

# Goals and Actions: Learning by Imitation

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## Abstract

Imitation is a powerful form of learning used in many animal societies. Imitation encourages the social interaction and the cultural transfer. Hence, Imitation represents many advantages, which have inspired the roboticists to reach imitation in order to approach social intelligent social intelligent robotics systems. The paper presents a mechanism of imitation, which permits a robot to acquire new behaviours through the extraction of the goals from the perceived actions. Experimental results with a simulator are also presented to demonstrate such a mechanism.

## 1 Introduction

Robotics researchers have developed individual autonomous robots to solve some specific domain tasks. Nevertheless, many applications require a team of autonomous robots working to solve a common problem. Tasks such as space exploration, hazardous environments, service robotics, cleaning, emergency handling, transportation and so forth, require robots being able to cope not only with objects but also with other robots in the same environment (Liu and Wu, 2001).

Up to now, it remains a big challenge for us to develop a team of robots performing complex behaviours and presenting an intelligent interaction with the environment. Traditional approaches to this issue such as programming and learning strategies have demonstrated to be very complex, slow and restricted in knowledge (Bakker and Kuniyoshi, 1996). Thus, learning by imitation could present a useful, promising and alternative solution.

Therefore, Roboticists have begun to focus their attention on imitation. Since the capability to obtain new abilities by observation represents many important advantages, and also imitation intends to fill the gap to build social robots (Dautenhahn, 1994; Dautenhahn, 1995; Dautenhahn and Nehaniv, 2002). Imitation seems as a tool to acquire new behaviours and to accommodate these within new contexts (Acosta Calderon and Hu, 2003).

The rest of the paper is organised as follows. Section 2 presents the influence of imitation in robotics. Section 3 gives details of some key issues that are taken into consideration for the mechanism of imitation. The experimental results are presented in section 4. Finally, section 5 summarises the paper. We also discuss future work using the mechanism proposed here.

## 2 Influence of imitation

Physiologists have tried to explain the phenomenon of imitation. Meltzoff and Moore presented an approach that tends to explain imitation. In their mechanism of imitation, the imitator recognises equivalences between body movements that they see. By detecting a mismatch of the current observed state of the imitatee and the stored representation of the imitator, imitation is triggered in order to reduce this difference (Meltzoff and Moore, 1989).

It is also proposed that the perception of an action might be registered in such a way that it could be used directly for the execution of a motor plan. Therefore, perception and motor processes share a common language.

Besides, many researchers in psychology support the idea that imitation of actions is strongly influenced by the pursuit goal (Demiris and Hayes, 1996; Nadel, 2000; Meltzoff, 2000; Bekkering, Wohlschlagel, and Gattis, 2000). Chaminade et al suggested that human cognition is able to make the distinction between matching an observed action and reproducing the correct use of an object (Chaminade, Meltzoff, and Decey, 2002), rather than the attention in the particular relation of physical movements to complete the action. This goal directed imitation implies that the condition of the imitatee as well as the environment might be the starting point for imitation.

The individuals in the societies remember their interactions with others as well as the environment. These experiences outline the way that the individual perceives the world (Meltzoff, 1999; Meltzoff and Moore, 1992). Thus actions are regularly related to conditions or states regard to the body of the individual and environments. These states and actions are registered. These states would lead to intentions of the individual to achieve a goal.

### 3 Mechanism of imitation

Our approach of learning by imitation is based on the pursuit goal. We introduce a mechanism of imitation that allows the imitator to match the perceived state of the imitator with an action which once executed would produce a similar state that the one sensed by imitator. The proposed mechanism presented in this paper intends to bring as a contribution, identify the goal from an observed action.

In learning by imitation the robot should learn to extract the goals of the perceived actions, instead of learning the physical relation between its limbs only. Thus, once a goal has been extracted from an action, there are many different means can lead to reach the same goal. Hence the essential effects of the observed action are imitated rather than just the particular physical motions. Otherwise, an imitated action that is based only on physical movements might fail when it is reproduced in some altered environments or even when the environment is the same but the robots have different bodies (Nehaniv and Dautenhahn, 1998).

