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Comparing Epistemic Frames: An exercise in visual comparison

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Abstract

We consider the comparison of Epistemic Frames as an example of a visual comparison problem. Epistemic Frames (also known as Epistemic Networks) are a representation used by Learning Scientists to encode the state of one's knowledge about a domain. The data consist of association strengths between a set of concepts, which can be thought of as edge weights of an undirected graph. The important tasks involve comparing networks or their trajectories. We describe the nature of the data and the tasks and some of our initial efforts to create visualizations of the data including using the problem as a design challenge in a class. We also discuss how this problem is indicative of the general class of visual comparison problems.

1. Introduction

Comparing complex data objects is a challenging task that occurs in many domains. Visualization typically focuses on examining a single object, rather than comparison: many methods for exist for displaying a graph, molecule, or volume, but few tools help directly with comparing these objects. This poster describes our initial work on a specific comparison problem from Learning Science: comparing Epistemic Frames. While the data is typically small, the Epistemic Frame (EF) comparison problem provides a rich domain for exploring issues in visual comparison.

The Epistemic Frame (or Epistemic Network) Hypothesis is an idea in Learning Science that a community of practice (such as Urban Planning or Journalism) has a set of entities that are important, and must be bound together correctly for one to be a successful practitioner [Sha06]. The set of entities (skills, knowledge, identity, values, and epistemology) is defined for the community. An individual's Epistemic Frame is a measurement of how closely coupled these entities are for that person at a particular time. The idea of the EF theory is that a particular pattern of connections is important, and the training process in a field develops the correct connections. Epistemic Frames give a tool for the design of pedagogy, as it suggests what kinds of connections students must be assisted in developing, as well as a tool for assessment, by measuring students' frames to see if they are becoming more like experts or watching the trajectory of their frames to measure their progress.

Abstractly, EFs are weighted networks. The entities form the nodes. The set of nodes is common to a domain (frames for journalism have the same nodes). For any individual, there will be a measured set of weights between each pair of concepts. The networks are dense graphs. Comparisons are always made between frames with the same sets of nodes. The abstract data type of small, dense, weighted networks probably exists in other fields (e.g. a social network measuring strength of association between people) although we have not seen study of comparing this type of data.

The data for an EF can be encoded as an association matrix storing the strength of the connection between each pair of concepts. Since the connections are symmetric, only the upper triangle of a matrix is important. The connection strengths are estimated by coding observations. The measurements are noisy and the connection values must be normalized to account for the different total number of observations used to determine the measurements. Because of the limitations of the process of obtaining measurements, the frames are typically small (6-20 items). Even as automated measurement is developed, we expect the size to stay small (a few dozen), as the sets are designed specifically. While the number of nodes might be small, the actual data to be compared grows quadratically.

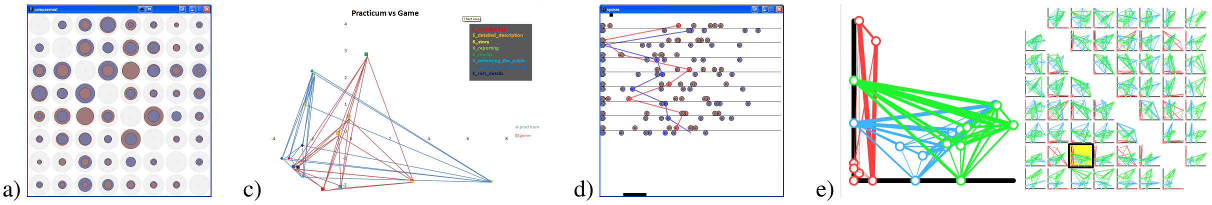

Figure 1: *4 of the initial designs: a) matrix view using size of circles; b) dimensionality reduction; c) spoke view; d) matrix of 2D dimensional projections (a selected projection comparing 3 frames on left).*

1.1. Tasks

The tasks that we consider all involve a set of frame measurements (association matrices). Each measurement might be an individual measurement (a particular person at a particular time), or an aggregate measurement (the average of a class at a particular time, or the average of an individual over a number of times. For all tasks, scientists need help in making an initial assessment (e.g. overall, are these networks more or less similar), as well as being able to drill into the specifics (what particular elements are similar or different).

Our initial efforts focus on tasks involving comparison of a small number (2-4) frames. For example, we might have 3 different classes and ask which are most similar, or look at an individual an decide are they more like one category or another (novices vs. experts). Another category of questions involves the *trajectories* of frames: how an individual or group evolves over time. For example, a user might see if a trajectory is moving towards a desired goal. The most challenging questions involves comparing trajectories.

2. Initial Designs

We considered a number of designs, based on common ways to show individual graphs. Several are illustrated in Fig 1.

Matrix Views: show the array of weights as an array, similar to writing out the matrix. The array might be depicted using numbers to show each value, or some other visual encoding such as color or circle size (Fig 1a). To compare frames, we either presented the arrays side-by-side, or superimposed the arrays (showing the value from each network within each array cell). While array views are quite effective for examining individual connections, our users felt they were ineffective for seeing patterns or making overall judgements.

Graph Layout Views: encode the data of weights by the positioning of the nodes in a graph. Connection strengths are used to suggest the distance between nodes. Standard force-directed graph layout methods were applied. While our users like the graph layout views in principle, they proved ill-suited for tasks as they do not readily support comparison. Fixed (e.g. radial) layouts encoding strength as edge thickness or color were deemed too difficult to interpret.

Dimensionality Reduction: considers the association matrix (with its redundant symmetry) as a high-dimensional data set. Principle Components Analysis (PCA) is used to project this to 2 dimensions. The nodes are then drawn on this plane, and edges are connected (Fig 1b). For comparison, one of the frames was used to compute the principle components, and others projected onto the first two vectors from that reference frame. Issues with this approach stem from the lack of direct interpretability.

Other encodings: We also explored other encodings of the data, for example using one line for each node and encoding the weights as positions along those lines (Fig 1c). While some of these visual encodings could be animated or superimposed nicely, none provided satisfying overviews.

2.1. Student exploration of the Design Space

EF comparison was assigned as a design challenge to students in an inter-disciplinary, graduate-level visualization course. Students teams generated potential solutions that were discussed with domain collaborators. While many designs were variants of the main categories above, some new ideas were discussed based on perceptual topics discussed in class and ideas brought from the varying backgrounds of the students. These ideas included the use of the eye's natural symmetry seeking ability by presenting mirrored views of the matrices, richer statistical analyses, and animated interaction techniques. The ddomain experts prefered traditional views coupled with interaction, such as a tool for exploring all possible dimensional projections (Fig 1d).

3. Future Directions

Our experiments with trying to provide for visual comparisons of EFs have not yet yielded satisfactory solutions. Good methods for a single frame do not necessarily lead to meaningful comparisons or scale to large multi-way comparisons, viewing trajectories, or to compare trajectories.

The various ways in which our designs have failed to scale to comparisons suggest general issues in the creation of comparative visualizations beyond those for displaying individual objects. For example, when doing comparisons, the encodings may need to be "stable" (small changes in the data should yield small changes in the results), animatable (the parameters that change can be smoothly varied), and overlayable (that is, to afford superposition which requires being in a similar spatial arrangement, and having sufficient "space" for other objects).

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References

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