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Twelve years of diagrams research ☆

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ABSTRACT

Research into the use of diagrams is an interdisciplinary endeavour, encompassing disciplines as diverse as psychology, architecture and artificial intelligence. It is also a relatively new research area, with the first meeting of like-minded researchers interested in studying diagrams taking place in 1997. Now that diagrams research is more established, it is timely to review its scope, nature and progress. This paper reviews diagrams research over the past twelve years, as represented in the proceedings of the *International Conference on the Theory and Application of Diagrams*. In summarising the contents of these proceedings, a taxonomy describing the scope of diagrams research is proposed, the several research issues covered are identified, and the extent to which layout and aesthetics form part of this body of research is discussed. In concluding, trends and under-represented areas are noted and discussed. The aim of the paper is not only to summarise the research covered in this particular conference, but to provide a basis for on-going discussion on the changing nature of diagrams research.

1. Introduction

Diagrams are ubiquitous, and, as a means of communicating information, can be found in all areas of research and practise. Leveraging off the power of the visual processing system (our primary means of perception), they provide a flexible means for representing information in an engaging and direct manner. Diagrams are, however, useless if not effectively communicated and understood – and fully understanding this comprehension process requires knowledge from a wide range of disciplines, including psychology, social science, applied linguistics, education, and communicative technologies. Bringing these areas together in an interdisciplinary forum enables diagrams themselves to be the focus of research endeavour.

The specific area of diagrams research may be said to have been launched by the publication of Larkin and Simon's [1] seminal 1987 *Cognitive Science* paper "Why a Diagram is (Sometimes) Worth Ten Thousand Words". This paper references no prior work specifically relating to diagrams research, although, as befitting a cognitive science article, it refers to several papers on cognitive models and 'mental imagery'.

Prior to 1997, there was no specific forum for the interdisciplinary study of diagrams. The first *Thinking with Diagrams* workshop was held in Portsmouth in January 1997, with its discussion papers collated as a Medical Research Council Cognition and Brain Science Unit publication. An extract from the introduction to this document reads [2]:

> *There is increasing understanding of the benefits of diagrammatic representations for reducing cognitive load, enabling different styles of problem solving and exploiting perceptual judgement skills. It is important that this evidence be applied to both technology and general education, but there is surprising ignorance about the function of diagrams. New graphical representations and educational approaches are still being devised on a purely intuitive basis, and this brings some urgency to the need for a broader theoretical base and wider dissemination of specialist research on thinking with diagrams.*

The second *Thinking with Diagrams* workshop in Aberystwyth in 1998 was entitled "Is there a science of diagrams?"

☆ This paper has been recommended for acceptance by S.-K. Chang.
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and aimed to "directly address the lack of cohesion in the discussion as to the nature of diagrams". The proceedings of this workshop was published by Springer Verlag as *Diagrammatic Representation and Reasoning* [3]. It posed the question [4]:

> ...*are* [*we*] *in a position to claim that we have a science of diagrams? That is: a science which takes the nature of diagrams and their use as the central phenomena of interest; a science which is attempting to understand how diagrams differ from other representational systems and trying to develop principles for the design of effective graphical representations; a science which considers how diagrams communicate information and how they are used to solve problems.*

In the introduction to a special issue of *Artificial Intelligence Review* on "Thinking with Diagrams" (Volume 15, Issue 1–2, March 2001), Blackwell [5] provides an explanation for the upsurge in interest in diagrams research:

> ...*diagrammatic representations are becoming more common in everyday human experience. Bit-mapped computer displays have encouraged the use of diagrams in human-computer interaction. Improved publication technologies, especially the PostScript language, have provided the means for standardised reproduction of diagrams. Modern thought has already been greatly influenced by the ability to publish conventional pictorial illustrations in books and it seems that the widespread facility to create and interact with diagrams will encourage new styles of literacy in a similar fashion.*

And so the Diagrams Conference Series was born. The first *International Conference on the Theory and Application of Diagrams* was held in Edinburgh in September 2000, and was described as "the joint successor of a number of workshop series: Thinking with Diagrams, Theory of Visual Languages, Reasoning with Diagrammatic Representations, and Formalizing Reasoning with Visual and Diagrammatic Representations". It was motivated thus [6]:

> *Driven by the pervasiveness of diagrams in human communication and by the increasing availability of graphical environments in computerised work, the study of diagrammatic notations is emerging as a research field in its own right. This development has simultaneously taken place in several scientific disciplines, including, amongst others: cognitive science, artificial intelligence and computer science... It is intended to become the premier international conference series in this field and will attract participants from applied linguistics, architecture, artificial intelligence, cognitive science, computer science, education, graphic design, history of science, human-computer interaction, philosophical logic, psychology and others.*

The Diagrams conference has been held every two years since then: in 2002 (Callaway Gardens, USA), 2004 (Cambridge, UK), 2006 (Stanford, USA), 2008 (Herrsching, Germany), 2010 (Portland, USA), and 2012 (Canterbury, UK), with all the proceedings published by Springer Verlag in their Lecture Notes in Artificial Intelligence series. It emphasises its interdisciplinary nature by describing itself as "the only conference that provides a united forum for all areas that are concerned with the study of diagrams" [7].

After seven Diagrams conferences and twelve years, it is timely to review the nature of diagrams research over this period. While the publication of articles on diagrams research is obviously not confined to the Diagrams Conference Series (DCS), it is clear that, as the premier forum for this area, this is the most important place to look. This paper reviews the proceedings of all seven conferences in the DCS – effectively a 'vertical census' of diagrams research. Its aim is to review the nature of diagrams covered, and the range of research activities and trends. In addition, it considers the extent to which aesthetics and layout are features of this research.

1.1. Research questions and methodology

The aim of this paper is to address the following questions:

(a) **What is the scope of 'diagrams research'?**
What are the types of diagrams considered, and how can we define and distinguish them?

(b) **What is the nature of diagrams research, and what are the trends?**
What is the range of research questions and issues addressed by diagrams research, and have research priorities changed over time?

(c) **To what extent do 'layout and aesthetics' feature in diagrams research?**
What do 'layout' and 'aesthetics' mean in the context of diagrams research, and how are they addressed?

All the papers and posters in the DCS proceedings (Table 1) were reviewed, summarised and classified. Short abstracts of keynote talks, tutorials or workshops were not included, as they give insufficient detail for classification.

Answering question (a) entailed classification of the types of diagrams used in the 312 papers and posters, based on the range and variety of all the diagrams included in these papers.

Answering question (b) entailed classification of each of the 177 papers by the research aim it addresses; sometimes this aim is obvious by the conference theme under which it is listed (where available), although this is not

Table 1
Papers and posters published in the Diagrams conference proceedings.

	papers	posters	
2000	31	9	40
2002	29	8	37
2004	21	37	58
2006	27	9	36
2008	25	28	53
2010	22	23	45
2012	22	21	43
total	**177**	**135**	**312**

always the case. Trend information was derived from this classification.[1]

Answering question (c) entailed defining what is meant by 'layout' and 'aesthetics', and how they are distinguished within the classification of diagrams produced as a result of addressing question (a). The 312 papers and posters were then analysed to see how (and if) layout and aesthetics are considered.

1.2. Structure of this paper

This paper is structured as follows. Section 2 describes the scope of diagrams research, and, in doing so, proposes a taxonomy of diagram types and associated definitions. Section 3 reports on the range of research issues addressed by the papers in the DCS, and how they can be classified. It also discusses trends in the most common research areas. Section 4 considers the topic of this special issue: aesthetics and layout, providing definitions to distinguish between them, and describing the extent to which they are the focus of the research aim of the papers in the DCS. Section 5 discusses the results, and concludes with some pointers as to where diagrams research might be heading in the future.

2. The scope of 'diagrams research'

2.1. Definitions

The Oxford Dictionary [8] definition of a diagram is "A simplified drawing showing the appearance, structure, or workings of something". This definition is somewhat circular in referring to the concept of a 'drawing'. The definition of 'diagram' proposed here is necessarily more detailed, as it allows us to refer to the individual components that make up a diagram, and the manner in which they are arranged.

For the purposes of this paper, a *diagram* is taken to mean a composite set of marks (*visual elements*) on a two-dimensional plane that, when taken together, represent a concept or object in the mind of the viewer. Example visual elements include lines, geometric shapes, "blobs, crosses and arrows" [9] – any visual mark that cannot be decomposed. A word (or a phrase that is not intended to be separated into its individual words) is also considered a visual element.

The Oxford definition refers to the fact that the purpose of diagrams is to depict "appearance, structure, or workings of something." Diagrams are usually employed to support a viewers' task – such tasks may include learning, designing, communicating, or simply understanding the concept depicted. This task dimension is not considered here within the classification of diagrammatic forms; rather, it is referred to where necessary.

2.2. Classification

Within the DCS papers, some broad classifications have been proposed and discussed. Novick [10], drawing on the work of Hegarty, Carpenter and Just (1991) describes three classes of scientific diagrams as "iconic", "charts and graphs" and "schematic diagrams".[2] Garcia and Cox [11], in their analysis of the diagrams used in the UK national curriculum, produced a list of 20 different types of diagram, including "illustration chart", "conceptual diagram" and "network diagram". Elsewhere, Blackwell and Engelhardt [12] surveyed a variety of diagram taxonomies presented in a range of domains, identifying the distinguishing characteristics between them as being the manner in which they make their distinction: with respect to their signs ('visual elements' as defined above), structure ('layout' as defined below), meaning (the semantics) and context of use.

Based on the analysis of all the articles published in the DCS, the classification presented here separates diagrams broadly into two categories: *abstract* and *concrete*. The definition of these categories can usefully borrow from the field of semiotics (as referred to by [13–15]) which distinguishes between *symbols* (where there is an abstract relationship between diagram and concept), and *icons* (there is direct perceptual relationship between diagram and object). Thus, a depiction of a family tree is a symbolic abstract diagram; a map is an iconic concrete diagram.

A *diagram* is that which is perceived; a *diagram notation* comprises the rules which ensure that what is perceived is meaningful. A viewer who knows the rules of a notation will be able to understand a diagram which uses that notation, provided that it is well-formed (i.e. it conforms to notation's rules).

The rules for interpreting concrete diagrams are typically simple: because of the direct perceptual relationship between the diagrammatic form and the object it depicts, understanding which object is being represented can be trivial. This depends on how well the object has been depicted, of course; a concrete diagram needs to include sufficient correct visual elements for the viewer to be able to interpret it: a badly-drawn diagram of a rabbit might be interpreted as a hare; a poorly painted portrait of a woman might look more like her sister. Interpretation can also depend on the context within which the concrete diagram is perceived: a diagram of a clock face will be interpreted as a clock if shown on a wall, as a watch if shown on a wrist. So rules for creating and interpreting concrete diagrams do exist, even if they are not formalised.[3]

Abstract diagrams on the other hand, always need a clear set of rules that need to be known by the viewer for correct interpretation. Terminology from linguistics is useful here: the *syntax* of a notation is the set of rules which determine how the visual elements should be arranged in relation to each other; the *semantics* of the notation is the set of rules that determines the concept represented when elements are correctly arranged according to the syntax.

[1] Posters were not considered in this categorisation, as, because they tend to be work-in-progress or present only preliminary or speculative results, it is typically more difficult to identify a clear research aim.