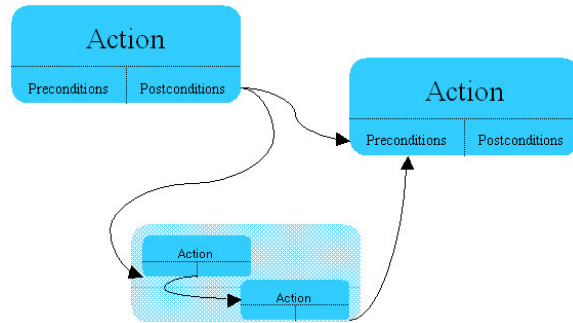
Therefore, we introduce a mechanism of imitation that allows the imitator to match the perceived effects of imitator's action with its own action, which once executed would produce a similar state that the one sensed by imitator. This mechanism of imitation is able to extract the goals from the observed actions, which would permit to adapt the actions to new contexts. Imitation then would be just seen as a tool that robots use to acquire new knowledge, which could be applied to a diversity of problems and not only as a mechanism to solve a specific one.

Our mechanism as well as the hybrid architectures, called three-layer systems, work with high-level goals and present the robustness of behaviour-based systems (Bonnaso, Firby, Gat, Kortenkamp, Miller and Slack, 1997; Gat, 1998). Hybrid systems have a deliberative part, which is responsible to find a solution for a particular task. In contrast, in our mechanism the solution is found by learning it first.

Imitation always involves the perception of the actions of the imitator, the learning of those actions, and finally, the performance of these new behaviours even when this performance would be just a mental rehearsal of the behaviours. Learning then, is the bridge between perception and action and this determines the success of the imitated behaviour.

In order that the link between perception and action could be correctly established, it is necessary that both perception and action would agree in the same representation for the behaviours and primitives. Once the representation is common among perception and action, the learning process is in charge to record the relation of the primitives that compound the new action. This register of the actions has to be done using a memory, which would permit that the imitator recalls

this new action in future times and even more without the need of observing the imitator performing such action.



**Fig. 1. The action representation is a net of sub-action that is related by the precondition and postconditions.**

In our approach, a new learnt action is represented as a net of sub-actions (Fig. 1). This net corresponds to a plan to achieve a particular task. The actions could be either primitive actions or nets of sub-actions. In addition, every action has preconditions, which have to be satisfied before the action would be executed, and postconditions, which would be the environmental state after the action would be performed. Thus, the sub-actions and primitive actions are connected in the net through the preconditions and postconditions. The action's conditions are typically abstracted environmental states that are interpreted as embedded goals of the action (Nicolescu and Mataric, 2000; Nicolescu and Mataric, 2001).

The mechanism of imitation proposed here consists of three main elements, Perception, Learning and Execution.

- **The perception unit** is responsible for obtain the condition of the imitator and its relation with the environment. The process is described as it follows. First, the robot obtains an image by employing the camera. Second, the image is processed and relevant objects in the scene are extracted. Third, this information along with data received from others sensors is used to obtain both the environmental state and the current state, where the environmental state represents the situation of the imitator and the condition of the environment, and the current state represents the condition of the robot itself.
- **The execution unit** carries out the action that once performed would achieve similar effects that the one executed by the imitator. This unit contains an interpreter, which receives the action to be executed, and each sub-action that compound the actions is performed when its preconditions are known. The interpreter also monitors that the effects of the executed action would be obtained.

- **The learning unit** is responsible for establish the relation between the perceived imitatee’s actions and the own possible actions to execute. The learning ability relies on the robot capability to relate the observed states of the environment to the known effects of its own behaviours.

