Cooperative Multi-robot Box Pushing Inspired by Human Behaviour

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This paper investigates mechanisms underlying cooperative behaviour in a group of miniature mobile robots around the problem of coordinating a group of robots to push collectively a heavy object. Numerous solutions to this problem have been proposed [5,7,4]. The performance of these however typically deteriorates as the number of robots increases to more than a dozen. The cause of this is often said to be robot interference—there are many robots but insufficient space to manipulate the object effectively. The situation is particular difficult when the object itself occludes the view of robots [3]. In this case, robots can benefit from division of labour (e.g., see [2]). Here, we take inspiration of the division of labour in teams of humans pushing a large object towards a target location: persons who can see the target push the box only when the transporting direction needs to be corrected, while all other persons simply push the box forward. The two roles in this cooperation are indicated in Fig. 1(a).

We have developed a simulation framework based on the Bullet Physics and Enki Libraries[1], see Fig. 1(a). The simulated robot model is the e-puck robot [8]. It has two differential wheels, a directional colour camera pointing forward, and eight proximity sensors distributed around the robot's perimeter. Each robot executes an identical finite-state machine. Transitions between states are triggered based on perceptual cues [6]. The robots reside in a bounded arena of 5 m x 5 m dimensions. The object to be transported is a blue cube which is tall enough to occlude the target location. It is placed in the centre of the arena. The target location, a red cylinder, is located at a fixed distance. The robots start from random locations within a starting zone. Further details can be found in the on-line supplementary material [1].

Fig. 1(b) shows the results of a series of computational experiments. A trial was considered successful, if the object reached the target location (5 cm tolerance) within 1200 s. The figure shows that there was a benefit from increasing the number of robots up to 64. Visual inspection indicated that the controller succeeded in allocating the different roles to the robots as intended (for video recordings, see [1]). The transport behaviour was reliable as long as there was a sufficient number of robots involved. However, in most cases, the box moved on average by about 1 cm/s only. By comparison, the robots can move with up to 12.8 cm/s when having no load. In the future, the finite state machine model will be refined and the role allocation will be studied in more detail.

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[1] http://bulletphysics.org/ and http://home.gna.org/enki/

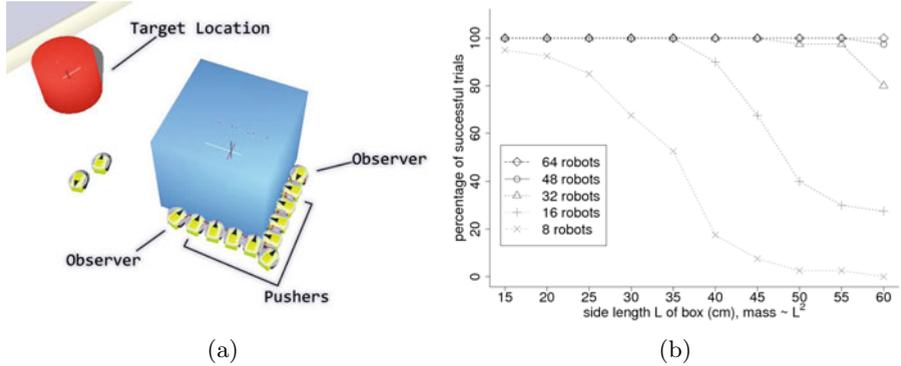(a)   (b)

Fig. 1. (a) Robots that have pushed a cuboid object near to the target location. (b) Percentage of successful trials for 8, 16, 32, 48 and 64 robots transporting objects of different size/mass (40 trials per data point).

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