GEOGRAPHY, PSYCHOLOGY AND SPACE

Towards an interdisciplinary approach to spatial behaviour

15TH European Colloquium on Theoretical and Quantitative Geography
September 7-11, 2007, Montreux, Switzerland

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ABSTRACT

Geography and psychology are both interested in the way human beings acquire and use spatial information in order to navigate. This paper presents a simple agent-based simulation of human trail formation, as well as an experimental approach to linear movement in an effort to illustrate the different points of view of the two disciplines and the relations that can be found between trail formation and path integration.

KEYWORDS

Cognitive psychology, spatial behaviour, trail formation, linear path integration, agent-based systems

INTRODUCTION

The investigation of spatial navigation requires focusing on the gathering and the encoding of spatial information. This information is at least connected to the relations on the earth's surface, and the position of landmarks. Such a field of research is ideal for interdisciplinary approaches combining the geographical and psychological points of view. For example, both disciplines have provided indications that people acquire and store information about their surroundings in a schematized and structured form commonly called a cognitive map (e.g. [2], [3]). This mental map appears to be shaped and updated by the interaction with one's environment, and provides an interface between subject and environment allowing the adjustment of behaviour to the context.

Although the selection of an appropriate navigation strategy seems to rely on the interplay between cognitive map, spatial behaviour, and environmental properties, several points concerning the foundation of this capacity remain unclear. For example, little is known concerning how physical tracks influence path choices, and how cognitive processes support these choices. Such questions provide another framework for the combination of the geographical and psychological approaches. On the one hand, one of the simplest forms of interaction between environment and behaviour concerns trail formation. On the other, the simplest form of navigation is path integration, which allows returning to the starting point of a displacement without making use of familiar landmarks.

The aim of this paper is to combine these two approaches in order to investigate the relation between trail formation and path integration. To this end, we first present an agent-based simulation revealing the organisation of an agent's walk through an unexposed area. This simulation provides information on trail formation as well as on the selection of a path navigation strategy. Then, we expose results of an experimental approach to linear movement, investigating the human capacity to reproduce linear distances without visual input in both active and passive travelling.

AN AGENT-BASED SIMULATION OF HUMAN TRAIL FORMATION

The use of agent-based systems to simulate geographic events is constantly gaining popularity. The simulation that is presented here is an ideal case because the simulated environment is very realistic and allows straightforward understanding. Moreover, it consists of both the environment influencing the agent's spatial behaviour and the agent's behaviour modifying the environment's structure.

Helbing et al. [4] have shown that "the way system (resulting from human trails formation) is the shortest one which is compatible with a certain accepted relative detour". We have tried to replicate their simulation using the smallest possible number of rules for pedestrian movement in order to explore whether a path navigation strategy simply depending on a maximum deviation from target threshold could be responsible for the resulting way system. The main characteristics of the model are briefly presented in what follows.

Environment

The environment consists of a bi-dimensional grid of 100x100 cells. Most of these are green and some are black representing respectively grass and buildings. Buildings are positioned so as to form a triangle, square or polygon, according to their number. Each green cell has a track variable attached to it, measuring the degree of the grass's degradation, and determining its colour (ranging from light green to dark green). The track variable is incremented in a constant rhythm representing the grass's growing back.

Agents' properties and behaviour

Each agent is characterised by the current position's coordinates and the destination's coordinates. A double visual range is determined for all agents: there is a maximum distance from current position where it is still possible to inspect the ground for tracks and there is an angular threshold on both sides of the agent's main direction beyond which cells are not inspected at all (figure 1a). A new destination building is randomly selected each time an agent arrives on a black area. Before each step, a turn is operated towards the direction of the destination. Every agent inspects the cells around them according to the double visual range. A step is taken in the direction of the cell within this range that has the largest degree of degradation, or if all cells' track variables have the same value, a step is taken towards the direction of the destination. An agent always moves step by step, i.e. from one cell to a neighbouring cell, following this procedure.

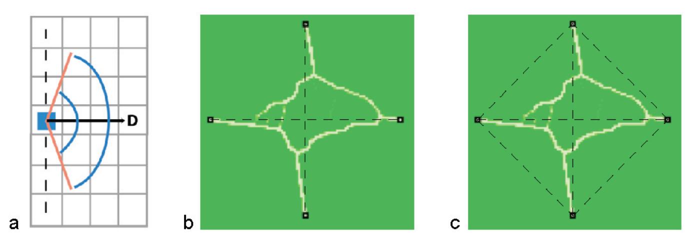


Figure 1: a) the agent's inspection of cells, b) a snapshot of the simulation with four buildings with dashed lines representing the minimum length way system, c) the same snapshot with dashed lines showing the direct way system.

When the simulation runs for some time a clear pattern appears that is in accordance with Helbing et al.'s findings and observations in public parks and other green areas. It seems that the definition of a threshold for the angle between current direction and target direction of the agents is the minimum condition in order to achieve the observed compromise between the minimum length way system and the direct way system.

