Notes

GIS As a Spatial Decision Support System for Offshore Pipeline Route Optimisation

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Geographic Information System (GIS) applications have grown from inventory and map drawing systems to ones that support comprehensive methods of analysis. The functionality that they now support has led to the proliferation of Spatial Decision Support Systems (SDSS). SDSS are computer based packages that display criteria for objective viewing, thereby supporting the decision making process. An example of the use of GIS as an SDSS is their implementation in the offshore oil and gas industry. A research project undertaken at The University of Edinburgh examined the use of GIS in the optimal routing of offshore pipelines. This is a task that is important to engineers, as proper initial investment leads to reduced installation costs and maintenance. Poor decisions in the routing of a pipeline may lead to higher long-term expenses and in the extreme case, pipe abandonment.

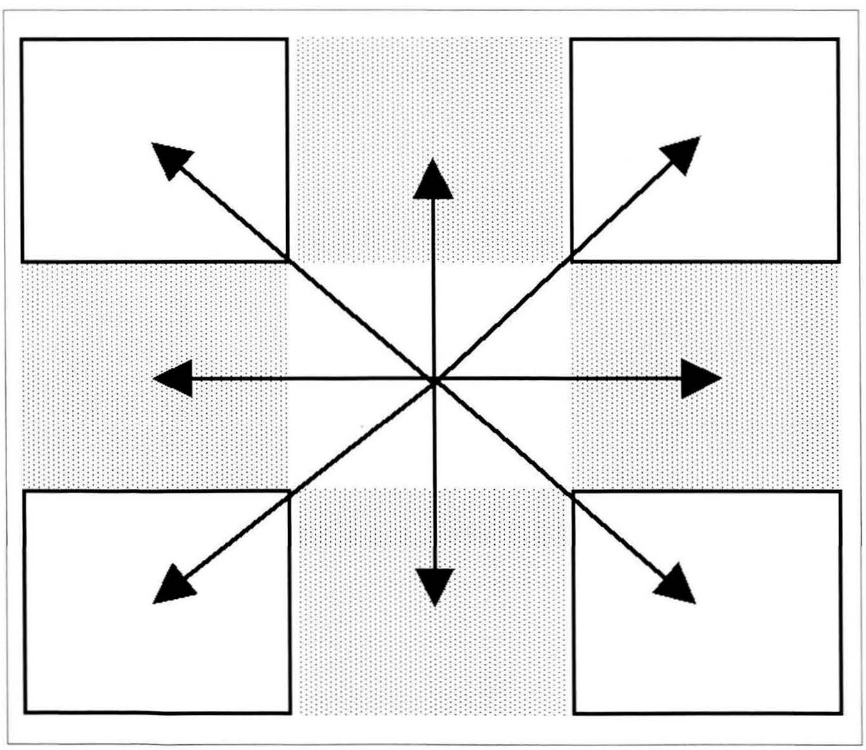

Figure 1: Defining the potential path through space using a cell based approach

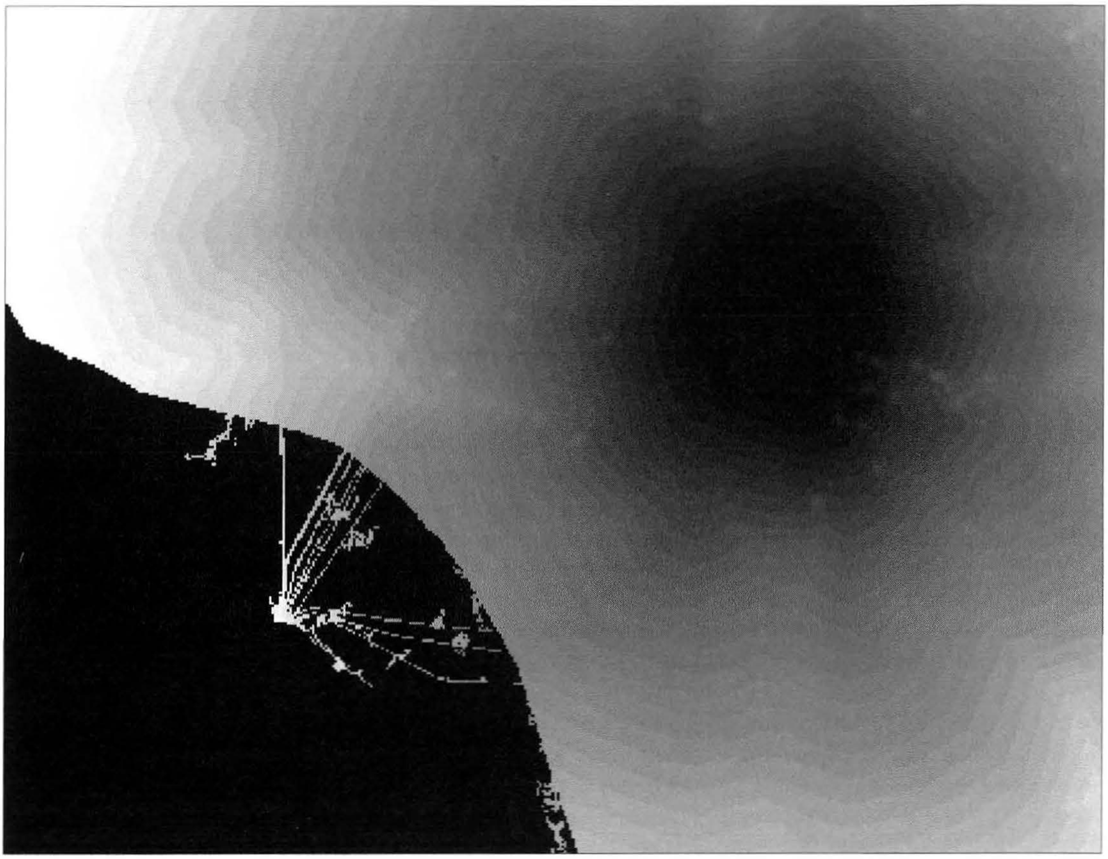

Figure 2: Distance calculation grid (dark areas are low cost and light shaded areas are high cost)

Route selection of an offshore pipeline is a *complex multiple criteria* problem, where there is no clear answer to the question. Selection of a route is done case by case and involves instinct and experience. Engineers must consider a wide variety of criteria, including social, economic, legal or environmental factors. Some criteria may be easily modelled mathematically, while others are more subjective. All these factors react and interact with each other, creating a dynamic system. In essence the final decision is a compromise within a set of competing constraints. Presently, route designs are carried out by hand and on CAD packages. The incorporation of GIS enables us to consider a range of variables and to explore 'what if' situations by altering the degree of importance attached to criteria.

Modelling Movement and Cost

