# Human Knee Simulation Using CMAC ANN

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*Abstract*— **This paper aims to show the use of a CMAC (Cerebellar Model Articulation Control), a kind of ANN (Artificial Neural Network). The CMAC is based on cerebellum of mammals, but despite this characteristic, actually, what promotes its use, is its very fast operation, which makes it suitable for adaptive control in real time. This type of control is needed, for example, to control an active transfemoral prosthesis. Simulation of knee angular velocities, based on collected data from the contralateral knee, is presented. The simulation is available as open source software.**

*Keywords*— **CMAC, machine learning, knee, simulation.**

## I. Introduction

The quest to improve the life quality is constituted as one of the prerogatives of Biomedical Engineering. Rehabilitation discipline is supported by biomedical engineering, for example, in prostheses constructions. Prostheses can be passives or actives [1]. Passive form use intrinsically passive actuators and active form have automatic actuators.

The construction of an active transfemoral prosthesis is not a trivial problem solution. To build them is required before to develop or to use a biomechanical model. From this, one must create a control method using control engineering techniques and / or intelligent systems.

The rise of intelligent systems brought a new landscape for Biomedical Engineering. This kind of solution allows previously unimagined system classes. It is possible to build intelligent systems which are not solvable easily by traditional PID (Proportional-Integral-Derivative), with many variables, many parameters and nonlinears. Intelligent systems are everywhere, in digital cameras, Internet search engines, speech recognition systems, cell phones, car brake systems and countless other devices.

Among the techniques for building intelligent systems, there are the ANNs (Artificial Neural Networks). This kind of system is too classified as machine learning based system [2]. They are systems which learn to figure out complex problems during the learning phase, through historical collected data, without the necessity of complex physical models. The CMAC (Cerebellar Model Articulation Control) [3] is a ANN inspired on cerebellum of mammals [4], which compared with another kind of ANN called MLP (Multi-Layer Perceptron)[5], with at least one hidden layer, has the advantage of needing much less calculations to update their weights during training [6].

Lin shows in [7], the effectiveness of CMAC model, by preliminary studies of kinematic control and gait synthesis. After training an ANN based on CMAC, to learn multivariable and nonlinear relationships kinematics of quadruped gait, the ANN was used to control straight and uphill walk of quadruped robots.

The [8] depicts the robustness of a CMAC in a biped robot running in conditions presenting disorders. The [9] presents strategies for using the CMAC in same type of robot.

Before one can build a prosthesis controller, is advisable first to simulate their behavior via software. This idea can facilitate prototypes production. In this context, the paper illustrates a human knee angular velocities simulation, using machine learning based CMAC model for possible knee control in a transfemoral active prosthesis.

## II. Materials and Methods

The simulation process is summarized in Figure 1.

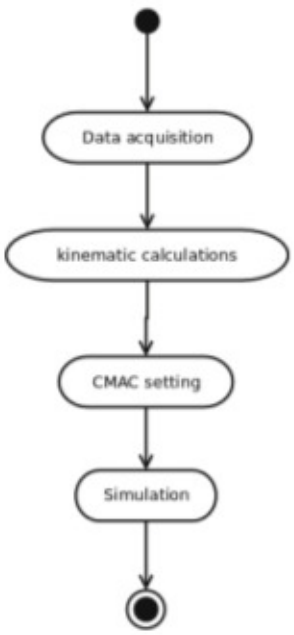


Fig. 1: Simulation Process



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