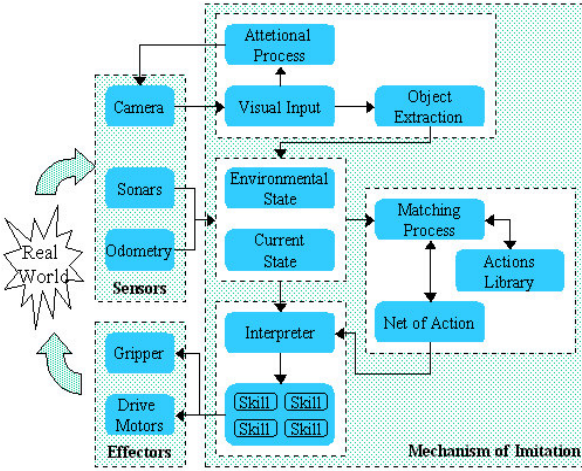


Fig. 2. The mechanism of imitation.

Figure 2 presents the mechanism of imitation and its key elements. The mechanism is in a close-loop with the environment.

In order to select an action from the library the current state of the robot is used as criteria for the preconditions, which reduce the possible set of actions. In a similar way, the environmental state is employed as criteria for the postconditions of the possible actions. Therefore, only actions that satisfy both conditions are taken into consideration.

## 4 Experimental results

To confirm the abilities of the mechanism presented, we describe our experience with a simulator using this approach. Our setup consists of a pair of robots, which have been assigned to a task to find the boxes scattered in the environment and move them into a particular area. One robot is programmed to do so. However, the second robot runs the mechanism of imitation.

Thus, the imitation process is described as follows. First, the imitator looks for imitatee. When it has found, its actions start to be observed through checking its environmental state. When the imitator receives the signal for learning, it starts to record all the environmental states of the imitatee, as the imitator relates these environmental states with its own actions, which would produce similar states. Finally, in a similar way, when the imitator receives the performing signal, it will execute the learnt behaviour.

In order to facilitate the acquirement of significant environmental states, only relevant information is taking into consideration. Hence, the relevant objects in the environment are marked with different colours. The experiment was conducted in two phases.

The first phase is the teaching phase. The course of action of this phase follows these steps. First, the imitator looks for the imitatee. When it has been found, its actions start to be observed through checking its environmental state. These environmental states are recorded. Meanwhile, the imitator also relates these environmental states with its own actions, which would produce similar states.

The second phase is the performing phase. In this phase the imitator reproduces the learnt actions. In our experiments we introduce different environments in which the robot could demonstrate how the learnt action is adjusted in new environments.

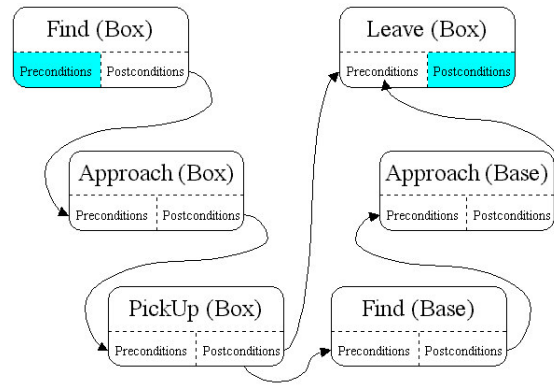


Fig. 3. The net of actions that solves the task of finding boxes in the environment and moves them to the base.

The figure 3 shows the net of action that compound the behaviour to achieve the task of moving the scattered boxes to the base. The preconditions and postconditions have been omitted. The initial state is the preconditions of Find(Box), and the final state is the postconditions of Leave(Box).

## 5 Conclusions and future work

Imitation is a powerful form of learning used by many animals. This learning method has permitted the societies to transfer and adapt knowledge between the members in order to solve their problems, in particular ensuring the survival of the society.

We presented a mechanism of imitation and key elements that delineate this process of imitation involved within the mechanism. This mechanism of imitation permits a robot to acquire new behaviours through perception by extracting the goals from the actions.

We have described our experiments in a simulator using two robots, i.e. an imitatee and an imitator. Our experiments show the feasibility of the proposed mechanism at its first stage.

Our next aim is to increase the complexity of the tasks to be imitated as well as to include the communication into the proposed mechanism.

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