Economical Implementation of Control Loops for Multi-Robot Systems

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1. Introduction

- Multi-Robot systems offer multiple advantages.
- To turn them into a realistic option they must be economically attractive.
- In a Multi-Robot system, generally the robots are similar.
- If an economic optimization is done in one of them, such optimization can be replicated in each member.

1. Introduction

- Each member has several low level subsystems to control.
- It looks like it's a good idea to implement low level controllers that can be used in each of these subsystems.
- These low level controllers must be cheap.
- These subsystems could be complex and classics controllers couldn't control them.

1. Introduction

- To implement these controllers we can use Filed Programmable Gate Arrays (FPGAs):
  - They are cheap components,
  - They are flexible, so we can redefine their functionality reprogramming it using software,
  - They are replaceable in a easy way.

1. Introduction

- In this way the computational capacity of each robot was devoted to high level functions that they have to perform due to being a member of a Multi-Robot system:
  - Coordination,
  - Communication,
  - Deduce cooperatively the global strategy of the team,
  - Etc.

2. Objectives

- Get cheap implementation of low level control loops that could be used by each member of a multi-robot system.
- Use Predictive Controllers to control complex subsystems that classics controllers can’t.
- Use Time Delayed Neural Networks to model Predictive Controllers.

3. Model Predictive Control (MPC)

- Advanced technique used to deal with systems that are not controllable using classic control schemas, as PID.
- It isn't a concrete technique: there are several possibilities.

3. Model Predictive Control (MPC)

- It works like human brain:
  - It doesn’t use past error between the output of the system and the desired value.
  - It predicts the value of the output in a short time.
  - It generates a signal to get that the output of the system was as closer as possible of the desired value.

3. Model Predictive Control (MPC)

- We use Dynamic Matrix Control (DMC):
  - It's a concrete MPC technique.
  - Subsystem model: Step response.
  - Objective function: measures the difference between the reference signal and the predicted output.
  - Control law: $\Delta u = \left(G^t G + \lambda I\right)^{-1} G^t \left(w - f\right)$

3. Time Delayed N. Networks (TDNN)

- They are used to model a tuned Predictive Controller.
- Main characteristics:
  - They are a kind of multi-layer perceptron neural networks.
  - They are dynamics.
  - Delayed versions of the input signals are introduced to the input.

4. Case Study

- An actuator modeled by:

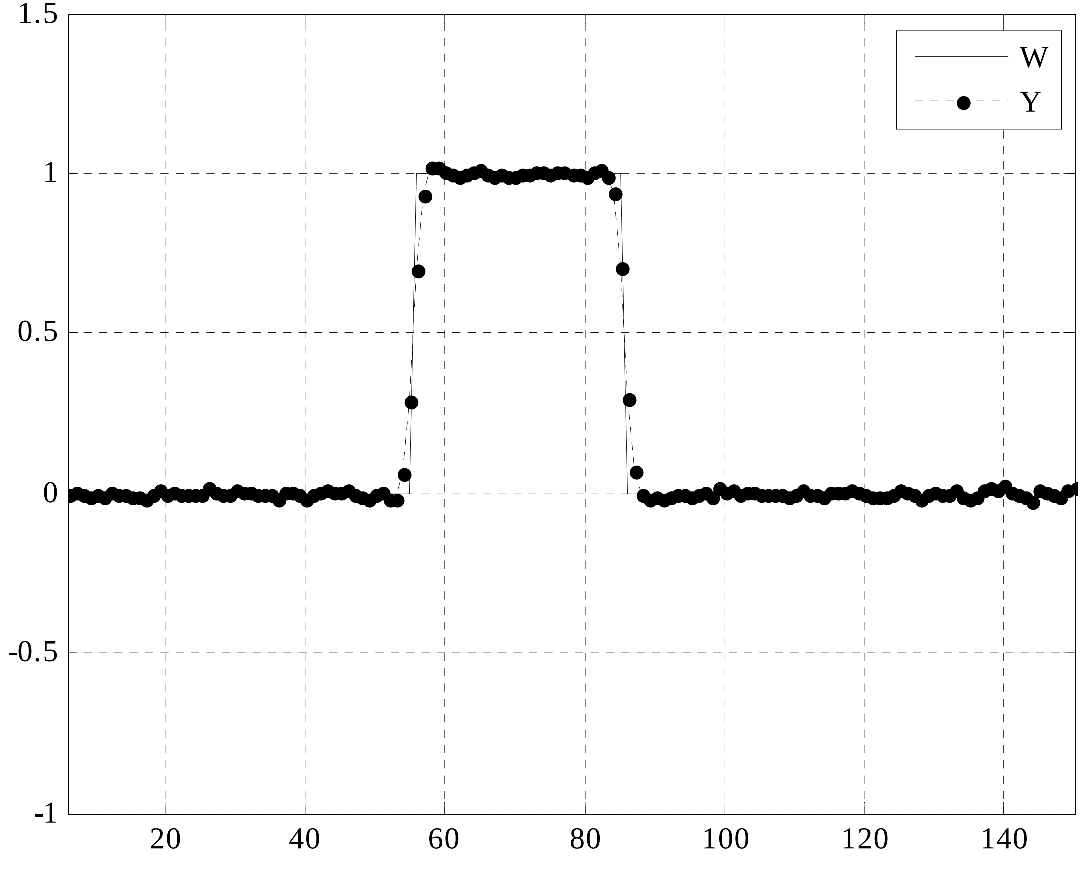
$$H(z) = \frac{1}{z - 0.5}$$

- It’s a stable system.
- But if we try to control it using a PID controller tuned by through Ziegler-Nichols method, it becomes unstable.

4. Case Study

- But we can control it using a Dynamic Matrix Control tuned with the following parameters:
  - Prediction Horizon: $p = 5$
  - Control Horizon: $m = 3$
  - Lambda: $\lambda = 1$

4. Case Study



4. Case Study

- But Predictive Control in general, and Dynamic Matrix Control in particular has a drawback: it's computational expensive even in the working phase.
- To deal with this we have modeled the DMC controller using Time Delayed NNs.
  - They are very fast.
  - They have the ability of generalizing responses.

4. Case Study

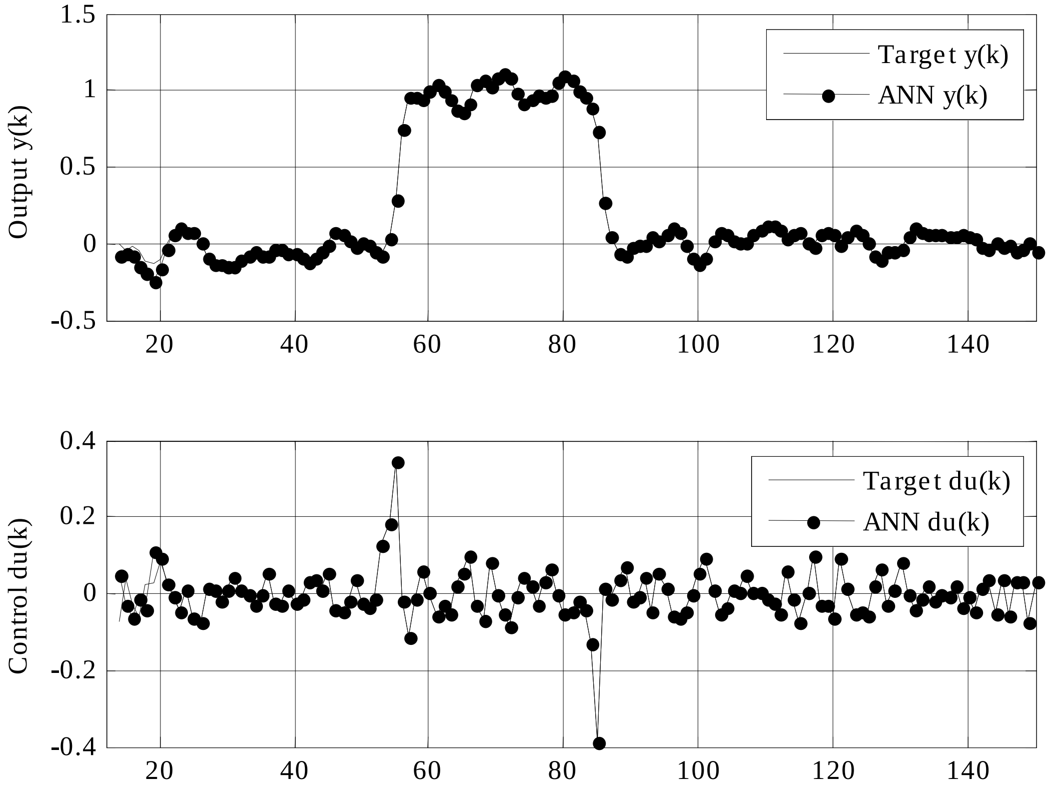
- Training experiments with multiple structures, varying:
  - Number of hidden layer neurons h.
  - Number of delays of the time delay line d.
- The Levenberg-Marquardt method has been used to carry out the training.
  - Target vector: $P = [w(k), y(k), \Delta u(k-1)]'$
  - Output: $\Delta u(k)$