[2] In the classification given later in this section, these diagrammatic forms are, respectively, *concrete*, *abstract charts*, and *abstract graphs and sets*.

[3] These rules also need to be learned, but that is another story.

It is important to note that the flexibility of human perception and cognition means that even if a diagram does not exactly conform to its defining rules, it may still be understood by the viewer. However, a diagram creator cannot ever predict whether this will be the case or not, and so it is wise to conform to notation rules so as to encourage correct interpretation.

2.2.1. Concrete diagrams

These are iconic diagrams that have a perceptual relationship to the objects that they represent. Note that these concrete diagrams necessarily entail some sort of abstraction, as they cannot exactly portray every aspect of the object; often they depict only those features of the object that are of relevance to a task.

Concrete diagrams can be classified into three broad categories:

- *Schematics* used to depict objects in a similar form to their physical attributes; examples include pulleys [16], cisterns [17], the heart and blood circulation [18] and kangaroos [19]. (For example, Fig. 1, from [16]). Sub-types of the schematic form are maps [20–22] and architectural diagrams [23,24] whereby the physical attributes represented are bound by geographical position.
- Arrangements of *geometric shapes* used to depict physical positional relationships between objects; examples include blocks world representations [25], seating arrangements [26] and non-convex shapes [27].
- *Digital images* which use a pixel matrix to depict objects; examples include the representation of numbers [28] and images [29]. (For example, Fig. 2, from [28]).

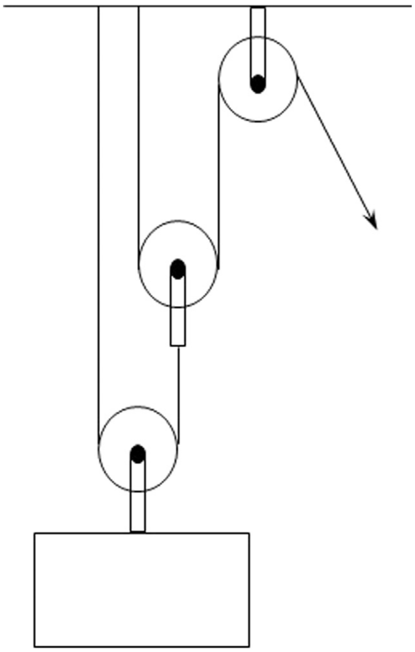

Fig. 1. Example schematic: a pulley (from [16], reproduced with permission).

2.2.2. Abstract diagrams

These are symbolic notations which produce diagrams that have no perceptual relationship to the concepts that they represent.

Notations for abstract diagrams can be classified into three broad categories:

- Networks to depict relationships between objects (*graphs*), using geometric shapes to represent objects, and lines to depict how objects are related to each other. The relationships between the objects may be directed or undirected relationships [30–32]. Sub-types of graphs are defined by the structure of the relationships; examples include trees [33,34], and directed acyclic graphs [35,36]. (For example, Fig. 3, from [33]).
- Overlapping geometric shapes to depict set membership *(set diagrams*), where the type of set diagram is

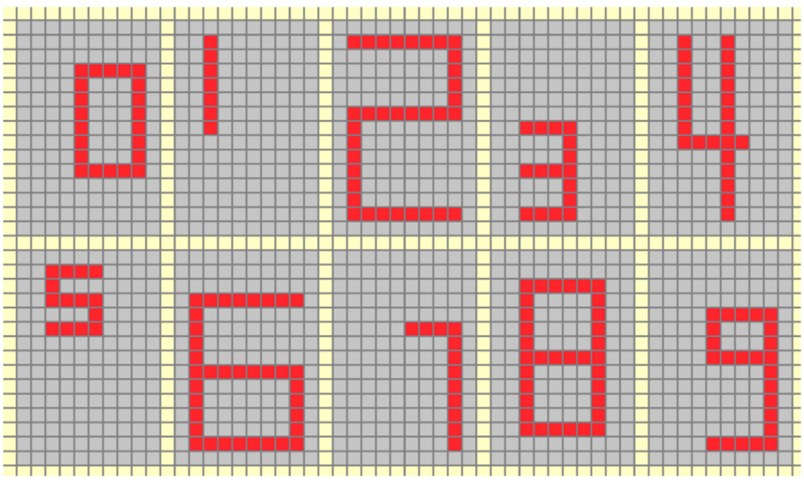

Fig. 2. Example use of pixel matrices: numbers (from [28], reproduced with permission).

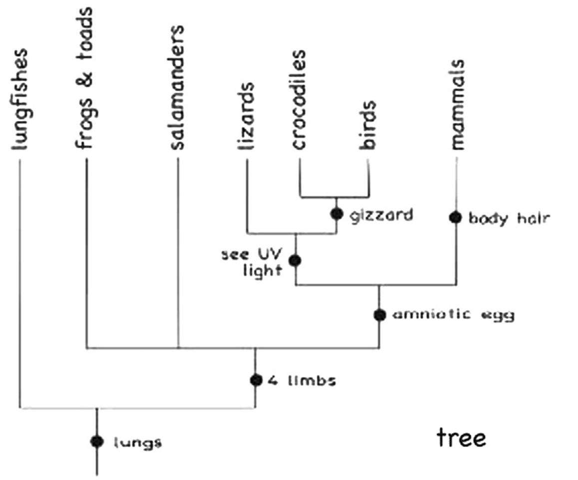

Fig. 3. Example network sub-type: a tree representation (from [33], reproduced with permission).

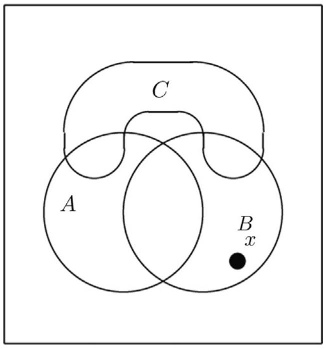

Fig. 4. Example set diagram: an Euler diagram (from [41], reproduced with permission).

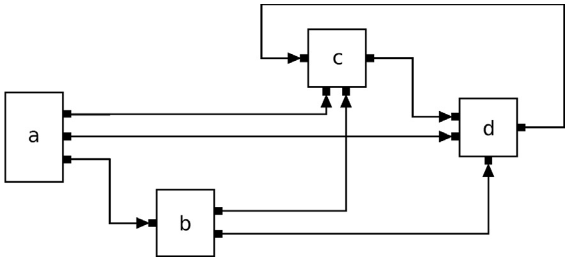

Fig. 5. Example embellished abstract diagram: an embellished graph used to depict data flow (from [55], reproduced with permission).

Fig. 6. Example embellished concrete diagram: a diagram representing the concept 'go' (from [56], reproduced with permission). The pony-tail, eyes, dress and shoes make this diagram more realistic (i.e. less abstract) than if a simple stick figure had been used – even though a stick figure would have been adequate for illustrating the concept.

defined by the manner in which the shapes overlap; examples include Euler diagrams [37,38] and Venn diagrams [39,40]. (For example, Fig. 4, from [41]).

- *Charts* which present data in a manner that summarises a set of values, of which there are several different types [42,43]. Examples include bar charts [44,45] and their sub-types (e.g. grouped bar charts [46,47]), line charts [48,49] and pie charts [50]).

2.2.3. Embellishment and composition

Embellished notations are based on one of the categories above, but include additional visual elements (e.g. lines, arrows, dots, and labels) that are used to augment the rules of a notation. Visual elements have been defined above: these are the individual marks on the 2D plane: a pixel, a line, a square, a dot, an arrow. Embellishments form part of the syntax of the augmented notation and, importantly, carry semantic weight.

Abstract diagrams correctly produced using an embellished notation have enhanced meaning. This phenomena is most evident in the embellishment of graphs – the basic abstract graph notation (simply comprising nodes and relationships between them) is actually rather rare; more common are notations that augment graph notation for specific purposes: for example UML diagrams specifying software structure [15,51], flow diagrams [52,53], and petri nets [54]. (For example, Fig. 5, from [55]).

Concrete diagrams can also be embellished by the inclusion of additional visual elements so as to provide more detail, effectively reducing the extent to which the concrete diagram is an abstraction of the object depicted. (For example, Fig. 6 from [56]). In some cases, these additional details may make the diagram more useful for a wider range of tasks.

Composite notations are those where one or more types of notation are combined, with the semantics of each combined in a meaningful way. For example, spider diagrams combine set and graph notations [57], nodes in trees can be grouped into sets [58], or bar charts can be placed in trees or maps [59]. (For example, Fig. 7, from [59]).

2.3. Summary of the classification

In summary, a diagram comprises visual marks on a 2D plane, and can be either concrete or abstract. Concrete

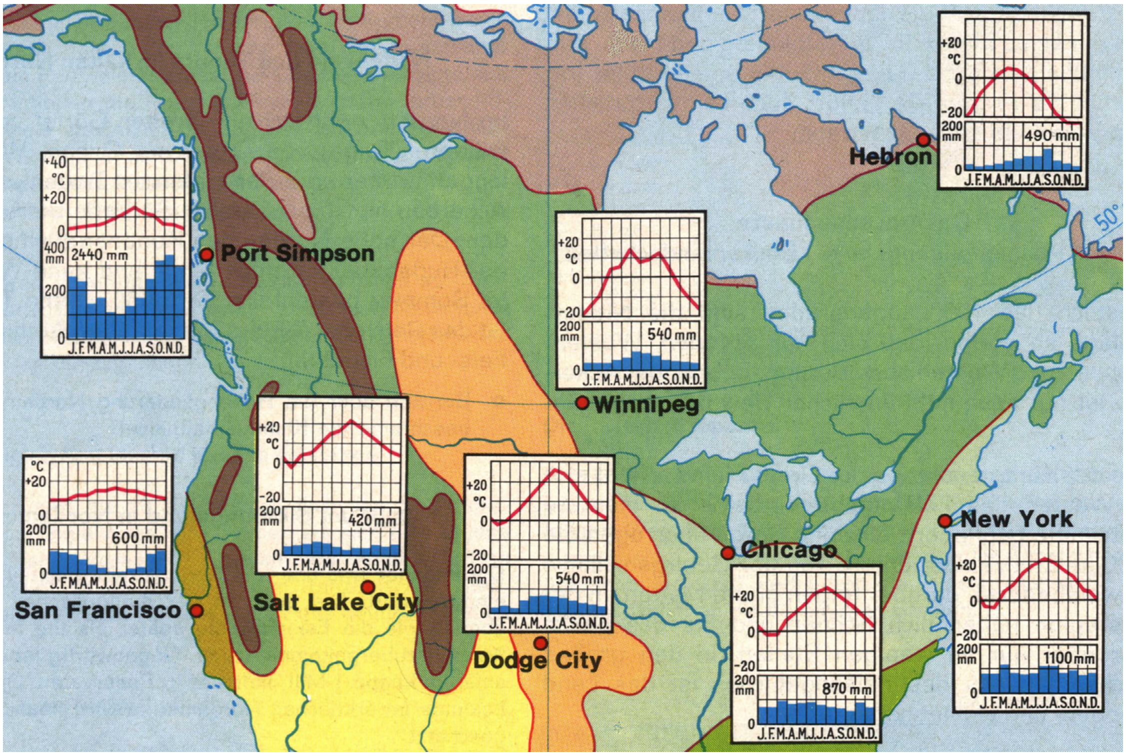

Fig. 7. Example use of a composite notation, combining maps and data presentation charts (from [59], reproduced with permission) (This figure originates from a German text book published in 1973: *Seydlitz für Gymnasien, Band 3B*, by C. Deng, E Eggert and A. Kolb).

diagrams typically represent objects, and use schematics, geometric shapes or pixelated images. Abstract diagrams typically represent concepts, and use networks, overlapping geometric shapes, or data presentation charts; they are defined by a notation. Notations may be embellished with additional visual elements. Composite notations use more than one notation, and their semantics are the combination of the constituent notations.

