Diagrams 2004 - 3rd Intl. Conference on the Theory and Application of Diagrams, University of Cambridge, UK, March 22-24, 2004. Appears in Diagrammatic Representation and Inference, A. Blackwell, K. Marriott and A. Shimojima, Editors, Lecture Notes in Artificial Intelligence 2980, Berlin: Springer-Verlag, pp. 376-378.

Constructing Diagrams Representing Group Motions [1]

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Abstract. Certain domains, such as military activities and weather phenomena, are characterized by a large number of individual elements moving in a field, either in pursuit of an organized activity in groups at different levels of aggregation (military action), or subject to underlying physical forces that cluster different elements in different groups with common motion (weather). Reasoning about phenomena in such domains is often facilitated by abstracting the mass of data into diagrams of motions of groups, and overlaying them on diagrams that abstract static features into regions and curves. Constructing such diagrams of motion basically calls for clustering at different time instants and joining the centers of the clusters to produce lines of motion. However, because of incompleteness and noisiness of data, the best that can be done is to produce plausible hypotheses. We envision a multi-layered abductive inference approach in which hypotheses largely flow upwards from raw data to a diagram to be used by a problem solver, but there is also a top-down control that asks lower levels to supply alternatives if the original hypotheses are not deemed sufficiently coherent.

1 Introduction

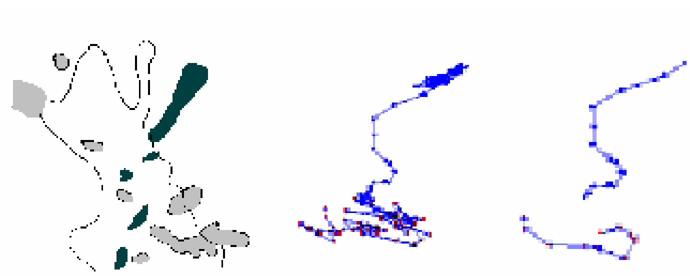
In different domains, often the locations of a large number of entities at close intervals of time are available, but in order to be useful it is often necessary to abstract from this mass of information a condensed representation of salient information to the decision maker. Specifically, we wish to construct a diagram that captures the motions of significant groups of entities. Constructing such diagrams involves making hypotheses about groups at various instants and coming up with a hierarchical grouping hypothesis that is consistent across time. This diagram is to be used by a higher level diagrammatic reasoner for situation understanding, i.e., constructing an account of what

[1] The research was supported by participation in the Advanced Decision Architectures Collaborative Technology Alliance sponsored by the U.S. Army Research Laboratory under Cooperative Agreement DAAD19-01-2-0009. We thank Robert Winkler and John Josephson for their help in the work.

is happening at higher levels of description. In the current paper, we discuss several issues related to the construction of such diagrams, with emphasis on the special features of the domain of interest, viz., construction of coherent accounts of groups and their motions from data obtained about the locations, sampled at several time instants over hours, of a large number of military units engaged in an exercise. We also outline an algorithm that solves some aspects of the problem. This part of the paper is in the spirit of an interim report on a large project

2 Discussion of the Problem

Different types of diagrammatic abstractions for different inferential needs. A military commander looking at a movie – suitably speeded up – of thousands of military units, each represented by icons that point to their type, moving over a field that is marked with information corresponding to terrain and the location of the forces and assets of the other side will often quickly start making hypotheses about the plan, along the way constructing on a map of the region a diagram of locations and motions of various groups. Different types of diagrammatic abstractions help for different problem solving needs. The motions of individual units might be abstracted into motions of "blobs" [1]. This abstraction (below left, redrawn from the image produced by the algorithm in [1]) is useful when for inferences where the spatial distribution of the group in motion is relevant, but it requires a temporal display like a movie. The same motions might also be abstracted into curves of motion (below center and right, of the same data), helping the problem solver to focus on direction of motion alone. In either case, enormous amount of detail about the individual units is discarded so that salient phenomena can be attended to.



Relevant and irrelevant motion. Depending on the specific inference need, a certain detailed bend in the curve of motion may be relevant or irrelevant and, for perspicuity, the motion line may be straightened. The curve on the right in the picture is a further abstraction of the figure in the middle, by abstracting away details in the motion.

Available information is incomplete and noise-laden, but requirements of consistency can be exploited to overcome these problems. At different time instants, information about different units might be missing, and even when available, is prone to be noisy. Fortunately, we are not interested in the behavior of the individual units, and a robust summary of group behavior can still be constructed even in the face of noise and incompleteness. We can exploit the fact that phenomena have a lot of consistency – physical constraints make it impossible for radical changes in membership of groups at neighboring time instants.

Detailed identity information is useful, but not essential. Our experiments indicate that the individual identity information is not crucial. This is good because real world data often do not contain identities of individuals.

Information flow downwards from higher levels of problem solving can be used to improve lower level hypotheses. The diagrams are intended to be used for higher level problem solving, such as guessing the plans of the sides, either by an automated reasoning system, or by a human viewing the diagram on an interface. When such problem solving faces inconsistencies, that is a signal for selected lower level decisions to be questioned and alternate solutions are sought. Appropriate design of these algorithms should be able to make use of such top-down information flow.

3 Solution Approach

We model the problem as one of *layered abduction* [2]. Each layer performs abductive inference, i.e., takes data to be explained and produces the hypotheses that best explains the data. In layered abduction, explanations from one level become the data to be explained at the higher level. In our work, the grouping and motion hypotheses are performed at one or at most two layers. Clustering algorithms produce a small number of alternative grouping hypotheses for each time instant, and hypotheses are chosen at instant such that the combination of hypotheses across time instants is consistent. (That means that the overall hypothesis of motion of groups may not consist of a sequence of best hypotheses at each instant.) The best grouping and/or motion hypothesis is passed on to the problem solver. The problem solver will use the diagram to build an account of the maneuvers. If more detail is needed or the diagram as supplied does not produce a consistent account, the problem solver identifies an alternate hypothesis for the relevant part of the diagram, and the lower level algorithm will attempt to see if a plausible group or motion hypothesis is possible with that alternative hypotheses. Lower level abductive algorithms have been constructed that interact with a stubbed higher level problem solver, and work is continuing on the problem solver.

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