In the domain of shape, form and structure representation, there were some attempts at modeling shapes ontologically, as an exhaustive class hierarchy. But instead of forcing this somehow artificial categorization upon the shape world, we would do the shapes more justice by defining them as property restrictions on classes. We can start by defining many different properties which would help us precisely describe the shapes we need. In this way, there is no need to a-priory decide which categorization should happen higher up in the hierarchy, they can peacefully co-exist together. The process is versatile and applicable in many different contexts. It also enables very natural comparison of shapes and establishes their similarity based on properties.

If we define shapes as property restrictions (on values and cardinality), we can find similar shapes by comparing their properties, starting from Tversky's feature-based model of similarity. Given two shapes S_1 and S_2, for each property p, we calculate how much the property p contributes to common features of S_1 and S_2, distinctive features of S_1 and distinctive features of S_2, respectively. How these values are calculated depends on how the property p is defined in each of S_1 and S_2. The property-based similarity of equivalent classes is equal to 1. For instances we simply compare the values-property pairs declared for each instance. The subclass relation is taken into account, providing each class with the property definitions inherited from parent classes.

Apart from modeling shapes as property restrictions on classes, this approach would bring new insights into modeling forms and patterns as well, as it avoids strict categorizations, providing a flexible environment for expressing various features of complex forms.

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The Shape of Absolute Coincidences. Salmon's Interactive Fork Model as shape of coincidental processes

According to a particular view, chance events are not uncaused but they are simply the result of intersecting causal lines. More precisely, the intersections between different processes that belong to independent causal chains are the origin of accidental events, called *absolute coincidences*.
In the talk I will provide a new account devoted to showing the strong relation between absolute coincidences and Salmon's interactive fork criterion, in an attempt to endorse the idea that coincidences can be shaped in terms of a causal model.

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Representing numbers and figures in problem-solving activities in mathematics

In our presentation we rely on research by Grosholz (2007) and consider her thesis of the irreducibility of shape in the sense of iconic representation in mathematics. Against this background, we aim to discuss the epistemic value of iconicity both in the representation of numbers in arithmetic and figures in the case of geometry.
We bring in two case-studies selected from Leibniz's work with notations and diagrams in problem-solving contexts of work. In our first case-study that concerns the representation of number systems Leibniz argues for the view that the iconic aspects present in binary notation reveal structural relations of natural numbers that remain concealed in other numerical modes of representation such as the system of Arabic numerals. In our second case-study, we show how Leibniz designs a method which allows him to re-conceive a given shape – triangles – by transmuting it into another kind of shape – rectangles – as part of his strategy to solve the thus far unsolved problem of the squaring of the circle.
In the case of arithmetic, we focus on the idea that representations "articulate likeness by visual or spatial means". Grosholz suggests that even highly abstract symbolic reasoning goes hand in hand with certain forms of visualizations. To many this may sound polemical at best. Granted to the critic that "shape is irreducible" in geometry as it is the case with geometrical figures, but what is the role of iconicity in the representation of numbers, and more generally, what is involved in visualizing in arithmetic?
In visualizing we need to understand articulated information which is embedded in a representation, such articulation is a specific kind of spatial organization that lends unicity to a representation turning it intelligible. In other words, spatial organization is not just a matter of physical display on the surface (paper or table) but "intelligible spatiality" which may require substantial background knowledge so that the ability to read off what is referred to in a representation will depend on relevant training and expertise of the reader. Such cognitive act is successful only if the user is able to decode the encrypted information of a representation while establishing a meaningful relationship between the representation and the relevant background knowledge which often remains implicit.

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Shaping up: The Phenotypic Quality Ontology and Cross Sections

The Phenotypic Quality Ontology (PATO) uses the notion of a cross section to relate two- and three-dimensional shapes and to describe the shape of biological entities. What is a cross-section? What is a truthful ontological description of cross sections? In this communication I (1) explore possible answers to these questions, approaching the task from philosophical and ontological perspectives, and (2) provide a preliminary examination of the PATO shape hierarchy. I discuss some observations, suggestions and potential structural revisions for the shape portion of PATO.

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Dynamic Assembly of Figures in Visuospatial Reasoning

An exploratory, qualitative experiment sheds light on the depictive theory of mental imagery. The study analyzes the very operations subjects undertake when solving visuospatial tasks. Preliminary results indicate that subjects do not make use of stable mental images: instead, they continuously assemble and re-assemble different perspectives through the guidance of heuristics and prototypes. These observations allow a reinterpretation of mental imagery. We want to forward the hypotheses that a) the assembly process itself is of much higher importance than usually acknowledged; b) that an assembled perspective (or figure) is defined by one's orientation towards certain operations; and c), that heuristics and prototypes are instantiated by a heterarchical organization of mental operations.

