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Improving User Comprehension of Euler Diagrams

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***Abstract*—The graphical choices made when laying out Euler diagrams impact upon both aesthetic quality and comprehensiveness. Graphical choices include the shape, size and colour of closed curves which are commonly described as retinal variables to which we are known to be perceptually sensitive. There is copious literature providing guidance as to how best use retinal variables to visualise both quantitative and qualitative information for a wide range range of diagram types. Further, this guidance is explicitly defined to optimise the users' comprehension of such information. However, there exists little, if any, literature affording guidance as to how best to use retinal variables when laying out Euler diagrams. Here we present a novel insight as to where retinal variables manifest in Euler diagrams, how they might influence our perception of Euler diagrams and, as a consequence, provide motivation and guidance for establishing layout guidelines.**

I. Introduction

An Euler diagram is a visual representation of sets and their relationships. They are drawn using graphical elements referred to as closed curves. Each such curve divides the plane into two regions. The interior region represents elements that are members of the set. The outer region represents elements that are not members of the set. The curves are augmented with labels or glyphs pertaining to the represented domain.

Euler diagrams form the basis of various visual languages, such as spider diagrams, as well as being a visual language in their own right. They are regarded as a natural and effective way to depict sets and their relationships and, consequently, are used for both information visualization and logical reasoning. To this end, they can be found in a wide variety of application domains including education, law and architecture as well as the sciences, arts and literature. There is also significant effort and resource devoted towards the automated layout of Euler diagrams. To use them for best effect, we argue there is a need to understand how layout choices impact on user comprehension. Such an understanding is important when manually drawing Euler diagrams as well as for the development of automated layout tools.

Given a data set to be visualized, there are numerous choices of Euler diagram that represent the information. We categorize these choices into three types: descriptional (abstract syntax level), topological and graphical (at the concrete syntax level). To illustrate, figure 1 shows four Euler diagrams that visualise the same information yet vary the choices made. Firstly, the abstract syntax *describes* the set intersections to be represented. Descriptional choices vary between diagrams 1 and 2: diagram 2 has an additional region (called a zone) which is shaded to indicate it contains no elements. Diagram 3 has the same description as diagram 1, yet it has different topological properties because of the concurrency between the curves 'b' and 'c'. Lastly, diagram 4 has the same descriptional and topological properties as diagram 1 yet it is drawn using irregular shaped closed curves. This graphical choice of irregular shaped curves renders a distinctly different diagram from the other three. The authors of [1], [2] provide clear guidance regarding descriptional and topological choices: Gurr's theory tells us that diagrams should be *well-matched* and Rodgers et al. empirically established that diagrams should be *well-formed*. Well-matchedness operates at the descriptional level and tells us to avoid the use of shaded zones. Well-formedness operates at the topological level and tells us to avoid properties such as concurrency. We view these as guides to Euler diagram layout. However, there remains little guidance regarding graphical choices. We now examine perceptual theory and relate this to Euler diagram layout, with particular regard to graphical choices in section II. We then proceed to briefly present the results of two empirical studies concerning , firstly,diagram orientation and, secondly, the shape of the curves used to represent sets.

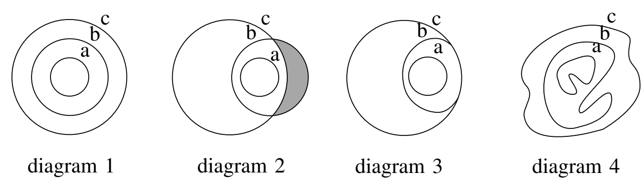

Fig. 1. Choices of Euler Diagram

II. Graphical Choices

Graphical choices are well defined by information visualisation theorists. Bertin's Semiology of Graphics [3], first published in 1967, is widely regarded as one of the classical works of graphical visualisation. Bertin's work, embodied in the theory of graphic representation, recognises our sensitivity to these properties and defines two important visual variables to which we are known to be perceptually sensitive. These variables are referred to as planar and retinal. Planar variables describe the horizontal and vertical position in the plane. Retinal variables describe the graphical properties to which we are known to be perceptually sensitive. We use Bertin's text to dichotomise graphical choices into elements and their properties. Elements correspond to an Euler diagram's closed curves and graphical properties correspond to, for example, their shape, size and colour.

