HUMAN VISUO-MOTOR LEARNING FOR BIOLOGICALLY REALISTIC ROBOT MOTION SYNTHESIS

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INTRODUCTION

We describe a novel approach for biologically realistic robot motion synthesis based on human visuo-motor learning ability. The conceptual idea is to consider the target robot platform as a tool (e.g. like computer mouse) that can be intuitively controlled by a human. Once the robot can be effortlessly controlled, the target motion can be obtained by the human on the robot through practice. The successful execution of the task by the human via the robot means that the required control commands have been discovered by the human, and can be used for designing controllers that operate autonomously. The idea has been highlighted in our recent publications [1] and it is very well supported by neurophysiological experiments – primates have very plastic representations of limbs, which are expanded immediately upon acquisition of tools [2].

METHODS

The approach we are proposing can be considered as a closed loop approach where the human subject is included in the main control loop as shown on Figure 1. During the control of the robot, the partial state of the robot is fed back to the human subject. The feedback we used was the rendering of the position of the center-of-mass superimposed on the support polygon of the robot.

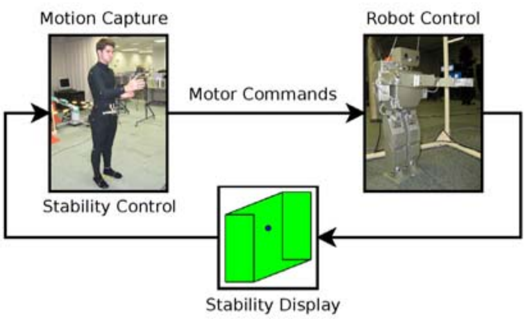

Figure 1: Experimental setup used for statically balanced reaching skill. Subject was given the feedback of robot stability by a graphical rendering of the support polygon and the center-of-mass location.

The subject's task was to perform reaching movements as directed by the experimenter while keeping the robot's center-of-mass within the support polygon. With a short practice session the subject was able to move his body and limbs with the constraint that the robot center-of-mass stays within the support polygon. Therefore the robot was statically stable when the human generated motions were either imitated by the robot in real-time or played backed later on the robot alone. The robot employed in this study was Fujitsu HOAP-II small humanoid robot.

RESULTS AND DISCUSSION

The light blue wiggly curve on the right panel of Figure 2 shows the human-generated robot end-effector position data during which the robot was reaching outwards and was statically stable. For each data point of this curve, the robot joint angles were recorded. Based on the end-effector position trajectory and the joint angle trajectory we performed a nonlinear data fit using Gaussian Basis Functions. A set of used computational steps are illustrated on the left panel of Figure 2. Over-fitting was avoided by using cross validation. Blue circular curve on the right panel of Figure 2 is the desired end-effector trajectory and the red curve is the resulting robot's end-effector trajectory obtained by sending the predicted joint angle trajectory to the robot.

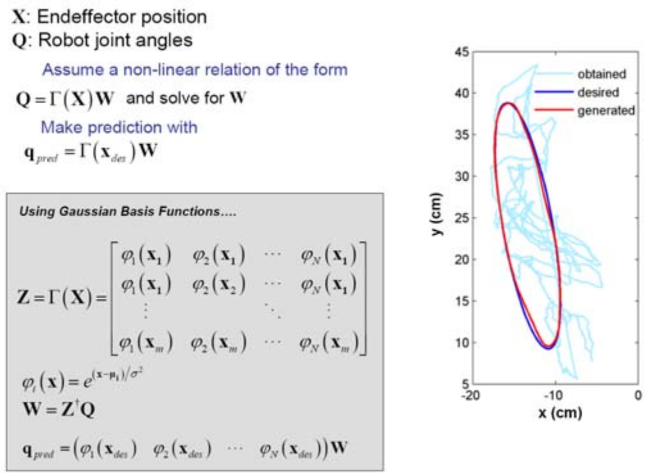

Figure 2: (Left) The logic of non-linear data fitting is shown. The gray inset shows how the non-linearity is introduced using Gaussian Basis Functions. (Right) The generalization obtained is illustrated. The desired end-effector trajectory (blue) was used as the input for the joint angle prediction producing a joint angle trajectory. When this was played back on the robot the end-effector position (red) was in good agreement with the desired trajectory (blue).

The described reaching skill is an example of a slow statically stable motion where dynamic properties of the robot don't influence the stability of the robot. However, when the robot is commanded to track a trajectory at higher speeds, the dynamics has a significant effect that needs to be taken into account. When the motion of the robot was performed at the twice speed, the robot became fairly unstable. Although it could track the trajectory it could just barely keep its balance.

REFERENCES

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