Choice of route is influenced by factors such as 1) morphology of the seabed and slope, 2) existing infrastructure, 3) the need to avoid licensed exploration blocks 4) variation in stability of sediments, 5) avoidance of wrecks and fishing grounds, and 6) a desire for the shortest path. Such factors can be modelled as a set of cost surfaces. Regions to be avoided have a high cost, whilst ideal areas have a minimum cost. By weighting the surfaces (according to their relative importance), and combining them, it is possible to apply a least-cost path algorithm that searches through the cost surface, connecting start and end points via a route that is the minimum accumulated cost. Thus Least-Cost Path algorithms (LCP) are geared towards determining optimal paths based on user defined cost functions. LCPs are applied using a cell based approach, in effect dividing the space into discrete regions (Figure 1) and restricts movement from one cell centre to its surrounding eight neighbours' centres, via a user defined function.

Cost Surfaces

Once all of the relevant available marine survey data was collected, such as bathymetry, and sites of scientific interest, each variable was made into a map layer and converted into a cost surface. Cost surfaces are map layers in which restrictions are placed on a map variable through: logical/boolean operations, arithmetic operations and datatype operations. Some cost surfaces were created through the use of buffers, which formed a halo representing a physical barrier within the system interpreted as a non-traversable area. The degree to which the algorithm was deterred from crossing the buffer depended on whether the buffer used was absolute or graded. An absolute buffer, if crossed, will incur a higher cost on the route, whereas a graded buffer will draw a variable cost depending on the degree of infringement of the buffered zone.

Weighting and the Overlay Process

Each factor is modelled as a cost grid to which we apply a weighting according to the importance of that variable in the decision making process. The weight values were derived from questionnaire responses received from various offshore contractors. Contractors rated the variables on a scale of 1-10 based on their experience. These ratings were then used as the weights for each layer, and defined cost grid importance in relation to the others.

The next phase was the calculation of the Euclidean distances between each of the cell centres to each of it's neighbours within the grid, beginning from the start point. This was done using an *accumulated average of movement function* between the two cells. In essence the cost of movement (distance) between cell one and two would be mathematically added to the cost of movement between cell two and three, and so on (Figure 2).

