Imitation for Motor Learning on Humanoid Robots

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Motivation

- Motor control in humanoid robots is a challenging task due to the high number of degrees of freedom that must be dealt with.
- Most solutions presented for the motion control area rely, heavily, on domain specific information about the robot or the concrete motor task to be developed.
- How to program motor skills for a humanoid robot with an easy to scale and model free approach?

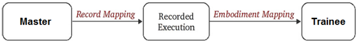
Why imitate?

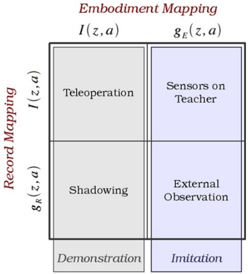
- Imitation is an important learning mechanism we can find it in almost all biological systems.
- Improves learning process reducing the exploration space.
- As robots move into human environments, the ability to learn and imitate human behaviours based only on observation will become of utmost importance.
- Learning by imitation arises as an easier alternative for programming motor skills in robots.

master-trainee mapping

- The Learning By Demonstration data set is composed of state-action pairs recorded during master's performances

- Record mapping.
- Embodiment mapping.

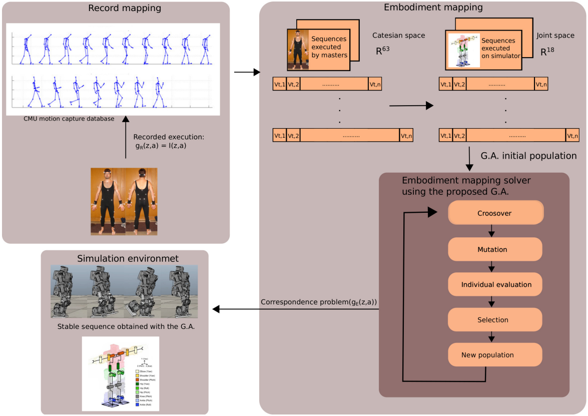




Proposal

- Model-free architecture for the learning of motor tasks in humanoid robots.
- Formulation of the correspondence problem as an optimization problem.
- Validated using the biped walk as the behaviour to be learned.

Proposal



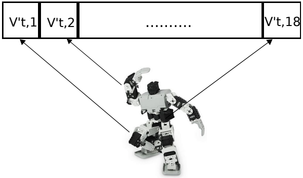
Record mapping
CMU motion capture database
Recorded execution:
$g_R(z,a) = I(z,a)$
Embodiment mapping
Sequences executed by masters
Catesian space
R^{63}
Sequences executed on simulator
Joint space
R^{18}
Vt,1 Vt,2 .... Vt,n
G.A. initial population
Embodiment mapping solver using the proposed G.A.
Croosover
Mutation
Individual evaluation
Selection
New population
Correspondence problem($g_E(z,a)$)
Simulation environmet
Stable sequence obtained with the G.A.

Problem Formulation

- A demonstration dataset is composed of state-action pairs recorded during performances.
- The set of states (T) is represented by a set of integer numbers; there will be one state for each measure of the postural position of the master.
- The set of actions is conformed of the captured positions of a set of 63 markers which describe the postural position of the master $v_t \in R^{63}$.

The Embodiment Mapping Function

- The Embodiment Mapping Function g_E describes how the recorded state-action pairs are finally mapped onto the trainee.
- $g_E(t, v_t) = v'_t$ for $t \in T, v'_t \in R^{18}$ and $v_t \in R^{63}$; t and v_t values must correspond with the ones recorded by g_R.



Each element of v'_t corresponds to the the angular value of the j joint for the instant of time t for the motor task performed.

Correspondence Problem

- The Embodiment Mapping function can be expressed using a time serie as input: $g_E(X) \equiv g_E(t, x_t); t \in T$.
- The embodiment mapping function can be seen as the one that transform the X time series in the Y time series; where its elements describe the adapted posture that successfully represents the motor task under consideration for each instant of time.
- We propose to apply an optimization method to find Y, starting from X and using a metric for the evaluation of the Intermediate calculated Y' temporal series.

Proposed Genetic Algorithm

- Initial Population conformed of the recorded master performances.
- Individuals are represented by a variable size time series where each gene corresponds with a pose.
- Specific mutation, crossover and selection operators are defined.

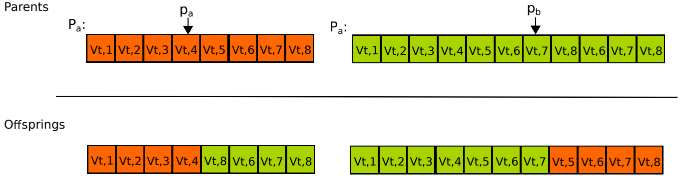
Proposed Genetic Algorithm

- Fitness function:
  - Depends on the motor task to be learned.
  - For the biped walk problem we define as function a weighted sum of:
    * distance traveled.
    * similitude between the first and the last pose.
    * the percentage of frames executed.
    * deviation from a straight line.
    * a measure of how erected the robot finishes execution.

Proposed Genetic Algorithm Operators

- Crossover operator:
  - Variant of the single point crossover
  - Neighbour genes are modified to get a smooth trajectory.

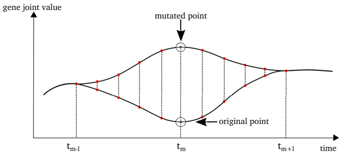
Proposed Genetic Algorithm Operators



Given two parents named P_a and P_b, a random gene p_a is selected in P_a then a p_b gene is selected, where the Euclidean Distance in between is minimal.

Proposed Genetic Algorithm Operators

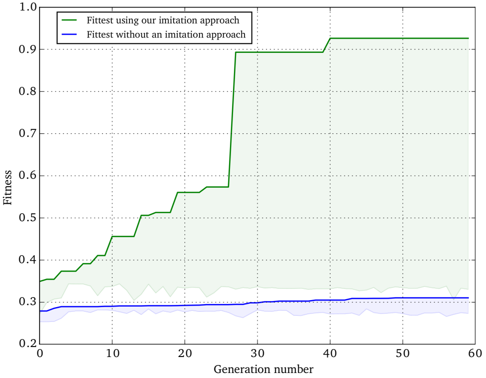
- Mutation operator:
  - A Gaussian mutator is used to explore new solutions that are close to the randomly selected pose (gen).
  - Near in time poses are recalculated to get a smooth transition, using a cubic spline.



Proposed Genetic Algorithm Operators

- Selection operator:
  - Hybrid operator.
    - Elite selection retaining 30% of fittest individuals.
    - Other 70% using Tournament Selection.

Results



Fittest using our imitation approach
Fittest without an imitation approach
Fitness
Generation number
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
10
20
30
40
50
60

Stable sequences on simulator

Conclusions

- The proposed approach allows a humanoid robot to learn how to walk solely based on human-motion capture information without needing a model of the robot.
- The imitation learning approach has shown a big impact in finding a feasible solutions, reducing the exploration space.
- The use of genetic algorithm technique is an unexplored but promising approach for the correspondence problem solution.

Future work

- We are working on solving the reality gap in order to test the obtained results in the physical platform.
- A similar approach to the one presented in this work for solving the gap between the human master and the robot trainee could be employed to solve the gap between the simulated trainee and the physical one.

Thanks for your time!

Please send your questions or comments to aaguirre@fing.edu.uy