# Robot System Identification using 3D Simulation Component Applied on VIPRO Platform

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*Abstract*. **The paper presents automated estimation techniques for robot parameters through system identification, for both PID control and future implementation of intelligent control laws, with the aim of designing the experimental model in a 3D virtual reality for testing and validating control laws in the joints of NAO humanoid robots. After identifying the maximum likelihood model, the PID amplification factors are optimized and introduced into the Unity environment as a script for controlling the joint. The program used for identifying PID parameters for the NAO robot is developed using the virtual reality platform Unity 3D and integrated into the Graphical Station component of the VIPRO Platform for the control of versatile, intelligent, portable robots. The obtained results, validated in the virtual reality environment, have led to the implementation of the PID identification and optimization component on the VIPRO Platform.**

*Keywords—intelligent robotic control systems; robotic system identification; modelling system; virtual reality; robot stability*

## I. INTRODUCTION

The last few years have seen mobile robots gain increased attention in the research community, as well as in the manufacturing industry, resulting in remarkable hardware and software development. Among the applications of great interest for researchers are: dangerous activities such as detection of antipersonnel mines and other explosives, surveillance activities ("Remotec" has developed the Marauder technology which later led to the development of the Andros Mark V robot) and rescue operation in case of calamity.

Following the devastating earthquakes in Japan, an international project has been developed which reunites renowned research teams from all over the world for the design of search and rescue robots, under the banner of the RoboCup – Rescue Project, divided into two sub-projects: multi-agent simulation using a virtual robot and development of a real robot.

Developing remote-controlled, autonomous mobile robots, which can support humans in search and rescue operations in a contaminated nuclear environment, after fires or in calamitous earthquake areas has become a priority and entails a complex challenge. To this end, numerous robot control methods have been developed for moving on uneven and uncertain environments, which allows improvements in robot mobility and stability, through intelligent algorithms: fuzzy logic, extenics, neutrosophy, neural networks, Petri nets with Markov models, hybrid force-position control method, among others.

## II. 3D UNITY SIMULATION COMPONENT APPLIED ON VIPRO PLATFORM

Real time, remotely-controlled robots with the capabilities of a human operator have an increasingly important role in hazardous or challenging environments, where human life

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might be endangered, such as nuclear contamination areas, fires and earthquake zones [1 - 3].

Research in these fields have led to an accumulation of important expertise regarding robot movement in virtual environments, with improvements in navigation, obstacle avoidance, high fidelity environment simulation, etc., but lacking the environment – virtual robot – robot interactions. In this context by developing an innovative platform [4 - 7], the VIPRO Platform has been conceived for brings virtual robots into the real world, mainly consisting in the projection into a virtual environment of the robot mechanical structure, and communicate in real time through a high-speed interface with real robotic control systems, in order to improve performances of the robot control laws. The result is a versatile, intelligent, portable robot platform (VIPRO), which allows improved of the robot motion and stability performance in a virtual and real environment on uneven and unstructured terrain for mobile, autonomous, intelligent robots, such as the NAO robots, or in particular the search and rescue robots RABOT.
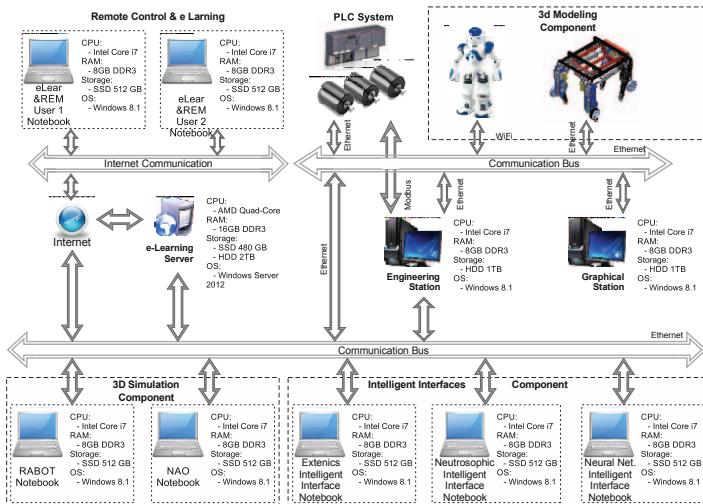


Figure 1. VIPRO Platform Architecture

The VIPRO Platform architecture for modelling and simulation of mobile robots is based on the virtual projection method [6, 8-11], through which robotics and mechatronics systems are developed in a virtual environment.