When attending an Euler diagram (i.e. looking at it), detailed vision occurs in a small area of the visual field [4]. During this process, one distinguishes graphical elements and their properties. For example, if one is working at a desk looking at a computer's screen, detailed vision for shape, size and colour takes place in a area of the screen approximately 1.5cm x 1.5cm. To view new areas of the Euler diagram, the eye moves quickly (3 to 4 times per second) between periods of fixation and saccades. During saccades the eye is moving, causing brief periods of blindness. During fixation the eye is static, acquiring detailed information about the Euler diagram. While accruing detailed information we are able to distinguish between the graphical elements. Perceptual discrimination detects the properties of an element defined by the layout and shape of closed curves in the plane. These properties are parsed into their constituent elements and, by a process of figure-ground segregation [5], separated from the plane.

Perceptual configuration organises elemental properties of an Euler diagram into structures and patterns. How these properties are organised is described, in part, by Gestalt psychology and the Laws of Perceptual Organisation [5]. These laws suggest there is a tendency to group portions or elements of an image that are in close proximity, exhibit smooth contours and share similar properties. This phenomena is referred to as contour integration and encompasses a number of principles. The principle of closure is said to form a bridge from perceiving 1-dimensional lines to 2-dimensional shapes and is further explained by the principle of good continuation which suggests the eye easily follows smooth curves. An important aspect of this principle is that changes in good continuation (e.g. when two smooth curves intersect) can yield large changes in shape discriminability.

Consequently, what we perceive when attending an Euler diagram is a complex function of the relationships they convey, i.e. disjointness, intersection and inclusion, coupled with the graphical elements and their properties manifest in their concrete syntax. Perceptual theory concerning graphical choices leads us to ask specific research questions concerning user comprehension of Euler diagrams. Specifically, we are led to ask how the retinal variables of the shape, size and colour of an Euler diagrams curves impact users' ability to accurately and quickly interpret Euler diagrams. In addition, we can perceptually distinguish shapes, which are visually different under rotation because their horizontal and vertical position is altered. Therefore we should examine whether the orientation of an Euler diagram impacts user comprehension.

III. Research Contributions

Our overarching research aspiration is to improve user comprehension of Euler diagrams. We argue that user comprehension can be improved if better graphical choices are made when laying out and drawing Euler diagrams. This aspiration can be realised, at least in part, by conducting a series of empirical studies. The studies described below are user-centred and utilise a model based on a between groups with repeated measures design. Consistent with other researchers who have undertaken similar studies, we measure comprehension in terms of task performance: one Euler diagram is regarded to be more comprehensible than another Euler diagram if participants can interpret it, on average, more quickly and with fewer errors. To date we have focused on orientation and shape, with size and colour remaining the subject of future work.

Our first study addressed the question 'does the orientation of an Euler diagram affect user comprehension?' [6]. An Euler diagram can be rotated in the plane without any impact on either its description (abstract syntax level) or topology (concrete syntax). However, if we take an Euler diagram and rotate it an arbitrary amount we render two perceptually distinct diagrams. While the description and topology remains the same, the curves and regions will occupy different positions in the plane. Given such stark visual discrepancies we conducted an emperical study to see whether orientation impacted user comprehension. Interestingly, we concluded that orientation does not significantly affect comprehension and we concluded that orientation should not constrain aesthetic choices when laying out and drawing Euler diagrams.

Our second study addressed the question 'does the shape of an Euler diagram's closed curve affect user comprehension?'. We have recently completed this study and are currently in the process of analysing the data. The study compared 'identical' Euler diagrams with respect to their underlying description and topology but each one was drawn with different shapes of curves. We chose to use circles, ellipses, squares and rectangles to draw closed curves as these were indicative of the most common shapes found in application domains. Our preliminary analysis strongly suggests that the time it takes to interpret an Euler diagram is significantly effected by the shape of its closed curve. In particular, participants performed significantly better when interpreting Euler diagrams drawn with circles than any of the other shapes.

IV. Conclusion

We cannot escape our perceptual sensitivity to Euler diagrams. This observation has been reinforced with the results of our studies which established that orientation does not affect comprehension, unlike shape. We are, therefore, strongly encouraged to continue our research in this direction. To this end, we intend to study the effect of other retinal variables, such as size and colour, on user comprehension of Euler diagrams. In turn, we will fill a gap in the research landscape. We intend to develop guides that establish how to use retinal variables such as shape, size and colour, to draw effective Euler diagram. These guides will complement existing literature that already informs descriptional and topological choices.

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