Initialising and Terminating Active Contours for Vague Field Crisping

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1. Introduction

Many aspects of spatial language concerned with real-world features and the relationships between them are essentially vague. While this vagueness is managed quite effectively in natural language communication between people, there are currently only very limited facilities for interpreting such language when used to communicate with computers. To overcome this shortcoming a field-based model has been developed to provide a continuous representation of the spatial aspect of this vagueness.

Using fields to represent spatial information is not a new idea. Couclelis (1992) described how people alternate between a field and object views of the world, something a GIS also needs to be able to do. Yamada et al. (1992) describe a field-based system for locating the area described by a spatial expression. Liu et al. (2008) present a general field model and Guo et al. (2008), use fields to model the uncertainty and error in expressions such as “10km N of Kuala Lumpur”.

2. Vague Fields for Representing Spatial Information

The field as defined in this work is a matrix of field intensity values that vary between 0 and 1. The semantics of these field intensity values is that they represent how confident the field is that people would describe the cell as part of the area described by the expression. For an expression such as “Photo of a tree near Stackpole”, the value of each field cell specifies how “near” it is to “Stackpole”.

For some purposes, like ranking results in an IR task, the vague field can be used directly, but for many other methods it is necessary to transform the continuous field into the object representation that is used in most GI methods and systems. Such a transformation is called a crisping and various methods exist for creating such a crisp representation, with one frequently used method being thresholding, where the crisp boundary is drawn so that all field cells within the boundary have a field value higher than the threshold and all cells outside a lower value. The problem of this approach is that it can create very jagged outlines, even for seemingly smooth fields and that the integration of further constraints on the outline can be difficult. To overcome these shortcomings a more flexible crisping method based on active contours has been developed.

3. Active contour based crisping

Active contours are energy minimising splines, that were initially developed for delineating boundaries in medical image analysis Kass et al. (1988), but have also been used in a GIS context by Guilbert and Saux (2008). In most cases two energies are defined that shape the active contour. An internal energy maintains the cohesion of the active contour, and an external energy defined by the domain warps the active contour into the desired shape. Hall and Jones (2008) gives a detailed description of how these energies are iteratively applied to the active contour to create the boundary (see example in Figure 1). This paper expands upon that work and provides approaches on the problems of active contour initialisation and termination.

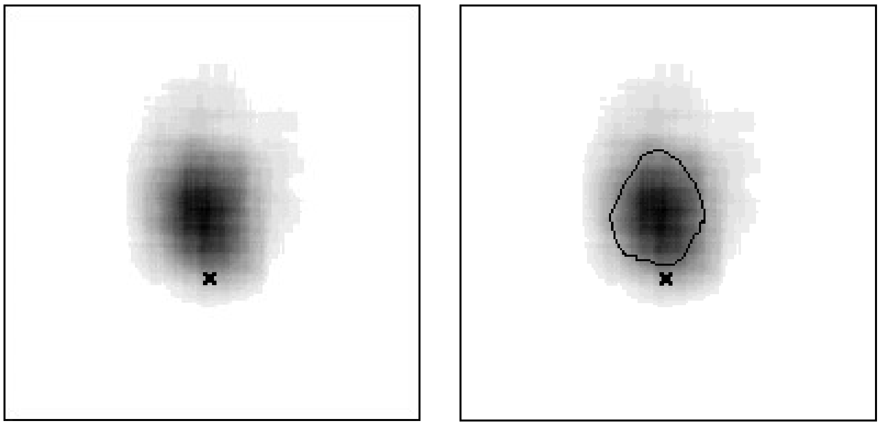

Figure 1. Vague field for the spatial preposition "north of" (left) and a crisping of the field (right, black line). The black x marks the position relative to which the field models"north-of-ness".

3.1. Active Contour Initialisation

Initialising the active contour is an important question, as the initial shape of the active contour directly influences the result quality and processing time. A simplistic approach would be to initialise the active contour as a rectangle around the whole field. While this is guaranteed to produce a consistent result, it is computationally inefficient. A more precise initial shape is required, without sacrificing result quality.

The basic concept for this more optimal initialisation is to use an arbitrary thresholding of the field as the initial shape. More complex spatial expressions such as "Old tree near Stackpole, north of the lily ponds in Pembrokeshire, UK" create multiple fields ("near Stackpole", "north of the lily ponds", "Pembrokeshire", "UK") and to avoid having to threshold the combination of these fields the active contour is initialised using only the field created by the first spatial sub-expression ("near Stackpole"), based on the assumption that the first sub-expression is the focus of the whole expression. The threshold is calculated on this field and then to simplify the initial shape the convex hull of the threshold points is determined, the vertices of the convex hull becoming the control points of the active contour.

3.2. Active Contour Termination

The second problem is how to determine when to stop the active contouring process. The simplest approach is to place a hard limit on the number of iterations that the active contour runs through. This has one major problem and that is that it is impossible to find one number of iterations that always produces good quality results and is computationally efficient. If the number of iterations is too small, then the result might not be correct, as there were still major changes happening in the active contour's shape. On the other hand choosing too high a number leads to wasted iterations, after the active contour has already achieved its final shape. To overcome this a dynamic termination based on the total energy (the sum of energies acting on all control points) in the active contour and the number of modified control points is presented. Clearly evaluating the number of control points that move between iterations is the most precise method, but also computationally very intensive, so the total energy changes are used as filters to determine when to check control point modification.

In order to be able to evaluate the active contour changes, a history of the control point locations and total energies for the previous ten iterations is maintained. On the total energies two thresholds α and β are used to determine when to check control point locations, where α is the maximum total change between the oldest and newest item in the history and β the maximum change between consecutive steps. In the shape comparisons the newest shape is compared to all previous shapes by calculating the number of control points that have moved. The comparison is based on the set of control point coordinates and not control point identity, in order to not falsely detect control points switching location as active contour changes. The active contour terminates if the number of modified control locations is zero or a hard limit of 2000 iterations is reached to guarantee termination.

4. Conclusions

Vagueness in natural language expressions needs to be modelled to enable their use in GIS, and a field-based model has been developed for this task. To integrate this continuous vague field with existing, crisp GIS methods and systems an active contour based crisping algorithm has been developed. This paper focuses on how to initialise and terminate this algorithm.

For the initialisation problem an algorithm was presented that determines the central field in the spatial expression and then uses a combination of thresholding and convex hull calculation to provide an initial shape for the active contour. Termination is based on a two-step approach that combines the total energy acting on the active contour and the movement of the active contour's control points to determine when the final active contour state has been reached. The combination of these two methods improves the efficiency of the crisping algorithm, while maintaining the result quality.

Future work will focus on evaluation. A series of human-subject tests is planned to determine how people rate the crisp shapes. Further spatial prepositions and handling of more complex spatial expressions is also being investigated.

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Biography

Mark M. Hall
Mark Hall is a PhD student focusing on spatial computational linguistics. His research interests lie within the areas of geographic information systems, semantics, linguistics, cognitive sciences and ontologies. Currently his focus is on spatial language, how it is used and what people understand when they hear or read spatial expressions.

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Chris Jones has been Professor of Geographical Information Systems (GIS) in the School of Computer Science at Cardiff University since 2000, having held previous academic positions at the University of Glamorgan, and the University of Cambridge. Research interests include geographical knowledge representation and indexing methods for spatially-aware web search engines.