Assistance Robotics: Implementation of human-like visuo-motor synergies on a teleoperated mobile device

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The overall framework of this project addresses the restoration of degrees of autonomy in disabled people by increasing their field of intervention. This involves a teleoperated system, composed of a mobile teleoperated robot-mounted arm and a remote control station. The required objective for the design of a machine to be used by a human operator is its adaptation to the user's capabilities. According to this logic, the ideal system should perfectly fit into the human sensori-motor control loop. The system would disappear from the field of consciousness and the operator would use it as a "natural" extension to his/her own body (hence the concept of *natural interface*).

The present experimental study investigated the potential interest of the implementation, on the robotic device, of behaviorally-plausible (human-like) action control modes, in terms of "sensori-motor coupling". In humans, the visual guidance of locomotion obviously involves visuo-motor coordination. Such behavioral organization appears to be (in temporal terms) from the head to the effectors, following a "go where you look" strategy of anticipation of the direction of gaze upon the direction of locomotion (Land & Lee, 1994; Grasso et al., 1996). In an analogy to this gaze-locomotion synergy, we implemented different modes of coupling between the camera (gaze) and the motorized wheels (locomotion) of a teleoperated mobile robot.

Concerning performance assessment, we tried to evaluate whether an operator, remotely controlling the displacements of a mobile robotic device, is able to integrate the dynamical properties of the robot into his/her sensori-motor schema. In order to evaluate the level of "appropriation" of the mobile robot by the human operator, we tried to go beyond classical measurements of the operator's performance, such as the task completion time. Specifically, during a "slalom" task, we evaluated the "quality" of the trajectory, in terms of its smoothness. More precisely, we computed the relationships between the kinematics and the geometry of a "teleoperated" trajectory, and compared these to what is observable in human "natural" locomotion behavior (Vieilledent et al., 2001).

The robot was composed of two principal elements: a mobile platform and a control station. The robotic platform was equipped with a mobile camera. The robot was moved by two independent driving wheels, a free wheel in front of the vehicle allowing its stability. The engines were of the same type as those which equip electric wheelchairs. The optical camera field of view was 50° in the horizontal and 38° in the vertical dimension. This sensor "sent" to the operator an image of the environment in which the robot evolved, on a terminal display having a height of 23 cm and a width of 31 cm. The whole system, engines and sensors, was controlled by a PC embarked on the robot. This PC was connected to the computer of the control station through a TCP/IP HF connection. Client/server software architecture structured the informatics part. The control interface was using the PC keyboard, by which the operator controlled the direction and displacement velocity of the platform (in the absence of direct vision of the platform). Three different control modes were tested, among a group of healthy volunteers. In a first condition, the camera was fixed, aligned with the robot's heading. In this case, the operator's commands affected directly the robot's direction of motion. In a second condition, the camera was mobile, the subjects controlled the robot's heading, and the camera's direction pointed towards the interior of the robot's path. In this case, the camera motion temporally followed the robot directional changes. In the last condition, the operator's command directly affected the camera's orientation, and the robot's heading was defined from the camera's orientation.

The results from this study clearly show that the trajectory control performance is overall improved when the robot is equipped with a mobile camera, confirming previous data (Peruch & Mestre, 1999). This suggests that a mobile camera increases the functional field of view, notably by enabling early detection of potential obstacles on the future trajectory. More interestingly, we found a clear difference in performance between the two tested conditions of mobile camera. This difference was not found concerning "raw" performance (like completion time) but in the velocity-curvature relationships of the trajectories. Only in the case where the subjects directly controlled the camera's orientation (the robot's direction of motion being temporally dependant on the camera's heading), did we find that the robot's movement followed the the so-called ‘two-thirds power law’ (Viviani & Falch, 1995) observed in human movements, stating that the angular velocity of the effectors (here the robot) is proportional to the two-thirds root of the curvature of its trajectory.

In other terms, we found that, when the "camera-wheels" synergy implemented on the robot followed, notably in a temporal order, the human visuo-motor synergy observed during locomotion, the robot's movement respected natural characteristics of human movements. This type of study has to be pursued, notably because we tested here only "healthy" young volunteers. However, this experimental approach suggests 1) that the implementation of "human-like" visuo-motor coupling models on complex assistance devices might improve human-machine compatibility and 2) that, beyond raw performance, the evaluation of the similarity between teleoperated movements and "natural" (non-mediated) movements might constitute an interesting way to foresee the usability of an assistance device.

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