The reason for this is that when moving towards a target in an open field, pedestrians would like to choose the trajectory with the minimum deviation from the target direction (least-angle strategy) depending on the presence of existing pathways. These will be used as long as the angle between their direction and the target direction doesn't exceed the mentioned threshold. The results of this simulation seem to indicate that the selection of a trajectory and the trajectory's deviation to a target depend on the presence of existing pathways. The question of how cognitive processes support trajectories' selection remains. It is addressed through an experimental study of linear displacement.

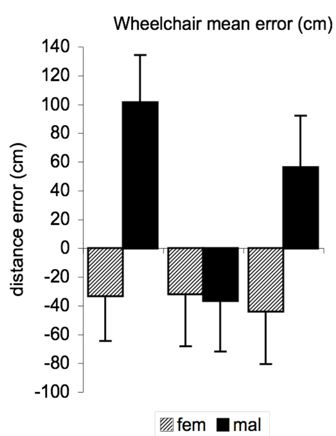
AN EXPERIMENTAL APPROACH TO HUMAN LINEAR PATH INTEGRATION

Research on path integration has mainly focused on paths comprising angles (e.g. [5]), but surprisingly few investigations concerning the computation of linear travel distances have been done (e.g. [1]). In this context, the reproduction of passive and active linear travelling by blindfolded male and female subjects was investigated.

To this end, path integration capacities of 120 participants (60 males and 60 females) were evaluated on three linear displacements. During the first phase of the experiment, all blindfolded subjects were randomly transported 3 times in a wheelchair to one of three fixed distances (9, 11 or 13 m). Each time, subjects were turned around and led back towards the starting point. They were asked to say "stop" when they thought they had reached the starting point. The same procedure was used during the second phase of the experiment, but all blindfolded subjects were randomly guided on foot 3 times to one of the three distances.

Results

Men's mean error is quite high for short distances in both active and passive travelling. However, it seems to decrease with distance, particularly when the displacement is active. Women's mean error appears to be stable on passive travelling whatever distances are, but seems to increase with distance when they have to walk (fig.2). Descriptive analysis of the distance estimations shows that distances are underestimated when the participants are passively displaced (fig 3).



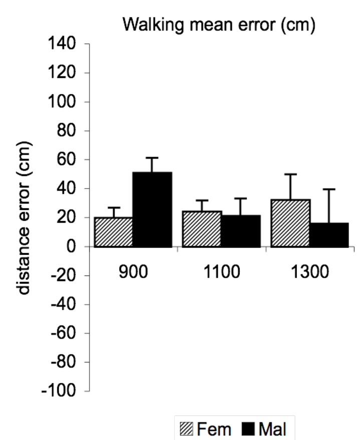


Figure 2: A 2-way ANOVA (sex x distance) with repetitions on wheelchair trials shows a significant effect of sex ($F[1,118]=7.18$; $p=0.008$) and no effect of distance ($F[2,117]=1.909$; ns). Moreover a significant effect of trial repetition was observed ($F[2,357]=4.25$; $p=0.041$). The same analysis on walking trials shows no effect of sex ($F[1,117]=0.26$; ns), no effect of distance ($F[2,116]=0.51$; ns) and a significant effect of trial repetition ($F[2,354]=11.98$; $p=0.001$).

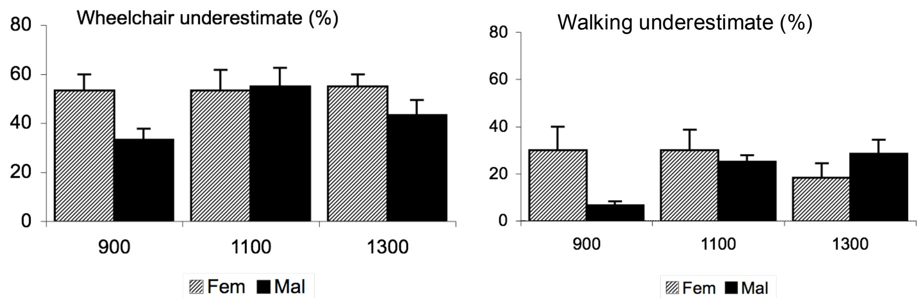


Figure 3: Percentage of underestimate distances during passive (wheelchair) and active (walking) displacements.

This experiment revealed a sex-related difference in the brain computation of travelled linear distance in the absence of visual input that could be rooted in basic mechanisms involved in spatial navigation. The fact that men show a higher error for short distances, and women for long distances may be due to evolutionary processes or to differences in brain activations.

CONCLUSION

The combination of these two approaches shows that in an open field trajectory selection depends on the presence of existing pathways and that travelling distance estimations vary according to sex. This result suggests that studies on spatial navigation cannot be fully interpreted without considering individual differences.

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