There are two orthogonal issues relating to these definitions. A single diagram is static. A series of diagram can be used to represent changes in the object or concept over time – the series as a whole is called a *dynamic* diagram, typically animated with the use of video technology.

The other dimension is the means of production: a diagram is a diagram regardless of the way in which it has been created. It can be sketched with pencil and paper or with stylus and tablet, automatically created as the output from a computer programme, or drawn with an interactive tool using a keyboard and mouse. The definition makes no distinction.

Having defined the scope of diagrams research as represented in DCS, the next section considers its various goals and aims.

3. The nature and trends of diagrams research

3.1. Classification of research aims

The Diagrams series is intended to be interdisciplinary, with an extensive range of research questions addressed. The Diagrams conferences papers (and some posters) are typically grouped within named themes in the proceedings (with the exception of 2004). Some themes are more common than others: “Applications of Diagrams” (general theme: 2008, 2012; specific applications: education (2008), HCI, software engineering, and mathematics (2002)), “Psychological and Cognitive Issues” (2000, 2006, 2008, 2012), “Reasoning with Diagrams” (2006, 2010, 2012). Some themes have only emerged in recent years: “Venn and Euler diagrams” (2010, 2012), “Aesthetics and layout” (2008, 2012), while some appeared only early in the series “Logic and Diagrams” (2000, 2002).

The approach taken here has been to consider each paper in terms of its aim; thus, each paper has a 'research aim' (or a 'research issue') associated with it, based on its purpose, its *raison d'etre*.

The research aims identified from the papers published in the seven DCS proceedings can be broadly classified within the following topics:

1. Notations
2. Translating between external representations of diagrams and their semantics
3. The nature of diagrams
4. Cognitive models of diagram comprehension
5. Empirical studies of diagram comprehension
6. Internal manipulation of diagrams
7. Tools to support diagram use
8. Graphical literacy
9. Miscellaneous

Note that throughout these papers, diagrams from several different domains are used (e.g. human biology, evolution, mechanics, and software engineering). As it is seldom the case that the primary research issue that the paper addresses is focussed specifically on the application domain of the diagrams, there is no separate 'application' category, as the wide range of applications used are interspersed amongst the other research aim categories.

Each of these nine categories is discussed below.

3.1.1. Notations (30 papers, 17% of all papers)

The research aim of these papers encompass both defining new notations for abstract diagrams as well as defining extensions to existing notations, in both cases including definition of the appropriate syntax and semantics. For example, a new notation for algebraic statements [60], a notation for representing army manoeuvres using a constraint satisfaction approach [61], and a notation for a simple 'blocks world' [62].

Proposing extensions to notations has been done both by adding embellishments to existing notations, or by formalising additional semantics for an existing notation. Much of the work in this area has been done on Venn and Euler diagrams (e.g. the extensive contributions from the Brighton Visual Languages Group [57,63,64], which includes extensions to the composite 'spider' notation.) The other common extension addressed is through embellishing network diagrams with arrows, as in data modelling [65] and data flow as represented in travel, recipes and data flow [66].

Some work has been done on applying existing notations to particular diagrams, for example in using logic to represent graph grammars [67], seating arrangements around a table [26] and truth puzzles [68].

Specific diagram notations have come under scrutiny by researchers who have discussed or critiqued them; all of these have been embellished network notations: UML [15], strategy roadmaps [52] and flow diagrams [53].

While there have been papers focussing on notational issues in all seven Diagrams conferences, there have been fewer in recent years.

3.1.2. Translating between external representations of diagrams and their semantics (19 papers, 11% of all papers)

The two types of research papers in this category have symmetry in their definition: the research aim is to present a method or an implemented system for either taking as input a diagram and creating a formal representation of its semantics, or generating a diagram from a given semantic representation.

When generating a diagram from its semantics, again, much of the work has been done in the area of set notation: Venn, Euler and spider diagrams (for example, [37,38, 69–73]). There is more recent work on the generation of embellished graph diagrams [55,74–76]. For an example of something rather different, the first Diagrams conference included a paper by Drewes and Klempien-Hinrichs [77] on the generation of Celtic knots from grammars, ensuring that the resultant drawings were consistent.

There is less work on the generation of semantic representations from diagrams, and all presented in the early periods of the conference [78–80]. Included in this category is the paper by Yaner and Goel [81] which describes a system that can take as input a diagram and, using analogical mappings, construct a data structure representation of it based on similarity with stored models.

Apart from a dip in 2006, the overall trend in this category appears to be upwards, mainly due to the increase in papers on automatic set or graph generation.

3.1.3. The nature of diagrams (18, 10% of all papers)

Papers whose primary concern is the nature of diagrams fall into two categories: those where the researchers discuss the nature of diagrams in general, or those where the focus is on particular types of diagrams.

While several researchers refer to the nature of diagrams in the introductions to their papers suggesting frameworks or terminology for the field (e.g. [10,82]) there are a few for which such a discussion is the focus of the paper itself. Norman [83] proposes dimensions of assimibililty and discretion, Chandrasekaran [84] discusses the role of diagrams in problem solving, Tversky et al. [9] define visual elements (“lines, blobs, crosses and arrows”), and Engelhardt [59] defines visual building blocks for composite notations, e.g. combining line charts with maps.

More common is a discussion or analysis of the nature of specific categories of diagram. Gärtner et al. [85] present metrics for measuring the complexity of data presentation visualisations, Purchase et al. [86] present the results of an empirical study focussing on the visual complexity of digital images, and Howse et al. [87] distinguish between token type and type syntax in the context of Euler diagrams. Theoretical analyses of specific diagram notations include existential graphs [14], spider diagrams [88,89] and Euclidean proofs [90].

The trend appears to be downwards for this category of paper in recent years.

3.1.4. Cognitive models of diagram comprehension (17 papers, 10% of all papers)

These papers propose models of how the eye and brain work together in enabling humans to understand and think about diagrams. Hegarty [91] and Cox [92] both use the term “external representation” to refer to the perceived (physical) diagram, and distinguish between it and the (cognitive) concept that is understood [91].

There are two types of paper in this category: those that propose a cognitive model of diagram comprehension based on prior observation or previous literature, and those that propose a model and then go on to test it empirically.

Models of diagram comprehension have been proposed for concrete diagrams (pulleys [16], hydraulic pumps [93], pianos [94]) as well as for abstract notations (bar and line charts [50,95–97], Euler diagrams [98] and constraint diagrams [99]).

Papers which present a cognitive model as well as an empirical study conducted particularly in order to test the cognitive model cover both concrete and abstract diagrams. An early paper [100] does both. It focusses on interactive multimedia presentations of a cistern and of a visual representation of the quicksort algorithm, proposing a cognitive method by which a dynamic mental model could be created. It then reports the results of an empirical study conducted to test this method. Other papers in this category look at notations: for example, bar charts [101,102] and unification and deletion in the context of Euler diagrams [41]. In a paper that looks at a wider context of diagram use, Kunda and Goel [103] propose and test “thinking in pictures” as a means of explaining some aspects of autistic behaviour.

There is no evident trend in this category; it continues to be a popular topic.

3.1.5. Empirical studies of diagram comprehension (41, 23% of all papers)

This is by far the most popular type of paper, always comprising the highest percentage of papers in each conference. These papers present the results of an empirical study conducted to investigate participants' understanding and use of diagrams. Like the section above, these studies are conducted both with concrete and abstract diagrams.

There are four tasks for which diagram empirical studies with human participants are reported: diagram interpretation, diagram use during problem solving, diagram creation, and diagram use during collaboration.

The interpretation studies are most common. In these cases, participants are typically asked to perform some task using a diagram, where successful completion of the task suggests that the diagram has been correctly interpreted by the participant. Sometimes the task is more subjective, with no 'correct' answer. For example, John et al. [104] investigated the perception of “clutter” in Euler diagrams.

A very wide range of diagram types are used in this category. Abstract notations considered include data presentation charts [45,49,105], set notations [106] and networks (social networks [31], trees and ladders [33], software specification [107]). Concrete diagrams include weather maps [108], Newton's cradle [109] and human body parts [110,111]. Some studies investigate the effects of animation on the interpretation of dynamic diagrams [30,32,109,112,113].

Some studies explicitly focus on the support that diagrams can give to problem-solving (not simply to the interpretation of diagrams). Grawemeyer's [114] evaluation of the ERST system showed that a system that suggests an appropriate data presentation method (e.g. scatter plot, bar chart etc.) to support a particular task can enhance performance in that task, especially if the suggestion is based on a model of students' previous diagram choices. Problems that have been addressed as suitable for diagram support are timetabling [115], solving syllogisms [116], comparing organic chemistry structures [117], and mechanical problem solving [118].

The creation of diagrams (especially by students during a learning activity) has been investigated empirically in several ways, and all through the medium of asking participants to write on a physical piece of paper. Clayton [24] analysed architectural students' design diagrams, while Clink and Newman [119] looked at the way in which professionals represented their future activities on hand-drawn timelines. The way in which participants depict syllogisms [120], processes [121], and the rules of a game [34] have all been investigated by asking participants to perform tasks supported by their own drawn diagrams. The manner in which bar charts are created has been used to investigate gender assumptions [122].

Diagrams are often used in collaboration, as a means of communicating information between people. There are papers on the remote use of a shared whiteboard [25,123] and on the means by which people communicate diagram information through speech [124,125]. Crilly et al. [126] conducted a broader, more realistic study, where professionals in the design industry were asked about the extent to which diagrams can be used to support the process of getting agreement from colleagues.

While there has been a high proportion of empirical papers in all the Diagrams conferences, there is a noticeable peak in 2006.

3.1.6. Internal manipulation of diagrams (22 papers, 12% of all papers)

These papers are concerned with the process of inferring additional information from a semantic representation of a diagram. They present either a method or an algorithm for enabling such inference, or an implemented working inference system. These papers are typically categorised under the “Diagrammatic Reasoning” conference theme.

Inference algorithms have been proposed for abstract notations (in particular, geometric shapes [127–131] and set diagrams [132,133]), pixel-based images [28,29], as well as concrete diagrams for army manoeuvres [134] and robot environments [135].

Carberry et al. describe two implemented systems that infer the intended meaning from data presentation diagrams (line charts [136] and grouped bar charts [46]), while Anderson and Anderson's [21] system permits maps to be queried. Yaner and Goel's [137] system compares stored diagrams against new ones and Anderson and Furnas [138] implemented parts of two diagrammatic reasoning systems in each other. Other inference systems use set diagrams [39,73] and network diagrams [139].