4. Case Study

- The control of neuronal controller is right even with noisy references that hadn't been used in the training phase.
- The chosen structure:
  - Number of hidden layer neurons $h = 5$.
  - Number of delays of the time delay line $d = 7$.

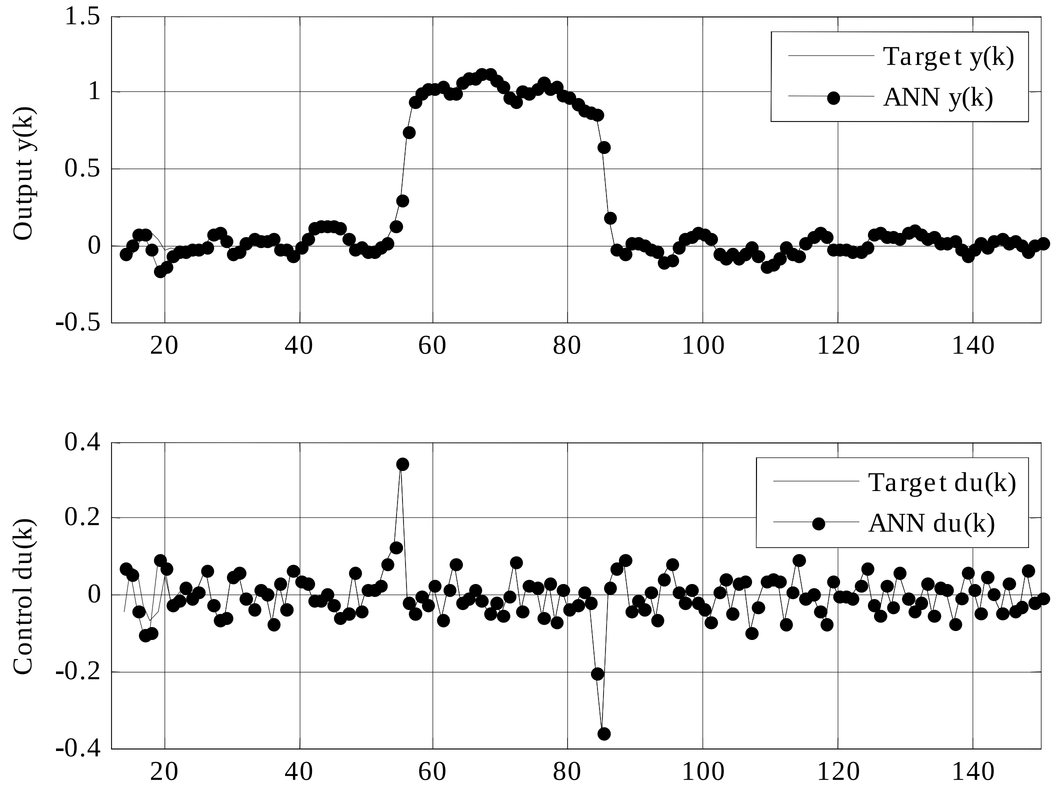
4. Case Study

- Example 1:



4. Case Study

- Example 2:



5. Conclusions

- Multi-Robot systems must be economically attractive.
- The computational capacity of robots of a Multi-Robot system was devoted to high level functions.
- The control of internal subsystems must be cheap.

5. Conclusions

- Predictive Control is a technique that can control subsystems that classic controllers can’t.
- Time Delayed Neural Networks are a kind of ANN that can model Dynamic Matrix Controllers.
- Field Programmable Gate Arrays (FPGAs) are suitable for implementing these Neuronal Predictive Controllers.

Thanks.

Questions?