Incremental Robot Skill Learning by Human Motion Retargetting and Physical Human Guidance
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Abstract - Research on skill acquisition and generalization to a different scenario has grown steadily in importance and became now a main topic of robotics research. Imitation learning, one of the main streams for robot learning, provides an efficient way to learn new skills through human guidance, which can reduce time and cost to program the robot. This extended abstract presents our research on incremental skill learning through physical human robot interactions. We introduce our method to teach a robot how to learn synchronized and coordinated whole body motions. Our controller provides a human user comfortable assistance for physical guidance beyond the gravity compensation. External force torque estimation allows further possibilities. One is teaching motion primitives of a legged humanoid robot by taking human intervention into consideration for a balancing problem. Another is teaching multiple tasks like end-effector motions and null space motions. The proposed algorithms are verified on multiple robotic systems including full size humanoid robots.

Keywords - Incremental skill learning and refinement, physical human robot interaction.

1. Introduction
Research on robot learning from demonstration has received great attention in the last decade since it can serve a useful methodology for intuitive robot programming, even by general users without robotics expertise [6][2]. In the earlier works of this field, demonstrations were provided either by teleoperating the robot or by vision/motion sensors recordings of the user doing the task. In the case of using human motion data directly, we need to solve the motion retargeting problem from a human demonstrator to a robot. Kinematics and dynamics differences between the demonstrator and the robot must be handled and it is very hard to ensure an optimal retargeted motion. Thus it may be desired that a human supervisor can modify the shape and timing of retargeted motion primitives in an intuitive way.

The recent hardware and software developments towards compliant and tactile robots can offer the user to physically interact with the robot to transfer or refine skills. Physical interaction in the context of robot learning is a young but promising upcoming research topic (see Fig. 1). It provides a natural interface to kinesthetic transfer of skills to the robot, where the user can demonstrate or refine the task in the robot’s environment while feeling its capabilities and limitations. With the new development of compliant controllers, backdrivable motors and artificial skins, new perspectives in learning arose by exploiting the natural teaching propensity of the user, already being familiar with social interaction such as scaffolding or kinesthetic teaching. In most works, kinesthetic teaching was realized by deactivating individual selected joints (e.g. by setting very low servo gains) or by a gravity compensation controller. As a consequence, these approaches often lead to unsynchronized motions because the teacher moves motors one by one rather than demonstrating natural coordinated movements. These limitations can be overcome by combining imitation of human’s whole body motion with a compliant behavior for physical interaction.

Kinesthetic teaching of a legged humanoid robot has been hardly studied. In existing works, an interaction control approach for the upper body motion was combined with a lower body balancing algorithm based on the reaction null space approach, however, in order to keep ZMP stable upper body might make big momentum and no disturbance estimation was used to take external force into account for balancing explicitly. In practice, disturbance estimation can contribute greatly to different situations, like legged humanoid kinesthetic teaching and incremental kinesthetic teaching of multiple tasks based on the priority control.

2. Proposed Approach
In order to achieve intuitive teaching of natural motions, we proposed a method for incremental learning by using physical interaction [1] [3] [4]. In order to ensure synchronization of complex whole body motions on a humanoid robot, our imitation learning procedure starts with observation learning (i.e. whole body motion retargeting from a human demonstrator to a robot) prior to...
As an ongoing work, we develop an incremental kinesthetic teaching method of stable dynamical systems using Gaussian process regression. The approach can modify the dynamics of a generic autonomous dynamical systems incrementally every time a new demonstration is provided. A control input is learned from demonstrations to locally modify the trajectory of the system while preserving the stability properties of the reshaped DS.

## References