All but one of the 24 papers that present a method or algorithm (without an implemented system) is confined to the first four conferences. Three of the eight papers presenting implemented systems were published in 2000 or 2002, the other five were published in 2010 or 2012.

3.1.7. Tools to support diagram use (15 papers, 8% of all papers)

Software tools to support diagram use are typically presented in terms of the problem or task they are designed for. These tasks are typically broadly defined: writing and programming [140], learning maths [141], collaboration [142,143], or visual programming [144]. However, some are very specific (timetabling [145], design [146]), and some are focussed on the means of interaction: supporting the input of diagrams using gestures [147] or direct manipulation [148]. There are also papers on tool-creating-tools; that is, tools that allow the user to specify a notation, which will be the notation that the resultant tool will support [51,149–153].

Over the whole seven conferences, there was a noticeable peak in papers describing tools in 2002, and a dip in 2006. All the tool-creating-tool papers appear in the first three conferences.

3.1.8. Graphical literacy (6 papers, 3% of all papers)

While this is a small category it cannot simply be subsumed by the others, since it focuses on the skills of the viewer in being able to interpret diagrams (rather than the nature of the diagram itself), and the fact that this is a skill that needs to be learned not assumed [10]. Most of the papers in this category are empirical, and investigate the extent to which 'graphical literacy' needs to be learned for people to make the most of their use of diagrams. Data presentation charts feature in half of these papers [42,154,155], although skills in architectural design are also considered [24]. Cox et al. [156] compared the use of three types of representation, and translations between them: natural language, first order logic, and blocks-world diagrams, concluding that such translations into diagram form require a skill that is not present in the symbol manipulation translations between the natural language and the first order logic.

Papers in this area peaked mid-term in 2006 and 2008.

3.1.9. Miscellaneous (10 papers, 6% of all papers)

There are some papers that proved impossible to categorise in any of the eight categories above. There are some historical reviews [36,157], 'diagram' information presented via non-visual senses [158–160], presentation and interpretation of statistical data [161,162], cultural dimensions of web interfaces [163], non-behavioural empirical studies using EEG signals [164] and a tool to support diagram experiments [165].

3.2. Numerical summary

Tables 2 and 3 present the number of papers in each category showing their relative percentage within each conference, and over all conferences.

It appears from Fig. 8 and the graphical abstract that most categories have maintained a reasonable presence throughout all the conferences (possibly with the exception of graphical literacy, a small category). Papers on the internal manipulation of diagrams and on tools to support diagrams were each absent from one mid-term conference, but have recovered their presence. Papers with the two most common research aims (empirical studies and notations) have kept an almost-equal percentage of the papers in all the seven conferences, indicating their prominence in the field.

4. Layout and aesthetics

4.1. A framework for the use of visual features in diagrams

Before considering the use of 'layout' and 'aesthetics' in diagram research, it is useful to consider the wider use of visual features in diagrams. *Visual features* are the means by which different visual forms of a given diagram might

Table 2
Number of papers in each category in each conference[a].

	2000	2002	2004	2006	2008	2010	2012	All conferences
Empirical studies of diagram comprehension	6	6	4	9	7	4	5	41
Notations	7	4	3	6	3	3	4	30
Internal manipulation of diagrams	5	5	5	2	0	3	3	23
Translating between external representations of diagrams and their semantics	3	3	2	1	3	3	4	19
The nature of diagrams	4	2	3	3	2	2	2	18
Cognitive models of diagram comprehension	2	2	3	2	4	3	1	17
Tools to support diagram use	3	6	1	0	3	1	1	15
Graphical literacy	1	0	0	2	2	1	0	6
Miscellaneous	1	1	0	2	1	2	3	10
	32	29	21	27	25	22	23	179

[a] There are 179 classifications for 177 papers; two papers were placed in two categories as they clearly each pursued two different research aims: [24,73].

Table 3
Percentage of papers in each category in each conference.

	2000	2002	2004	2006	2008	2010	2012	All conferences
Empirical studies of diagram comprehension	19	21	19	33	28	18	22	23
Notations	22	14	14	22	12	14	17	17
Internal manipulation of diagrams	16	17	24	7	0	14	13	13
Translating between external representations of diagrams and their semantics	9	10	10	4	12	14	17	11
The nature of diagrams	13	7	14	11	8	9	9	10
Cognitive models of diagram comprehension	6	7	14	7	16	14	4	9
Tools to support diagram use	9	21	5	0	12	5	4	8
Graphical literacy	3	0	0	7	8	5	0	3
Miscellaneous	3	3	0	7	4	9	13	6

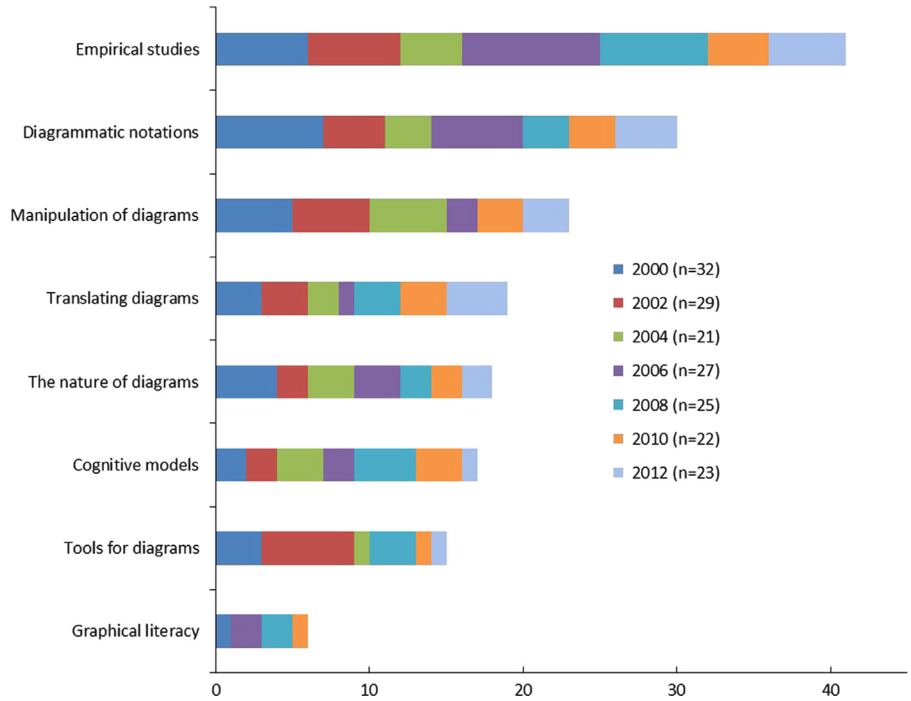

Fig. 8. Trends in the numbers of papers in each category in each conference, representing the data in Table 2. This data is also represented in the graphical abstract.

be created. Three types of such features are considered here: additional visual elements, the position of the elements on the 2D plane, and the format of the elements.

- *Additions* are visual elements added to a notation or diagram.
- *Layout* refers to the position in which the visual elements of a diagram are placed on the 2D plane.
- *Aesthetics* refers to the format of the visual elements: their colour, shape, shading, line curvature, font etc.[4]

There is an important additional distinction to be made here – whether the use of the visual features in a diagram is for the necessary purpose of representing additional semantic information, or optionally included so as to support the viewer in interpreting the existing semantics.

Embellishments are additions that are part of a notation, and form a crucial part of the syntax, as described above in Section 2.2.3. *Annotations*, however, are additional visual elements added to a diagram for the purposes of drawing the viewers' attention towards particular aspects of the drawing – they do not change the semantics of the diagram, but they do change the way in which it is perceived (for better or worse). For example, adding more numbers along the *x* axis of a bar chart does not change the meaning of the chart; including an arrow in a diagram of the brain that points to the frontal lobe does not change the semantics of the diagram.

Similarly, *notational layout* is part of the syntax of a notation; by specifying where on the plane particular visual elements must be placed, such elements can be given semantic weight. For example, in genealogical hierarchies, the ancestor is always depicted as the root of the tree, and either at the top or bottom of the plane (as in [166]).

Layout is not part of the notation: two semantically-equivalent diagrams may have their visual elements placed in different positions on the 2D plane. The notation itself is unchanged, but the positioning of the visual elements has been chosen to as to enhance understanding. While this might be most common in the positioning of nodes in a network diagram (e.g. [55]), it includes, for example, the ordering of bars in a bar chart. (For example, Fig. 9, [45]).

The use of *notational aesthetics* is embedded in the notation for the diagram, and these aesthetic features relate to semantics. Burns [167] describes a new notation for supporting the pairing of assets to targets in a command-and-control defence system, using colour to represent the gain value of each asset-target pair. In this case, colour is crucial to the notation – without it, the diagram is not semantically complete. Another common use of notational aesthetics is in the shape of elements: rectangles in UML class diagrams indicate classes (they cannot be represented as circles) (e.g. [15]); relationships in Entity Relationship diagrams are shown as diamonds (they cannot be represented as rectangles) (as in [168]).

[4] I am aware that this definition does not accord with other definitions of the word 'aesthetic' in the existing literature in diagrams and graph drawing research (including my own). It has been introduced here in an attempt to clearly distinguish between the *placement* and the *format* of visual elements, and thus clarify ambiguities in the use of these terms: *layout* is therefore “where things are”; *aesthetics* is “what they look like”.

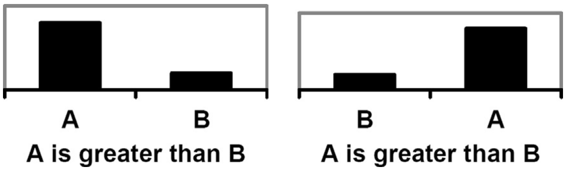

Fig. 9. Example use of different layouts for the same bar chart (from [45], reproduced with permission).

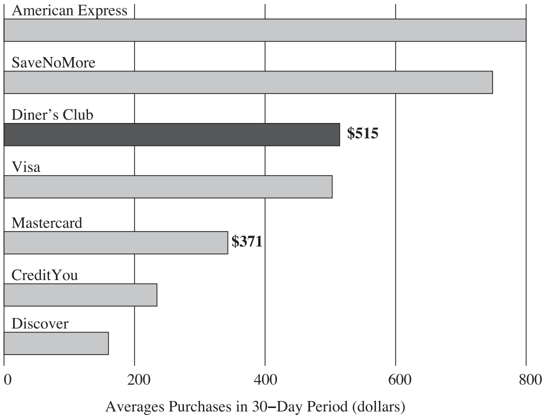

Fig. 10. Example of the use of aesthetics for the purposes of highlighting information (from [96], reproduced with permission). Note that this diagram uses annotations (by giving the values for Diner's Club and Mastercard) as well as aesthetics (using a different shading colour for Diner's Club).

Like layout, *aesthetics* is not part of the notation. Colour, shape, shading and font may be used to help the reader to understand the diagram, or to draw their attention to particular parts of it, but without it, the diagram is still semantically valid and complete (for example, Fig. 10, from [96]).

