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Gesture Recognition and Reproduction for a Humanoid Robot using Hidden Markov Models

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Research on Robot PROGRAMMING BY DEMONSTRATION (PbD) aims at developing adaptive and robust controller to enable a robot to learn new skills **by observing and imitating** a human demonstration. Our work aims at exploring the problem of recognition, generalization, and reproduction of arbitrary tasks to tackle the general issue of **learning which of the features are the relevant ones to imitate**. We present an implementation of this framework to the determination of the optimal strategy to reproduce arbitrary gestures [1]. The suggested model is inspired from studies of IMITATION LEARNING from various research fields, where a continuous task is segmented into key-features elements, and where imitating consists of learning the sequential regularities of these elements to acquire the new behavior. **To tackle the noise in a real-world application**, we suggest to address these problems in a probabilistic framework, using HIDDEN MARKOV MODELS (HMMs), that involve two concurrent stochastic processes: one modeling the sequential structure of the data, and one modeling the local properties of the data. Sequences of inflexion points (i.e. local optima) are extracted from the continuous flow of motion, and are learned by the HMMs to handle the statistical variations in the sequential structure of the data, and in the data itself. It is then possible to recognize gestures and generate new ones, generalized over the demonstrations. Their capacity to associate multimodal data through the hidden states is used to model the key-features elements composed of multiple variables (e.g. X,Y,Z Cartesian positions), represented both for the demonstrator (the user) and the imitator (the robot). It is thus possible to handle the different embodiment and affordance of the demonstrator and the imitator, by representing through the hidden states a relationship between the sensory representation of the demonstrated task perceived by the imitator, and the appropriate motor representation used by the imitator to reproduce the task.

The system is tested and validated on a humanoid robot, using recordings of the demonstrator's arm motion and the 7 DOFs arm of the robot to reproduce the gesture. Motion data are segmented into sequences of inflexion points encoded in the HIDDEN MARKOV MODELS (HMM) in Cartesian and joint angle space. After training, the system uses the optimal prediction of the models to generate the reproduction of the motion. The controller of the robot is selected depending on the best representation of the data found by the HMMs (joint angle or Cartesian representation).

References

1. S. Calinon and A. Billard. Stochastic gesture production and recognition model for a humanoid robot. In *Proceedings of the IEEE/RSJ Intl Conference on Intelligent Robots and Systems (IROS)*, pages 2769–2774, Sendai, Japan, September 28 - October 2 2004.