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Declarative Computing with Shapes, and their Shadows

We present a preliminary concept and a prototypical implementation of a declarative computing framework that is capable of reasoning about 3D physical entities, and the shadows that they cast in open or uniformly lit environments. For this paper, we restrict our scope of 'uniform lighting' to sunlight, and its incidence on a given geospatially and temporally referenced location.
The model extends traditional techniques from computational geometry and computer graphics that are primarily motivated by simulation or visualisation. In particular, our declarative framework is capable of deriving and reasoning about the objects and their cast shadows in a knowledge processing sense, e.g., involving qualitative abstraction and semantic specification of requirements, query capability, ensuring conceptual consistency of design requirements. Our ontology of objects and shadows, and the resulting computational framework serves as a foundational engine for high-level conceptual (spatial) design assistance technology.
The capabilities demonstrated in this paper are aimed at applications in spatial design, chiefly encompassing Computer-Aided Architecture Design (CAAD), Urban Planning, and Interior Design

Keywords: declarative languages, knowledge representation and reasoning, geometric and spatial representation and reasoning, computational geometry, shadows, CAAD, design.

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Mental "structures" in the Berlin school of Gestalt Psychology: can sensation be described as "structural"?

It is not exaggerated to affirm that the modern notion of structure arises in Koffka's Growth of the Mind and in his following article, "Perception : An introduction to the Gestalt-theorie" (1922). The importance of the notion of structure as Koffka uses it lies in the fact that it is designed to replace the old empiricist notion of "sensation" as a real and separable element of the phenomenal field, corresponding to a definite stimulus. But, yielding to many suggestions by Köhler, Koffka does not only understand the interdependency of sensations in a structure as a causal one: in fact, he decidedly understands it as a logical one. Thus he defines structures as "very elementary reactions, which phenomenally are not composed of constituent elements, their members being what they are by virtue of their 'member-character,' their place in the whole; their essential nature being derived from the whole whose members they are" ("Perception", p. 543).

I mean to show that the parts in such structures can only be what it is classical to name "relational attributes" or "relational predicates". In other words, structures are now internal relations between their terms, and more precisely still "directly constitutive internal relations", not internal relations reducing to the existence of their terms as were the internal relations against which Russell struggled, but relations to which their terms reduce (I shall develop this point further on in my talk). But the real importance of this notion of structure is that it rests and is built upon a truly impressive amount of empirical data. Nevertheless, I want to show that Koffka's conception of sensation is fundamentally impossible to conceive, and that the belief that it is empirically grounded rests mainly on a confusion between abstraction of a sense-datum and real separation of the stimuli underlying such a datum. As a consequence, phenomenal structures, if they exist, can only be external to their terms, as they are in Köhler's view, in spite of many ambiguities in his formulations. However, I will end by showing that, correctly understood, the notion of structure can still be of great help in phenomenology and psychology since it provides a naturalistic means to understand how a non-intentional "meaning" can be passively present at a sensory level.

Keywords: Structure; Internal relations; Sensation; Gestalt psychology; Phenomenology

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Statistical Invariants of Spatial Form: From Local AND to Numerosity

Theories of the processing and representation of spatial form have to take into account recent results on the importance of holistic properties. Numerous experiments showed the importance of "set properties", "ensemble representations" and "summary statistics", ranging from the "gist of a scene" to something like "numerosity". These results are sometimes difficult to interpret, since we do not exactly know how and on which level they can be computed by the neural machinery of the cortex. According to the standard model of a local-to-global neural hierarchy with a gradual increase of scale and complexity, the ensemble properties have to be regarded as high-level features. But empirical results indicate that many of them are primary perceptual properties and may thus be attributed to earlier processing stages. Here we investigate the prerequisites and the neurobiological plausibility for the computation of ensemble properties. We show that the cortex can easily compute common statistical functions, like a probability distribution function or an autocorrelation function, and that it can also compute abstract invariants, like the number of items in a set. These computations can be performed on fairly early levels and require only two well-accepted properties of cortical neurons, linear summation of afferent inputs and variants of nonlinear cortical gain control.

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Shapes 2.0 – Organisation

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