Real-Time Visual Workspace Localisation and Mapping for a Wearable Robot *

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Keywords: Simultaneous localisation and mapping (SLAM); wearable robotics; active vision

1 Introduction

This demo showcases breakthrough results in the general field **real-time simultaneous localisation and mapping (SLAM)** using vision and in particular its vital role in enabling a wearable robot to assist its user. It accompanies the full paper by the same authors at ISMAR2003 [1].

In our approach, a wearable active vision system (“**wearable robot**”) is mounted at the shoulder. As the wearer moves around his environment, typically browsing a workspace in which a task must be completed, the robot acquires images continuously and generates a map of natural visual features on-the-fly while estimating its ego-motion.

Naturally such real-time camera localisation permits the **annotation** of the scene with rigidly-registered graphics, but further it permits automatic control of the robot’s active camera: for instance, **fixation on a particular object** can be maintained during extended periods of arbitrary user motion, then shifted at will to another object which has potentially been out of the field of view.

This kind of functionality is the key to the understanding or “management” of a workspace which the robot needs to have in order to assist its wearer usefully in tasks. We believe that the techniques and technology developed are of prime importance towards the goal of a fully autonomous wearable assistant and of particular immediate value in scenarios of remote collaboration, where a remote expert is able to annotate, through the robot, the environment the wearer is working in.

* This research is supported by an EPSRC Advanced Research Fellowship to AJD, UK EPSRC Grant GR/N03266 and a Mexican CONACYT scholarship to WWM. The authors are particularly grateful to B.J. Tordoff for software collaboration.

Figure 1. Collar-mounted wearable robot equipped with a miniature camera manipulated by a three-axis motorized active platform.

2 Technology

The key role in this demonstration is played by a general algorithm for real-time, vision-only single-camera simultaneous localisation and mapping (SLAM) — an algorithm which is applicable to the localisation of any camera moving through a scene. Starting from very sparse initial scene knowledge, a map of natural point features spanning a section of a room is generated on-the-fly as the motion of the camera is simultaneously estimated in full 3D. The algorithm achieves robustness and real-time performance via rigorous application of probabilistic techniques for estimating the locations of camera and features during agile 3D camera movement.

Image capture is at 30Hz via the IEEE1394 “Firewire” bus and all processing is achieved on a notebook computer with a 1.6GHz Centrino processor, making a system which is completely portable.

The second key component in the demonstration is a wearable robot with **active vision** (Figure 1). Designed for minimum volume and weight, the robot is worn at the shoulder and provides a wearable active vision capability: under the computer's control, the viewpoint can be directed to objects of interest. Full control of the wearable robot is achieved via the USB port of the same notebook computer.

3 Demonstration Scenario

The demonstration scenario depicted in Figure 2 is one of cooperation between the wearer of the robot and a remote collaborator. The wearer browses a workspace, moving freely and manipulating objects, while the robot maps the scene and continuously estimates its motion.

Concurrently, the remote collaborator sees on his monitor both the visual output of the robot's camera, overlaid with landmark features and a 3D coordinate frame, and an external 3D view of the location of the robot and world features (Figure 3). The remote collaborator may highlight any objects of particular interest with the mouse in either view, annotate these objects with graphics which will then remain registered with the object as the wearer moves, and then also command the robot to remain fixated on a particular object during an extended period of wearer motion. This would permit prolonged examination of an object by the remote collaborator without disturbing the movements of the wearer. The full 3D localisation information maintained by the robot further allows full control of these periods of fixation, such that any known object can be fixated at will and then returned to at any later stage (Figure 4).

4 Conclusion

This demonstration presents technology of wide applicability and will be of interest to those not only in the fields of robotics and computing, but also more general robotic localisation or any form of real-time augmented reality. The demonstration features an exciting robot and convincing real-time 3D graphical output and we feel that it would be of general appeal.

References

[1] A. J. Davison, W. W. Mayol, and D. W. Murray. Real-time localisation and mapping with wearable active vision. In *Proceedings of the IEEE International Symposium on Mixed and Augmented Reality, Tokyo*, 2003.

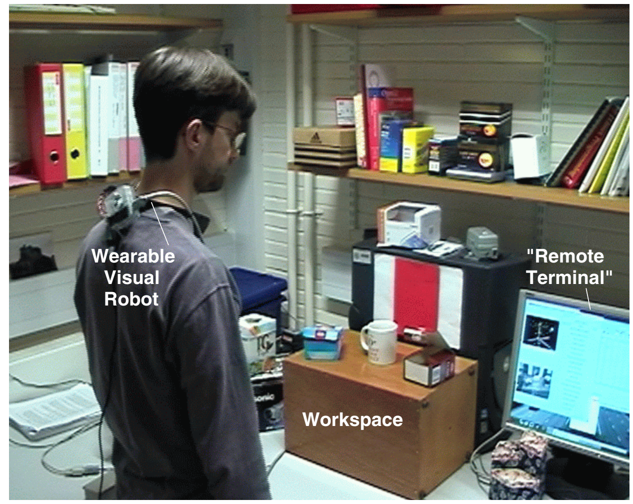

Figure 2. Demonstration scenario.

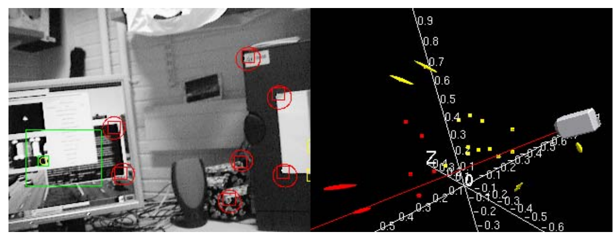

Figure 3. Real-time graphical output from the system: on the left, the camera's image view overlaid with feature uncertainty information and graphical overlays; on the right a 3D world-frame view of the estimated locations of camera and features.

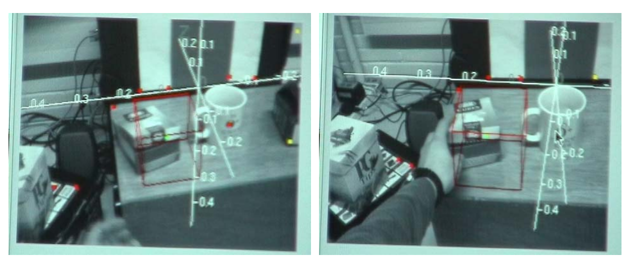

Figure 4. Graphical annotation and fixated tracking of objects during a manipulation task.

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