Other researchers have made similar distinctions in the use of visual features. Lowe and Boucheix [169] distinguish between two different types of "visual cues": those where attention is directed towards salient parts of the diagram incidentally ("intrinsic cueing", for example the central position of a node representing a person in a social network will draw attention to that node), and those where deliberate additions have been made to the diagram ("extrinsic cueing", for example colouring a node to indicate the importance of that person). Elzer et al. [96] define several forms of "communicative signals" in bar charts: highlighting using colour, shading or emboldening (aesthetics), showing the data values for some bars (annotation), bars that are much taller than others, or representing the most recent value (notational layout).

In summary, *notational layout*, *notational aesthetics* and *embellishments* (which can be also be termed *notational annotations*) are a necessary part of a notation and carry meaning; the rules of the notation explicitly refer to the placement, format and existence of visual elements. *Layout*, *aesthetics*, and *annotations* are not part of the notation used to create a diagram, but can be used to highlight important information, enhance understanding of the information embodied in the diagram, or simply to make the diagram 'look better'. The relationship between the terms introduced here is shown in Table 4, with examples from the DCS in Table 5.

4.2. Diagram aesthetics and layout

In considering the extent to which aesthetics and layout are considered within diagrams research,[5] the approach taken here is to focus on their use in supporting interpretation (rather than in representing semantics). Notational layout and notational aesthetics are part of the defined notation of the diagram, and so cannot be considered separately from the complete notation itself. Here, research on the use of layout and aesthetics *independent of the nature of the notation or its semantics* is discussed, i.e., the shaded areas in Table 5. Arguably, research on non-notational visual features is more interesting (and some may say more useful), as it is more concerned with the human process of interpretation than with the formal representation of semantics.

42 papers and posters in total were identified as using visual features for the purpose of supporting interpretation (5 annotations, 25 layout, 10 aesthetics, 2 combined).

4.2.1. Layout

For concrete diagrams, it is unlikely that the layout of the visual elements will be an important or interesting issue to research. Because such diagrams mirror the physical form of the object they represent, the positioning of the visual elements is somewhat fixed.[6] If the wheels in a diagram of a pulley are arranged horizontally side-by-side, then the diagram does not represent a pulley; if a waterfall is displayed upside down, then it is not a waterfall (and may even be interpreted as a fountain). There are no examples of layout being considered in the context of concrete diagrams in the Diagrams conference series.

For abstract diagrams, there is a wealth of research on the automatic placement of visual elements so as to enhance interpretation, and experiments to determine whether such placement enhances comprehension. Saund and Mahoney [170,171] explicitly discuss the potential usefulness of the Gestalt grouping principles in determining the most appropriate position for visual elements.

A large body of literature in this area is in the field of 'graph drawing' – the generation of graph drawings from an internal representation of a network. The International Symposium on Graph Drawing, held annually since 1992, is the main forum for research in this area. The 2012 survey paper by Gibson et al. [172] presents an extensive review of graph drawing research.

In DCS, several algorithms to support the layout of graphs for given purposes are presented: Wybrow et al. [75] and Ernstbrunner and Pichler [76] for electrical circuits, Klauske et al. [55] for data flow diagrams, Szwoch

[5] Although there are several examples of the use of annotations in the DCS, these are not considered in this paper, so as to focus on the theme of this special issue.

[6] Trivial manipulations aside, of course. If a diagram of a kangaroo or cistern is reflected along the vertical axis, it is still a diagram of a kangaroo or cistern. If a diagram of a chessboard or celtic knot is rotated by 90°, it is still a diagram of a chessboard or celtic knot.

Table 4
The framework of visual features use.

	Adding visual elements	Placing visual elements on the plane	Specifying the format of the visual elements
For the purposes of representing semantics	*embellishments*	*notational layout*	*notational aesthetics*
For the purposes of supporting interpretation	*annotations*	*layout*	*aesthetics*

Table 5
Examples of the use of visual features in the DCS.

	Adding visual elements	Placing visual elements on the plane	Specifying the format of the visual elements
For the purposes of representing semantics	*Howse et al.* [57] *describe an extension to the spider notation (called 'strands'), and demonstrate their semantics.*	*Novick* [10] *describes cladograms as a means of displaying evolutionary relationships, where the root is placed at the bottom.*	*Cheng and Barone* [82] *describe a nurse rostering system where colours indicate the extent to which rostering constraints have been satisfied.*
For the purposes of supporting interpretation	*Acarturk et al.* [49] *describes an experiment to test the effect of text annotations on line charts.*	*Rodgers et al.* [69] *present a method for laying out Euler diagrams from an abstract description.*	*Zambrano and Engelhardt* [161] *discuss how "info-graphics" use a variety of visual aesthetics to present data for raising public awareness.*

[173] for flowcharts, Dwyer et al. [74] for general hierarchical trees, and Kurata [174] for social networks.

Stapleton, Rodgers and their colleagues [69,71,72] have presented the layout methods for Euler and Venn diagrams, work supplemented by Sawamura and Kiyozuka [39], while Gange et al. [27] consider a more general problem of depicting non-overlapping (possibly non-convex) shapes.

Many empirical studies have investigated the effect of different positioning of visual elements within the same diagram on users' task performance, preference or behaviour. These cover a wide range of abstract notations: graphs [32,175–177], trees [33,178], bar charts [45], line charts [49], matrices [179], and the depiction of cyclic data [180]. In all cases, the researchers have varied the layout of the same information (using the same notation) to see if the position of the visual elements affect the perception of the diagram.

In some cases, the empirical study asks that participants draw diagrams (rather than interpret them). Yu et al. [181] asked people to draw their own social networks, and found that the vertical position of nodes was typically used to differentiate roles, and the distance between nodes used to indicate extent of intimacy. Hoffman et al.'s [182] earlier studies of people drawing concept maps pre-empt these results by showing that the location of concept nodes is important to the creation, revision and interpretation of concept maps.

Of the 42 papers and posters identified that address the use of visual features for interpretation, papers that specifically consider the position of visual elements for the purposes of enhancing understanding are by far in the majority: 25 in all.

4.2.2. Aesthetics

For concrete diagrams, there is more scope for researching aesthetics (as opposed to layout). In a concrete diagram, as for layout, changing some of the aesthetics of the diagram might not be acceptable – changing the shape of a wheel in a pulley to be a rectangle would not make sense.

However, changing its colour (an aesthetic change) may be appropriate, and, indeed, doing so may enhance understanding: in Fig. 11 (from [113]), colouring the two pulley ropes in different colours makes it easier for the viewer to distinguish between them.

In addition, like the use of embellishments in concrete diagrams, the use of aesthetics may make a concrete diagram more realistic. The shading of the bottom of the box and the bottom of the horizontal pole in Fig. 11 are aesthetic features that contribute towards making the diagram a more realistic representation of a pulley than in Fig. 1.

Despite this, there are few examples of papers where the research aim entails investigating the use of aesthetics in concrete diagrams. Grant and Spivey [110] identified in a pre-study which areas of a diagram used for determining how best to treat a tumour are most salient, and investigated the potential effects of aesthetic highlighting by changing the width of a line in an animated "pulse". The work of Lowe and Boucheix [19,169] focusses on the importance of drawing attention to different aspects of an animated diagram (using colour) at different stages. The use of the word 'aesthetics' in the context of architectural design diagrams is discussed by Clayton [24], where it is related to depicting architectural concepts (e.g. public and private spaces, circulation paths, servant/master spaces) through the use of shading, colour, and width of lines.

For abstract diagrams, colour has been considered in supplementing the representation of probabilities [183], linguistic phenomena in sentences [184], and information flow diagrams [185]. The shapes chosen to depict data in "diagrams for the masses" are discussed by Zambrano and Engelhardt [161]; for example, coffins represent deaths, babies represent births.

It may seem surprising that only 10 papers were found that explicitly address issues of aesthetics for enhancing diagram interpretation and use; this is explained by noting that several papers use the term 'aesthetics' when they are effectively referring to 'layout' as defined above.

Of course, it is not the case that aesthetics and layout need to be considered separately. Elzer et al. [96] include aesthetics, annotation and notational layout in their discussion of the range of communicative signals used in bar charts (as shown in Fig. 10). Thuessen [56] describes cues intended to support dyslexic children learning words that are difficult for them – these cues include colour (aesthetics), position (layout) and "graphic elements" (annotations). Bosveld-de Smet and de Vries' [184] empirical study of different ways of depicting linguistic phenomena used visual variations of colour (aesthetics), shape of the syntax tree (layout) and inclusion of referential links between words (annotations) (Fig. 12).

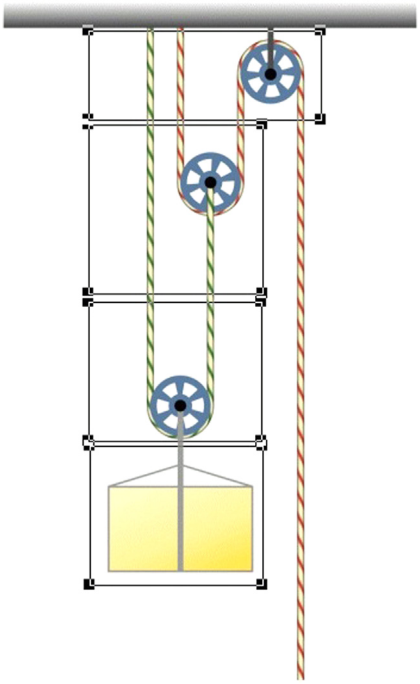

Fig. 11. Example concrete diagram with aesthetic visual features: a pulley (from [113], reproduced with permission). This diagram demonstrates both *annotations* (the diagonal lines on the ropes and the radial spokes within the wheels) as well as *aesthetics* (the colouring of the ropes and shading of the box and pole). The four superimposed rectangles are not part of the pulley: they indicate areas of focus identified during an eye-tracking study.

5. Discussion and conclusion

So what can be learned from this review of diagrams research? The area is healthy, growing in diversity, and truly interdisciplinary. It is informed by cognitive and empirical psychology, computing science, philosophy, logic, education, and design, with a touch of social science. The application domains are wide and varied, and include architecture, software engineering, electronic circuit design, the representation of time, biology (human and otherwise), geometry, geography, constraint satisfaction and remote communication.

While a few research issues tend to dominate the area, the fact that 9% and 13% (respectively) of the papers in the most recent two conferences did not fall easily into the common research categories (and were therefore classified as "miscellaneous") suggests that new relevant research issues are emerging. These may include, for example, the use of new technologies for accessibility (the "tactile" diagrams proposed by Goncu et al. [159,160]), historical reviews of this now well-established field in different application areas [36,157], and an increasing use of EEG signals to support empirical behavioural studies [164].

