Homing in Virtual Environments

Bernhard E. Riecke, Hendrik−Jan van Veen
and Heinrich H. Bülthoff

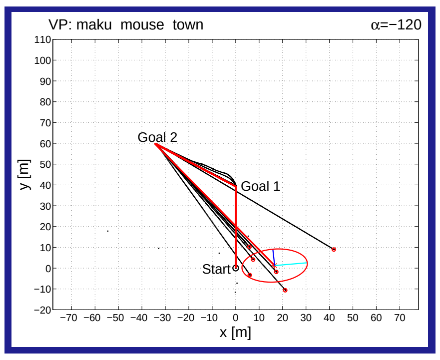
Max−Planck−Institute for Biological Cybernetics • Tübingen • Germany

E−mail: bernhard.riecke@tuebingen.mpg.de

MOTIVATION

Is optic flow information sufficient for homing by path integration?

Results from previous studies (e.g. Loomis et al., JEP, 1993) suggest that proprioceptive cues play a major role in human homing behaviour. We conducted triangle completion experiments in virtual environments to measure homing performance based solely on visual cues. In such experiments subjects have to return to their starting point after moving along two prescribed segments of an imaginary triangle. We were specifically interested in the role of visual landmarks versus optic flow in these homing tasks.



The figure shows typical examples of trajectories that subject ***maku*** produced in our experiment. The underlying isosceles triangle can easily be recognized. Single trajectories are plotted as black lines and their endpoints (i.e., the behavioural estimates of the starting point) are marked by red dots. The average trajectory (red line) and endpoint (red star) as well as a 1 sigma confidence ellipse are plotted too.

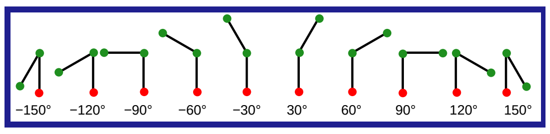
METHODS

We conducted triangle completion experiments in virtual environments.

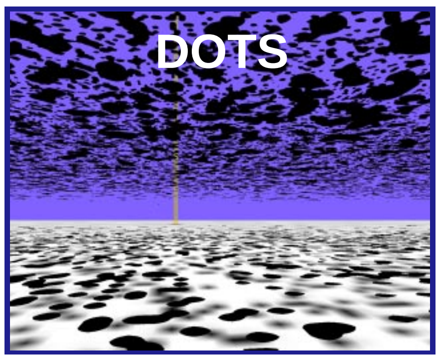
To exclude scene−matching as a homing strategy all landmarks were replaced just before the return path ("scene−swap").

Subjects were seated in the centre of a large half−cylindrical 180° projection screen and steered smoothly through the simulated scene using mouse buttons. Experiments were conducted in two environments: an extended volume filled with random dots or blobs (inducing strong vection), and a photorealistic town containing distinct landmarks (see pictures on the right). On each trial, subjects had to move from their starting position [•] to two subsequent goals ([•], indicated by vertical 'lightbeams' positioned in the scene). Those goals were not simultaneously visible. Upon reaching the second goal, subjects had to return to their starting point. To exclude scene−matching as a homing strategy, all landmarks in the scene were replaced by others during a brief dark interval just before the onset of the return path ("scene−swap" condition).

The first two segments of every triangle were 40m long and subtended an angle of 30, 60, 90, 120, or 150° to either side.



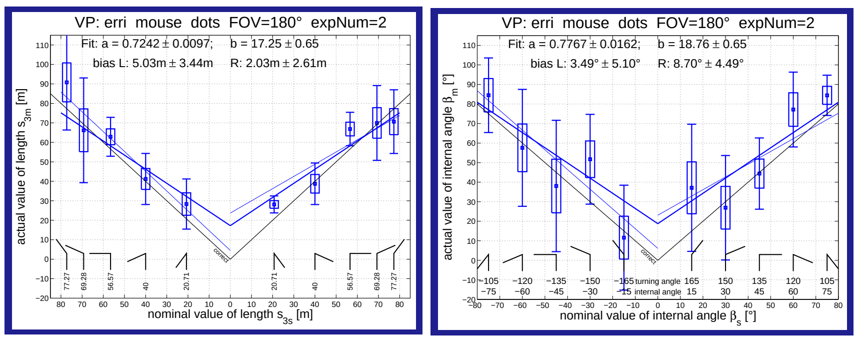
Eighteen subjects (10 female, 8 male) participated in the two main conditions, the DOTS−scene and the TOWN−scene, and seven of them participated in a control condition with the TOWN−scene but without scene−swap (thus allowing scene−matching as a strategy). Three additional subjects were unable to perform the task and were excluded from further analysis. The experiments were completed in single one−hour blocks of 60 homing trials per condition, i.e., 6 repetitions for each of the 10 different triangle geometries.