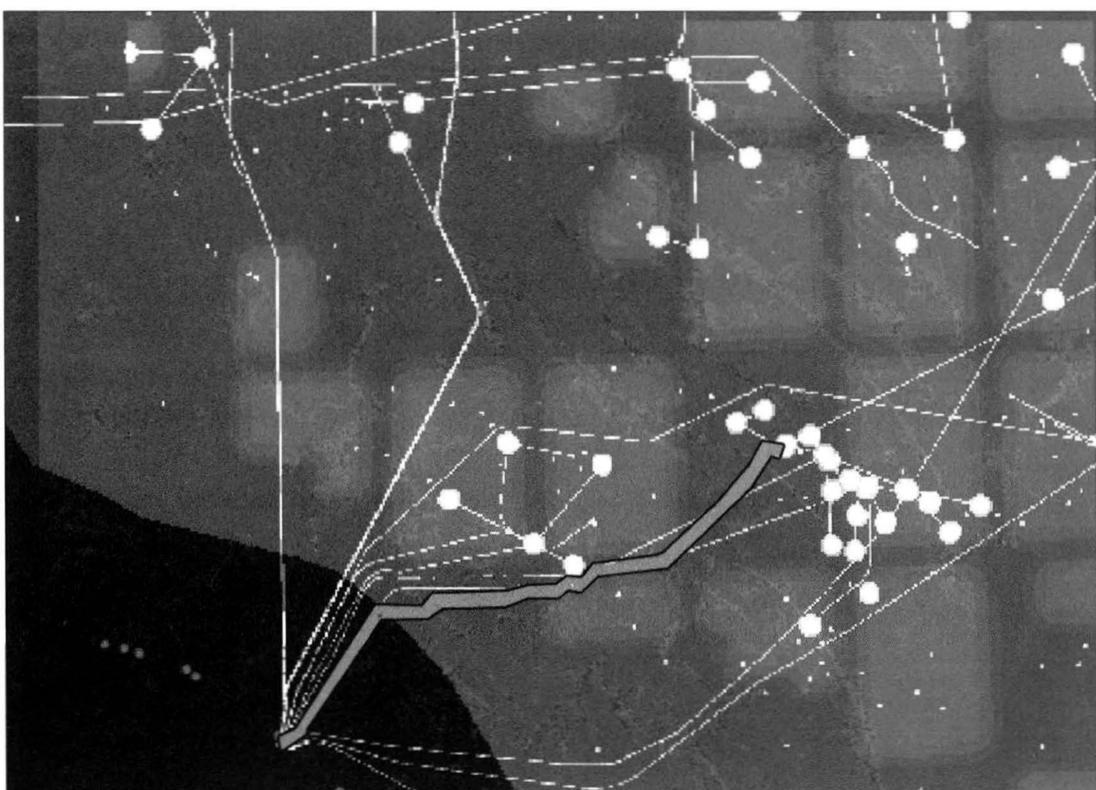

Figure 3: Result of applying the LCP algorithm to the combined surfaces (light regions are areas of high cost, dark areas are regions of low cost)

Figure 4a: Striped line indicates a route based on minimising changes in slope, whilst in Figure 4b the black line is a route placing more emphasis on the existing infrastructure

The overlay process resulted in a final cost grid to which the LCP algorithm was applied (Figure 3).

Changing the Landscape

Implicit in the idea of weighting criteria differently is the notion that this is a subjective process. The results merely reflect different emphasis or importance relative to others. This was reflected in the range of orderings given by respondents to the questionnaire. The interviews helped to rank the variables according to different criteria. This approach does not preclude the addition of other data as and when it becomes available. GIS coupled with simple forms of visualisation enables decision-makers to better understand relative importance of competing criteria, and to gain insight into the overall cost of such a project. Figure 4 shows alternate paths for a pipeline connecting a drillhead to the mainland. In Figure 4a the emphasis (or weight) was given to minimising bathymetric slope change, whereas in Figure 4b other criteria such as the existing infrastructure were allowed to influence the decision.

Evaluation

Several of the results proposed were close to those of the existing pipeline. Routes suggested by the system were within reasonable boundaries, and it was shown that the potential to integrate additional factors was possible. The system requires further sensitivity analysis and evaluation, as well as a more thorough analysis of the quality of the input data. As with any decision of this nature, it is important to develop confidence and belief in the system before it becomes an integral part of the human decision making process.

Acknowledgement

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Biography

Alexandra Bade completed her MSc. GIS at the University of Edinburgh in September 2000, and is currently working at Laser-Scan Ltd. in Cambridge. William Mackaness is the course director of the MSc by Research in Geographical Information Science at The University of Edinburgh.

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