Surprising omissions include the fact that there is only one paper on the popular topic of "info-graphics" [161], which, in the terminology introduced here, is an example of the use of aesthetics and annotations in data presentation charts. In addition, recent years have not, as might have been expected, seen more research using novel

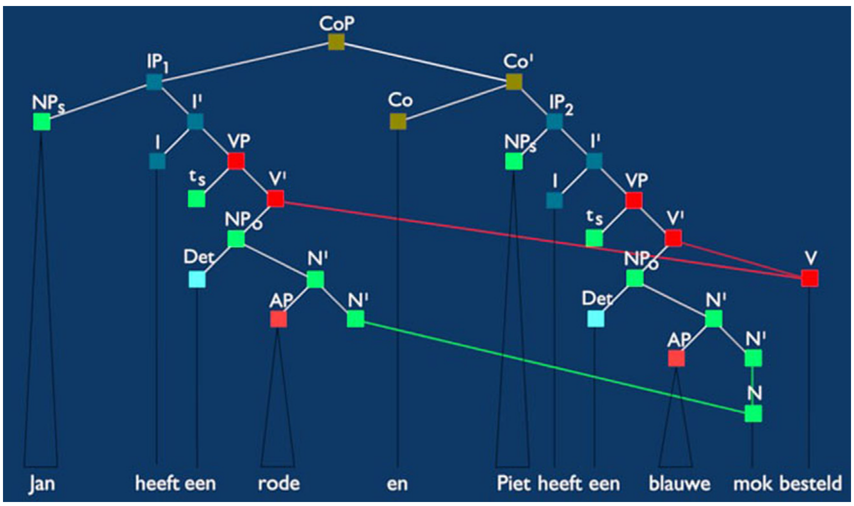

Fig. 12. A syntax tree illustrating the use of colour and annotation (from [184], reproduced with permission). The semantics of the tree is exactly the same as if the colour and annotations had not been used and if the nodes were in different positions.

technologies: none of the papers that discuss the manual creation of diagrams use sketching tool technology (as discussed elsewhere [186]), 3D presentation of diagrammatic information is considered only thrice [184,187,188], and even the use of diagrams on web pages is only covered peripherally [163].

It is also surprising to see no representation from the active research area of vision science – there are some eye-tracking studies (e.g. [189]), but these tend to be used to support behavioural studies, rather than to consider the visual perception system itself. The extensive existing research on, for example, the visual processing of colour, depth, texture, luminance etc. does not yet appear to have touched the main diagrams research community.

While the diagrams research reviewed here is very interdisciplinary, it still lies mainly so within the sciences. For example, there is no representation from the areas of art, graphic design, photography, music or marketing, none of which are excluded by the definition of 'diagram' presented above: *a composite set of marks ('visual elements') on a 2D plane that, when taken together, represent a concept or object in the mind of the viewer*.

Of course, the Diagrams Conference Series is only one possible publication outlet for diagrams research, and these under-represented areas appear elsewhere. This survey of diagrams research has necessarily been limited to one snapshot: twelve years of the Diagrams conference, the premier forum for diagrams research. There are many, many other places where diagrams research can be, and is published: IEEE Journal of Visual Language and Computing, IEEE Transactions on Vision and Computer Graphics, Computer Graphics Forum, IEEE Information Visualisation Conference (InfoVis), ACM SIGCHI Conference on Human Factors in Computing Systems (CHI), International Symposium on Graph Drawing, International Conference on Computer Vision, Academy of Marketing Science, Journal For Artistic Research etc.

In addition, there are some recent newcomers to the study of diagrams. *The Diagram Research Use and Generation Group* [190] has held symposia in London in July 2012 and February 2013, "addressing practical uses of diagrams in the arts, arts research and arts pedagogy from the perspectives of artists, lecturers, researchers and curators." The European Conference on Visual Perception held in August 2013 included a satellite symposium on "The Art of Perception - The Perception of Art"[191]. In October 2012, the sociology department at Goldsmith's University of London started an "ongoing workshop series in which members explore the application of diagrams, lines and patterns in response to a call … for modes of engagement with dynamic processuality" [192].

This paper has reviewed twelve years of diagrams research, which during this period has matured and become established and highly respected as an interdisciplinary research area. In doing so, the paper has proposed definitions and a taxonomic categorisation of diagram types, and distinguished between the way in which visual features can be applied to diagrams (including disambiguating the terms 'layout' and 'aesthetics'). Trends and omissions in current diagrams research have been discussed, while looking to the future to identify new disciplines that might soon be encompassed by its interdisciplinary umbrella.

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References

[1] J.H. Larkin, H.A. Simon, Why a diagram is (sometimes) worth ten thousand words, Cognitive Sci. 11 (1987) 65–99.
[2] A. Blackwell, Thinking with Diagrams, in: Interdisciplinary Workshop on Thinking with Diagrams.MRC CBSU, 3693, 1997.
[3] M. Anderson, B. Meyer, P. Olivier (Eds.), Diagrammatic Representation and Reasoning, Springer, 2002.
[4] P. Olivier, Workshop on Thinking with Diagrams, (Grant proposal: GR/M18102/01) 1998 ⟨http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=GR/M18102/01⟩.
[5] A. Blackwell, Thinking with diagrams, Artif. Intell. Rev. 15 (2001) 1–3.
[6] M. Anderson, P. Cheng, V. Haarslev, Theory and Application of Diagrams, Springer, 2000 (LNAI 1889).
[7] Diagrams Steering Committee, 2013 ⟨http://diagrams-conference.org/⟩.
[8] Oxford English Dictionaries, http://oxforddictionaries.com/.
[9] B. Tversky, J. Zacks, P. Lee, J. Heiser, Lines, blobs, crosses and arrows: diagrammatic communication with schematic figures, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 221–230. (LNAI 1889).
[10] L.R. Novick, The importance of both diagrammatic conversions and domain-specific knowledge for diagram literacy in science: the hierarchy as an illustrative case, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 1–11. (LNAI 4045).
[11] G.G. Garcia, R. Cox, Diagrams in the UK national school curriculum, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 360–363. (LNAI 5223).
[12] A. Blackwell, Y. Engelhardt, A meta-taxonomy for diagram research, in: M. Anderson, B. Meyer, P. Olivier (Eds.), Diagrammatic Representation and Reasoning, Springer, 2002, pp. 47–64.
[13] J.H. Connolly, Diagrams as components of multimedia discourse: a semiotic approach, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 479–482. (LNAI 1889).
[14] K. Stenning, Distinctions with differences: comparing criteria for distinguishing diagrammatic from sentential systems, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 132–148. (LNAI 1889).
[15] Z. Diskin, Visualization vs. specification in diagrammatic notations: a case study with the UML, in: M. Hegarty, B. Meyer, N. H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 112–115. (LNAI 2317).
[16] M. Hegarty, Capacity limits in diagrammatic reasoning, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 194–206. (LNAI 1889).
[17] S. Kriz, Understanding simultaneity and causality in static diagrams versus animation, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 338–340. (LNAI 2317).
[18] S. Price, Processing animation: integrating information from animated diagrams, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 360–364. (LNAI 2980).
[19] R. Lowe, J.-M. Boucheix, Supporting relational processing in complex animated diagrams, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 391–394. (LNAI 5223).
[20] R. Lowe, Animation of diagrams: an aid to learning? in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 475–478. (LNAI 1889).

[21] M. Anderson, B. Andersen, Heterogeneous data querying in a diagrammatic information system, in: M. Hegarty, B. Meyer, N. H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 109–111. (LNAI 2317).

[22] R.L. Vinyard, J.J. Pfeiffer, Using color component overlays for result visualization in a classification by sketch system, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 402–406. (LNAI 2980).

[23] M. Brösamle, C. Hölscher, Thinking with words and sketches – analyzing multi-modal design transcripts along verbal and diagrammatic data, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 292–294. (LNAI 6170).

[24] M.J. Clayton, Diagramming aesthetics: modernism and architecture in the 21st century, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 257–270. (LNAI 1889).

[25] P.G.T. Healey, R. McCabe, Y. Katagiri, A comparison of graphics and speech in a task-oriented interaction, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 245–256. (LNAI 1889).

[26] N. Swoboda, G. Allwein, Modeling heterogeneous systems, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 131–145. (LNAI 2317).

[27] G. Gange, K. Marriott, P.J. Stuckey, Smooth linear approximation of non-overlap constraints, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 45–59. (LNAI 5223).

[28] G. Furnas, Y. Qu, S. Shrivastava, G. Peters, The use of intermediate graphical constructions in problem solving with dynamic, pixel-level diagrams, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 300–313. (LNAI 1889).

[29] R. McCartney, P. El-Kafrawy, Inter-diagrammatic reasoning and digital geometry, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 199–215. (LNAI 2980).

[30] D. Yoon, N.H. Narayanan, S. Lee, O.-C. Kwon, Exploring the effect of animation and progressive revealing on diagrammatic problem solving, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 226–240. (LNAI 4045).

[31] C. Ware, A.T. Gilman, R.J. Bobrow, Visual thinking with an interactive diagram, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 118–126. (LNAI 5223).

[32] H.C. Purchase, A. Samra, Extremes are better: investigating mental map preservation in dynamic graphs, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 60–73. (LNAI 5223).

[33] L.R. Novick, K.M. Catley, Interpreting hierarchical structure: evidence from cladograms in biology, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 176–180. (LNAI 4045).

[34] S.L. Epstein, J.H. Keibel, Learning on paper: diagrams and discovery in game playing, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 31–45. (LNAI 2317).

[35] C. Mues, B. Baesens, C.M. Files, J. Vanthienen, Decision diagrams in machine learning: an empirical study on real-life credit-risk data, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 395–397. (LNAI 2980).

[36] S.J. Morris, O.C.Z. Gotel, The diagram of flow: its departure from software engineering and its return, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 256–269. (LNAI 7352).

[37] J. Flower, J. Howse, Generating Euler diagrams, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 61–75. (LNAI 2317).

[38] A. Verroust, M.-L. Viaud, Ensuring the drawability of extended Euler diagrams for up to 8 sets, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 128–141. (LNAI 2980).

[39] H. Sawamura, K. Kiyozuka, JVenn: a visual reasoning system with diagrams and sentences, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 271–285. (LNAI 1889).

[40] L. Choudhury, M.K. Chakraborty, On extending Venn diagram by augmenting names of individuals, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 142–146. (LNAI 2980).

[41] K. Mineshima, M. Okada, Y. Sato, R. Takemura, Diagrammatic reasoning system with Euler circles: theory and experiment design, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 188–205. (LNAI 5223).

[42] B. Grawemeyer, R. Cox, The effects of users' background diagram knowledge and task characteristics upon information display selection, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 321–334. (LNAI 5223).

[43] B. Grawemeyer, R. Cox, The effect of knowledge-of-external-representations upon performance and representational choice in a database query task, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 351–354. (LNAI 2980).

[44] Y.P. Zhou, C.L. Tan, Bar charts recognition using Hough based syntactic segmentation, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 494–497. (LNAI 1889).

[45] A. Feeney, A.K.W. Hola, S.P. Liversedge, J.M. Findlay, R. Metcalf, How people extract information from graphs: evidence from a sentence-graph verification paradigm, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 149–161. (LNAI 1889).

[46] R. Burns, S. Carberry, S. Elzer, D. Chester, Automatically recognizing intended messages in grouped bar charts, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 8–22. (LNAI 7352).

[47] B.M. Stewart, A.C. Hunter, L.A. Best, The relationship between graph comprehension and spatial imagery: support for an integrative theory of graph cognition, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 415–418. (LNAI 5223).

[48] S.B. Trickett, J.G. Trafton, Spatial transformations in graph comprehension, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 372–375. (LNAI 2980).

[49] C. Acarturk, C. Habel, K. Cagiltay, Multimodal comprehension of graphics with textual annotations: the role of graphical means relating annotations and graph lines, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 335–343. (LNAI 5223).

[50] S.B. Trickett, J.G. Trafton, Toward a comprehensive model of graph comprehension: making the case for spatial cognition, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 286–300. (LNAI 4045).