RESULTS

We found strong systematic errors in distance travelled but only small deviations in turning angles.

For each trial we compared the length and direction of the actual (measured) third segment with the nominal (correct) values. The graphs below show typical examples of actual versus nominal length resp. angle for a single subject in the DOTS condition. Notice the compression of response range for both length and turning angle. The compression rate is quantified by the slope of the linear fit to the data.

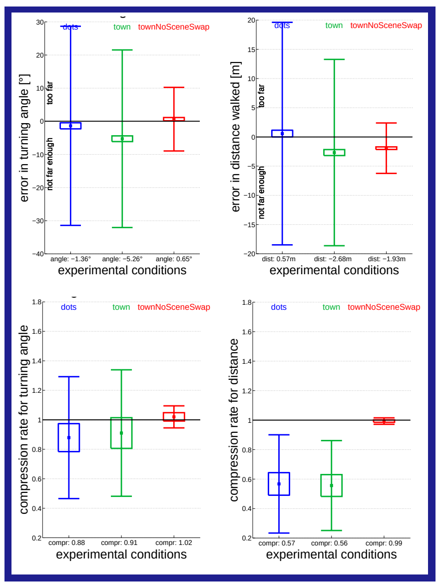


The left graph shows the actual turning angle versus the nominal value for subject ***erri*** in the DOTS condition. The right graph shows the actual length of the third segment (distance travelled) versus the nominal value for the same subject in the same condition. The solid black V−lines indicates correct behaviour, the solid blue lines symbolize linear fits to the data. Boxes and whiskers are centered around the mean and denote standard error of the mean and the standard deviation respectively.

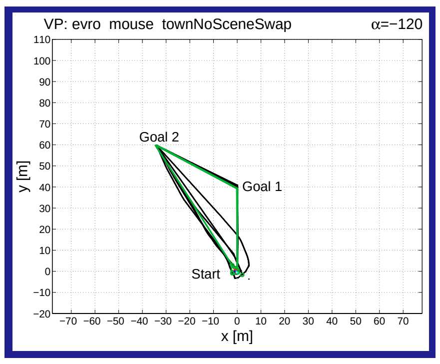
Omitting the "scene−swap" resulted in nearly perfect performance.

The four graphs to the right show the average biases (under− or overestimation) and compression rates of segment length and turning angle for each condition. We found strong systematic errors (compressions) in distance travelled but only small deviations in turning angles. The differences between DOTS and TOWN are negligable, but omitting the scene−swap in the control condition resulted in nearly perfect performance (also see lower right graph).

The standard deviation per subject * condition * triangle geometry was typically 15° for turning angle and 7m for segment length, and only half of that in the no−scene−swap condition. These small response variabilities indicate the existence of a rather accurate mental representation of the triangles.



The figure shows the biases (upper row) and compression rates (lower row) averaged over all subjects as a function of condition. Negative turning errors indicate that subjects didn't turn enough between the second and third segment. Negative distance errors indicate that the actual third segment length was shorter than the nominal value. Compression rates smaller than 1 indicate that the range of responses was smaller than the range of nominal (correct) values.



The figure shows typical examples of trajectories that subject ***evro*** produced in the condition without scene−swap. The approach towards the starting position is sometimes from behind, indicating a scene−matching type of strategy. The overall accuracy with which the goal is reached is substantially better than in conditions that do not allow scene−matching.

CONCLUSIONS

Path integration using optic flow alone is sufficient for basic homing tasks.

The overall level of performance shows that optic flow alone is sufficient for basic homing tasks. The negligable difference in performance between the DOTS and TOWN conditions proves that additional landmark information during the outward journey does not improve homing performance compared to optic flow alone. The nearly perfect performance in the TOWN condition without scene−swap stresses the dominant role of piloting (scene−matching) under natural conditions.