

**Final report on the contribution of Cambridge University to  
Esprit project P 940 on Depth and Motion Analysis**

H B Barlow, 9 Nov '90

We ceased work on this project with the departure of Dr Hentschel. A brief summary of the contributions we have made follows.

**Choice of primitives and segmentation** We studied the strategies used by human vision in stereo-matching, since these may be helpful in designing the system to be used by the mobile vehicle. This led us to emphasise the importance of segmentation, since segment boundaries can be shown to have special significance in human stereo-matching. The boundaries of importance appear to correspond to discontinuities or occluding contours, and the disparity of quite prominent features within these borders is often ignored. Occluding edges may prove to be reliable features for building up 3-D maps from multiple views.

**Mapping, parallelism, and choice of edge-segments** Work was done in setting up a model environment suitable for testing ideas about the use of ray-tracking (volumetric methods) and occlusions for mapping free space. This line was abandoned in favour of the Delaunay triangulation methods. We emphasised how the parallel methods of performing tasks found in biological systems gave them great robustness compared with any single method. We also emphasised the importance of selecting edge-segments for stereo tasks and for use as landmarks: not all segments of equal optical prominence and certainty are equally useful in performing visual tasks.

**Global matching** Using a 2-D projection on to the ground plane for matching the current scene to a stored representation of the environment is simpler, more economical, and potentially more noise free than using full 3-D representations, but has serious shortcomings. Using 3-D edge segments also has problems, and we were therefore led to consider the nature of the representation problem from a more abstract point of view. The essence of the problem is how to group the information provided by an edge-finder to generate representational entities that are more robust and noise free than the edge segments of which they are composed. This line of thought points in an interesting direction but not one that could be pursued within the Esprit project. We were however able to suggest some simple heuristics for guiding the search for matches of edges.

**Route planning** We proposed and implemented in a simulated environment a method a method of route planning that would give the shortest route to a given destination. This used a wave-propagation method and is very similar to an algorithm successfully used for path finding in VLSI circuits. The algorithm gives minimal paths and their lengths.

**Benefits to our group in Cambridge** It would be ungracious to conclude without mentioning the considerable benefits we have derived from participating in the project. This of course includes the contributions Esprit has made to our equipment, but there have been additional intangible benefits that can be summarised under these heads.

- 1) It gave us an inside and direct view of the "state of the art" in robot vision. This is not at all easy to gain from publications and conferences, but is obviously very useful as it enables one to see what are the unsolved practical problems, and what may be the theoretical lacunae that underlie the difficulties.
- 2) It directed our attention to the interesting problems that underlie position finding, and we believe this insight may also apply to the biological problem.
- 3) We were fascinated to see the extent of data-reduction accomplished by edge-finding, but wondered whether this was not too drastic to yield a robust and reliable system. It is not simply that much of the information discarded should be useable, but we also formed the opinion that a level of description above that of linked edges will have to be developed and made use of before robot vision develops into a practical tool. This has lead to our current interest in segmentation and object recognition.

H B Barlow

Cambridge, UK

9 Nov '90