[51] Y. Jin, R. Esser, J.W. Janneck, Describing the syntax and semantics of UML statecharts in a heterogeneous modelling environment, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 320–334. (LNAI 2317).

[52] A.F. Blackwell, R. Phaal, M. Eppler, N. Crilly, Strategy roadmaps: new forms, new practices, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 127–140. (LNAI 5223).

[53] S.J. Morris, O.C.Z. Gotel, Flow diagrams: rise and fall of the first software engineering notation, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 130–144. (LNAI 4045).

[54] J. de Lara, G. Taentzer, Automated model transformation and its validation using AToM3 and AGG, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 182–198. (LNAI 2980).

[55] L.K. Klauske, C.D. Schulze, M. Sponemann, R. von Hanxleden, Improved layout for data flow diagrams with port constraints, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 65–79. (LNAI 7352).

[56] M. Thiessen, Visualizing meaning: literacy materials for dyslexic children, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 430–432. (LNAI 5223).

[57] J. Howse, F. Molina, J. Taylor, On the completeness and expressiveness of spider diagram systems, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 26–41. (LNAI 1889).

[58] T.R.G. Green, A.G. Harrop, V. Dimitrova, Teaching children brackets by manipulating trees: is easier harder?, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 407–414. (LNAI 2980).

[59] Y. Engelhardt, Objects and spaces: the visual language of graphics, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 104–108. (LNAI 4045).
[60] P.C.H. Cheng, Algebra Diagrams: a HANDi introduction, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 178–192. (LNAI 7352).
[61] A. Degani, M. Shafto, L. Olson, Canonical correlation analysis: use of composite heliographs for representing multiple patterns, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 93–97. (LNAI 4045).
[62] A. von Klopp Lemon, O. von Klopp Lemon, Constraint matching for diagram design: qualitative visual languages, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 74–88. (LNAI 1889).
[63] J. Howse, G. Stapleton, J. Flower, J. Taylor, Corresponding regions in Euler diagrams, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 76–90. (LNAI 2317).
[64] A. Delaney, J. Taylor, S. Thompson, Spider diagrams of order and a hierarchy of star-free regular languages, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 172–187. (LNAI 5223).
[65] Z. Diskin, B. Kadish, F. Piessens, M. Johnson, Universal arrow foundations for visual modeling, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 345–360. (LNAI 1889).
[66] Y. Kurata, M.J. Egenhofer, Topological relations of arrow symbols in complex diagrams, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 112–126. (LNAI 4045).
[67] K. Marriott, B. Meyer, Non-standard logics for diagram interpretation, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 42–57. (LNAI 1889).
[68] B. Nagy, G. Allwein, Diagrams and non-monotonicity in puzzles, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 82–96. (LNAI 2980).
[69] P. Rodgers, L. Zhang, A. Fish, General Euler diagram generation, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 13–27. (LNAI 5223).
[70] A. Fish, J. Flower, Euler diagram decomposition, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 28–44. (LNAI 5223).
[71] G. Stapleton, L. Zhang, J. Howse, P. Rodgers, Drawing Euler diagrams with circles, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 23–38. (LNAI 6170).
[72] P. Rodgers, J. Flower, G. Stapleton, J. Howse, Drawing area-proportional Venn-3 diagrams with convex polygons, in: A. K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 54–68. (LNAI 6170).
[73] M. Urbas, M. Jamnik, G. Stapleton, J. Flower, Speedith: a diagrammatic reasoner for spider diagrams, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 163–177. (LNAI 7352).
[74] T. Dwyer, K. Marriott, P. Sbarski, Hi-tree layout using quadratic programming, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 212–219. (LNAI 6170).
[75] M. Wybrow, K. Marriott, P.J. Stuckey, Orthogonal hyperedge routing, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 51–64. (LNAI 7352).
[76] C. Ernstbrunner, J. Pichler, Aesthetic layout of wiring diagrams, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 80–94. (LNAI 7352).
[77] F. Drewes, R. Klempien-Hinrichs, Picking knots from trees the syntactic structure of celtic knotwork, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 89–104. (LNAI 1889).
[78] J. Thurbon, Executing diagram sequences, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 392–406. (LNAI 1889).
[79] D. Blostein, E. Lank, R. Zanibbi, Treatment of diagrams in document image analysis, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 330–344. (LNAI 1889).
[80] C.S. Collberg, A Fuzzy, Visual query language for a domain-specific web search engine, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 176–190. (LNAI 2317).
[81] P.W. Yaner, A.K. Goel, From diagrams to models by analogical transfer, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 55–69. (LNAI 4045).
[82] P.C.H. Cheng, R. Barone, Representing rosters: conceptual integration counteracts visual complexity, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 385–387. (LNAI 2980).
[83] J. Norman, Differentiating diagrams: a new approach, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 105–116. (LNAI 1889).
[84] B. Chandrasekaran, Diagrams as physical models, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 204–217. (LNAI 4045).
[85] J. Gartner, S. Miksch, S.C. McGrath, ViCo: a metric for the complexity of information visualizations, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 249–263. (LNAI 2317).
[86] H.C. Purchase, E. Freeman, J. Hamer, An exploration of visual complexity, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 200–213. (LNAI 7352).
[87] J. Howse, F. Molina, S.-J. Shin, J. Taylor, On diagram tokens and types, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 146–160. (LNAI 2317).
[88] G. Stapleton, J. Howse, J. Taylor, S. Thompson, What can spider diagrams say?, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 112–127. (LNAI 2980).
[89] A. Delaney, G. Stapleton, J. Taylor, S. Thompson, Fragments of spider diagrams of order and their relative expressiveness, in: A. K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 69–83. (LNAI 6170).
[90] J. Mumma, Ensuring generality in Euclid's diagrammatic arguments, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 222–235. (LNAI 5223).
[91] M. Hegarty, Diagrams in the mind and in the world: relations between internal and external visualizations, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 1–21. (LNAI 2980).
[92] R. Cox, P. Romero, B. du Boulay, R. Lutz, A cognitive processing perspective on student programmers' graphicacy, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 344–346. (LNAI 2980).
[93] R. Lowe, J.-M. Boucheix, Dynamic diagrams: a composition alternative, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 233–240. (LNAI 7352).
[94] R. Lowe, J.-M. Boucheix, Learning from animated diagrams: how are mental models built, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 266–281. (LNAI 5223).
[95] E.G. Freedman, P. Shah, Toward a model of knowledge-based graph comprehension, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 18–30. (LNAI 2317).
[96] S. Elzer, S. Carberry, S. Demir, Communicative signals as the key to automated understanding of simple bar charts, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 25–39. (LNAI 4045).
[97] B. Chandrasekaran, O. Lele, Mapping descriptive models of graph comprehension into requirements for a computational architecture: need for supporting imagery operations, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 235–242. (LNAI 6170).
[98] P. Coppin, J. Burton, S. Hockema, An attention based theory to explore affordances of textual and diagrammatic proofs, in: A. K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 271–278. (LNAI 6170).
[99] A. Fish, J. Howse, Towards a default reading for constraint diagrams, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 51–65. (LNAI 2980).
[100] N.H. Narayanan, M. Hegarty, Communicating dynamic behaviors: are interactive multimedia presentations better than static mixed-mode presentations?, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 178–193. (LNAI 1889).
[101] S. Elzer, N. Green, S. Carberry, J. Hoffman, Incorporating perceptual task effort into the recognition of intention in information graphics, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 255–270. (LNAI 2980).

[102] A. Feeney, J. Adams, L. Webber, M. Ewbank, Individual differences in graphical reasoning, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 271–285. (LNAI 2980).
[103] M. Kunda, A. Goel, What can pictorial representations reveal about the cognitive characteristics of autism, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 103–117. (LNAI 5223).
[104] C. John, A. Fish, J. Howse, J. Taylor, Exploring the notion of 'clutter' in Euler diagrams, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 267–282. (LNAI 4045).
[105] L.A. Best, L.D. Smith, D. Alan, Detection of sample differences from dot plot displays, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 293–307. (LNAI 5223).
[106] D.P. Calvillo, K. DeLeeuw, R. Revlin, Deduction with Euler circles: diagrams that hurt, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 199–203. (LNAI 4045).
[107] C. Britton, S. Jones, M. Kutar, M. Loomes, B. Robinson, Evaluating the intelligibility of diagrammatic languages used in the specification of software, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 376–391. (LNAI 1889).
[108] G.J. Trafton, S. Marshall, F. Mintz, S.B. Trickett, Extracting explicit and implicit information from complex visualizations, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 206–220. (LNAI 2317).
[109] R. Lowe, Changing perceptions of animated diagrams, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 168–172. (LNAI 4045).
[110] E.R. Grant, M.J. Spivey, Guiding attention produces inferences in diagram-based problem solving, in: M. Hegarty, B. Meyer, N. H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 236–248. (LNAI 2317).
[111] K. Scheiter, A. Eitel, The effects of signals on learning from text and diagrams: how looking at diagrams earlier and more frequently improves understanding, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 264–270. (LNAI 6170).
[112] S. Jones, M. Scaife, Animated diagrams: an investigation into the cognitive effects of using animation to illustrate dynamic processes, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 231–244. (LNAI 1889).
[113] E. Schneider, J.-M. Boucheix, On line elaboration of a mental model during the understanding of an animation, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 40–54. (LNAI 4045).
[114] B. Grawemeyer, Evaluation of ERST – an external representation selection tutor, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 154–167. (LNAI 4045).
[115] P.C.H. Cheng, R. Barone, P.I. Cowling, S. Ahmadi, Opening the information bottleneck in complex scheduling problems with a novel representation: STARK diagrams, in: M. Hegarty, B. Meyer, N. H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 264–278. (LNAI 2317).
[116] Y. Sato, K. Mineshima, R. Takemura, The efficacy of Euler and Venn diagrams in deductive reasoning: empirical findings, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 6–22. (LNAI 6170).
[117] M. Stieff, M. Hegarty, B. Dixon, Alternative strategies for spatial reasoning with diagrams, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 115–127. (LNAI 6170).
[118] D. Yoon, N.H. Narayanan, Predictors of success in diagrammatic problem solving, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 301–315. (LNAI 2980).
[119] S. Clink, J. Newman, Recording the future: some diagrammatic aspects of time management, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 207–220. (LNAI 1889).
[120] K.E. DeLeeuw, M. Hegarty, What diagrams reveal about representations in linear reasoning, and how they help, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 89–102. (LNAI 5223).
[121] E. Manalo, Y. Uesaka, Elucidating the mechanism of spontaneous diagram use in explanations: how cognitive processing of text and diagrammatic representations are influenced by individual and task-related factors, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 35–50. (LNAI 7352).
[122] P. Hegarty, C. Buechel, S. Ungar, Androcentric preferences for visuospatial representations of gender differences, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 263–266. (LNAI 4045).
[123] P.G.T. Healey, J. King, N. Swoboda, Co-ordinating conventions in graphical dialogue: effects of repetition and interaction, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 286–300. (LNAI 2980).
[124] I. Umata, Y. Katagiri, A. Shimojima, Movement conceptualizations in graphical communication, in: M. Hegarty, B. Meyer, N. H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 3–17. (LNAI 2317).
[125] I. Umata, A. Shimojima, Y. Katagiri, Speech and graphical interaction in multimodal communication, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 316–328. (LNAI 2980).
[126] N. Crilly, P.J. Clarkson, A.F. Blackwell, Using research diagrams for member validation in qualitative research, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 258–262. (LNAI 4045).
[127] D. Winterstein, A. Bundy, M. Jamnik, A proposal for automating diagrammatic reasoning in continuous domains, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 286–299. (LNAI 1889).
[128] R.K. Lindsay, Playing with diagrams, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 300–313. (LNAI 1889).
[129] D. Winterstein, A. Bundy, C. Gurr, M. Jamnik, Using animation in diagrammatic theorem proving, in: M. Hegarty, B. Meyer, N. H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 46–60. (LNAI 2317).
[130] N. Miller, CDEG: computerized diagrammatic Euclidean geometry, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 91–93. (LNAI 2317).
[131] R. Rood, The logic of geometric proof, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 221–225. (LNAI 4045).
[132] J. Flower, J. Masthoff, G. Stapleton, Generating readable proofs: a heuristic approach to theorem proving with spider diagrams, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 166–181. (LNAI 2980).
[133] B. Nagy, Reasoning by intervals, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 145–147. (LNAI 4045).
[134] B. Chandrasekaran, U. Kurup, B. Banerjee, J.R. Josephson, R. Winkler, An architecture for problem solving with diagrams, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 151–165. (LNAI 2980).
[135] J.J. Pfeiffer Jr., A prototype inference engine for rule-based geometric reasoning, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 216–226. (LNAI 2980).
[136] P. Wu, S. Carberry, S. Elzer, D. Chester, Recognizing the intended message of line graphs, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 220–234. (LNAI 6170).
[137] P.W. Yaner, A.K. Goel, Retrieving 2-D line drawings by example, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 97–99. (LNAI 2317).
[138] M. Anderson, G. Furnas, Relating two image-based diagrammatic reasoning architectures, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 128–143. (LNAI 6170).
[139] P. Papapanagiotou, J. Fleuriot, S. Wilson, Diagrammatically-driven formal verification of web-services composition, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 241–255. (LNAI 7352).
[140] S. Takada, Y. Yamamoto, K. Nakakoji, Two-dimensional positioning as visual thinking, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 437–452. (LNAI 1889).
[141] S. Tanimoto, W. Winn, D. Akers, A system that supports using student-drawn diagrams to assess comprehension of mathematical

formulas, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 100–102. (LNAI 2317).
[142] P.G.T. Healey, N. Swoboda, J. King, An environment for conducting and analysing graphical communication experiments, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 103–105. (LNAI 2317).
[143] S.L. Tanimoto, Enhancing state-space tree diagrams for collaborative problem solving, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 156–164. (LNAI 5223).
[144] A. Hassan, I. Mackie, J.S. Pinto, Visual programming with interaction nets, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 165–171. (LNAI 5223).
[145] D. Ranson, P.C.H. Cheng, VAST improvements to diagrammatic scheduling using representational epistemic interface design, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 141–155. (LNAI 5223).
[146] B. Dave, G. Jahn, DDA\repository: an associative, dynamic and incremental repository of design diagrams, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 270–276. (LNAI 7352).
[147] M. Frisch, J. Heydekorn, R. Dachselt, Diagram editing on interactive displays using multi-touch and pen gestures, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 182–196. (LNAI 6170).
[148] A.F. Blackwell, H. Wallach, Diagrammatic integration of abstract operations into software work contexts, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 191–205. (LNAI 2317).
[149] R.I. Ferguson, A. Hunter, C. Hardy, MetaBuilder: the diagrammer's diagrammer, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 407–421. (LNAI 1889).
[150] S. Gruner, M. Kurt, Diagrammatic control of diagrammatic structure generation, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 422–436. (LNAI 1889).
[151] O. Koth, M. Minas, Structure, abstraction, and direct manipulation in diagram editors, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 290–304. (LNAI 2317).
[152] A.R. Jansen, K. Marriott, B. Meyer, Cider:a component-based toolkit for creating smart diagram environments, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 415–419. (LNAI 2980).
[153] P. Bottoni, G. Costagliola, On the definition of visual languages and their editors, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 305–319. (LNAI 2317).
[154] Y. Uesaka, E. Manalo, Active comparison as a means of promoting the development of abstract conditional knowledge and appropriate choice of diagrams in math word problem solving, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 181–195. (LNAI 4045).
[155] Y. Uesaka, E. Manalo, S. Ichikawa, The effects of perception of efficacy and diagram construction skills on students' spontaneous use of diagrams when solving math word problems, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 197–211. (LNAI 6170).
[156] R. Cox, R. Dale, J. Etchemendy, D. Barker-Plummer, Graphical revelations: comparing students' translation errors in graphics and logic, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 257–265. (LNAI 5223).
[157] C. Lueder, Diagram ecologies – diagrams as science and game board, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 214–232. (LNAI 7352).
[158] D.J. Bennett, Effects of navigation and position on task when presenting diagrams to blind people using sound, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 161–175. (LNAI 2317).
[159] C. Goncu, K. Marriott, J. Hurst, Usability of accessible bar charts, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 167–181. (LNAI 6170).
[160] C. Goncu, K. Marriott, F. Aldrich, Tactile diagrams: worth ten thousand words, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 257–263. (LNAI 6170).
[161] R.N. Zambrano, Y. Engelhardt, Diagrams for the masses: raising public awareness – from Neurath to Gapminder and Google Earth, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 282–292. (LNAI 5223).
[162] M.T. Bradley, A. Brand, A.L. MacNeill, Interpreting effect size estimates through graphic analysis of raw data distributions, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 117–123. (LNAI 7352).
[163] A. Marcus, Cross-cultural user-experience design, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 16–24. (LNAI 4045).
[164] L.A. Best, A.C. Hunter, B.M. Stewart, Perceiving relationships: a physiological examination of the perception of scatterplots, in: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), 4th International Diagrams Conference, Springer-Verlag, 2006, pp. 244–257. (LNAI 4045).
[165] A.F. Blackwell, A.R. Jansen, K. Marriott, Restricted focus viewer: a tool for tracking visual attention, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 162–177. (LNAI 1889).
[166] C. Matuk, Animated cladograms: interpreting evolution from diagrams, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 395–397. (LNAI 5223).
[167] K. Burns, Bar-Gain boxes: an informative illustration of the pairing problem, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 379–381. (LNAI 2980).
[168] C. Veres, G. Mansson, Psychological foundations for concept modeling, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 26–28. (LNAI 2980).
[169] R. Lowe, J.-M. Boucheix, Attention direction in static and animated diagrams, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 250–256. (LNAI 6170).
[170] E. Saund, J. Mahoney, Perceptual support of diagram creation and editing, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 424–427. (LNAI 2980).
[171] E. Saund, J. Mahoney, ScanScribe: perceptually supported diagram image editing, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2008, pp. 428–431. (LNAI 2980).
[172] H. Gibson, J. Faith, P. Vikers, A survey of two-dimensional graph layout techniques for information visualisation, Inf. Visualization 12 (3–4) (2013) 324–357.
[173] W. Szwoch, Aestheticization of flowcharts, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 423–426. (LNAI 5223).
[174] Y. Kurata, A strategy for drawing a conceptual neighborhood diagram schematically, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 388–390. (LNAI 5223).
[175] H.C. Purchase, D. Carrington, J.-A. Allder, Experimenting with aesthetics-based graph layout, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2012, pp. 498–501. (LNAI 1889).
[176] B. Tversky, J.E. Corter, L. Yu, D.L. Mason, J.V. Nickerson, Representing category and continuum: visualizing thought, in 7th international diagrams conference, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 23–34. (LNAI 7352).
[177] K. Xu, C. Rooney, P. Passmore, D.-H. Ham, A user study on curved edges in graph visualisation, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 306–308. (LNAI 7352).
[178] D.L. Mason, J.E. Corter, B. Tversky, J.V. Nickerson, Structure, space and time: some ways that diagrams affect inferences in a planning task, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 277–290. (LNAI 7352).
[179] E. Mäkinen, H. Siirtola, Reordering the reorderable matrix as an algorithmic problem, in: M. Anderson, P. Cheng, V. Haarslev (Eds.), 1st International Diagrams Conference, Springer-Verlag, 2000, pp. 453–467. (LNAI 1889).
[180] O. Alacam, A. Hohenberger, K. Cagiltay, Effects of graph type in the comprehension of cyclic events, in: A.K. Goel, M. Jamnik, N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 279–281. (LNAI 6170).
[181] L. Yu, J.V. Nickerson, B. Tversky, Discovering perceptions of personal social networks through diagrams, in: A.K. Goel, M. Jamnik,

N.H. Narayanan (Eds.), 6th International Diagrams Conference, Springer-Verlag, 2010, pp. 352–354. (LNAI 6170).

[182] R.R. Hoffman, J.W. Coffey, P.J. Hayes, A.J. Canas, K.M. Ford, M.J. Carnot, One small step for a diagram, one giant leap for meaning, in: M. Hegarty, B. Meyer, N.H. Narayanan (Eds.), 2nd International Diagrams Conference, Springer-Verlag, 2002, pp. 344–346. (LNAI 2317).

[183] K. Burns, Bayesian boxes: a colored calculator for picturing posteriors, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 382–384. (LNAI 2980).

[184] L. Bosveld de Smet, M. de Vries, Visualizing non-subordination and multidominance in tree diagrams: testing five syntax tree variants, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 308–320. (LNAI 5223).

[185] C. Durugbo, Modelling information flow: improving diagrammatic visualisations, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 321–323. (LNAI 7352).

[186] B. Plimmer, T. Hammond, Workshop on sketch tools for diagramming, in: P. Bottoni, M.B. Rosson, M. Minas (Eds.), IEEE Symposium on Visual Languages and Human-Centric Computing, 2008, p. 4.

[187] D. Winterstein, A. Bundy, M. Jamnik, On differences between the real and physical plane, in: A. Blackwell, K. Marriott, A. Shimojima (Eds.), 3rd International Diagrams Conference, Springer-Verlag, 2004, pp. 29–31. (LNAI 2980).

[188] P. Khooshabeh, M. Hegarty, M. Keehner, C. Cohen, Benefits of constrained interactivity in using a three-dimensional diagram, in: G. Stapleton, J. Howse, J. Lee (Eds.), 5th International Diagrams Conference, Springer-Verlag, 2008, pp. 385–387. (LNAI 5223).

[189] M.-H. Yen, C.-N. Lee, Y.-C. Yang, Eye movement patterns in solving scientific graph problems, in: P.T. Cox, B. Plimmer, P. Rodgers (Eds.), 7th International Diagrams Conference, Springer-Verlag, 2012, pp. 343–345. (LNAI 7352).

[190] DRUGG: Diagram Research Use and Generation Group. 2013 ⟨http://diagramresearch.wordpress.com/⟩.

[191] European Conference on Visual Perception. The Art of Perception – The Perception of Art. 2013 ⟨http://www.ecvp.uni-bremen.de/node/51⟩.

[192] Diagrams, Lines and Patterns Working Group. 2013 ⟨http://www.gold.ac.uk/sociology/research-centres/unitofplay/diagrams-lines-patterns/⟩.