The technical solution, presented in an open architecture real time control structure (Figure 1), contains the main modules of the VIPRO Platform. The intelligent control interface module uses advanced control strategies adapted to the robot environment such as extended control (extenics) [12 - 14] , neutrosophic control [15 - 18], human adaptive mechatronics, etc., implemented through computational techniques for fast processing and real time communication. The following intelligent control interfaces have been designed and implemented on the VIPRO Platform: neutrosophic robot control interface (ICNs), extended control interface for robot extenics control (ICEx) and the neural network interface (INN) for dynamic hybrid force position control DHFPC [19, 20].

The two main components of the VIPRO Platform are the workstation "Engineering Station" for the PLC classic position control of robot joint actuators and speed control of load actuators, and the "Graphical Station" for the development of a virtual robot environment and virtual reality for robot motion.

The VIPRO Platform has allotted 5 user stations dedicated to modelling the NAO robot using direct and inverse kinematics, modelling the RABOT robot in the Unity development environment, neutrosophic intelligent control (ICN) through the integration of the RNC method, extended control through the extenics method (ICEx) and modelling inverse kinematics in the robot motion control using fuzzy inference systems and neural networks.

For remote control in establishing the e-learning component of the VIPRO Platform, a PC server was integrated to ensure large data traffic for internet communication, with two addition workstations for end-user applications.

The "Engineering Station" component is mainly aimed at integrating the AC500 development environment for programmable automate (PLC) applications, control of the application stand for the virtual projection method on 6 DOF, and testing of the intelligent neutrosophic control (ICNs), extenics control (ICEx) and dynamic hybrid force position control DHFPC interfaces.

After testing, these are integrated in real-time control of a new robot with improved performance and stability of motion through the Graphical Station, as follows: for multi-users through the components of the VIPRO Platform consisting of Remote Control& eLearning User 1, Remote Control& eLearning User 2 or individually through the VIPRO Platform components consisting of the dedicated intelligent interfaces on the Notebook workstations, namely "Extenics Intelligent Interface Notebook", "Neutrosophic Intelligent Interface Notebook" and "Neural Network Intelligent Interface Notebook".

Using 3D UNITY Simulation Component Applied to the VIPRO Platform, the paper presents automated estimation techniques for robot system identification.

## III. AUTOMATED TECHNIQUES FOR PARAMETER ESTIMATION

### A. Identification of PID parameters for the NAO robot

Designing the experimental model in a virtual 3D environment for testing and validation of the PID control law parameters of the robot joints entails an accurate identification of the system model through automated parameter estimation algorithms for both the PID controller, as well as the future implementation of intelligent control laws [21 - 23].

Ensuring the stability of the experimental virtual model, using PID control in the robot joints, requires knowledge of an approximate model of the controlled process, based on which the amplification factors for the parallel PID structure are established. The model is developed through system identification algorithms using known vectors of input and related output data of the unknown system. The Unity 3D environment allows data generation for input references to a virtual robot joint and monitoring its behavior, thus obtaining the required output data. These are used for the parameter estimation of system models applied to the phenomenon. After identifying the maximum likelihood model, the amplification factors for a PID controller structure are optimized and introduced into the Unity environment as a controller script for the robot joint. The robot joint in the Unity environment is treated as a black-box system, without the need to intervene on

the development environment's libraries or source code (as relates to understanding or modifying the physics engine).

## B. NAO Leg Joint 3D Simulation Data in UNITY

The two sets of data (the input and output vectors, respectively) are exported to an Excel working file in *.csv format, to be further imported into the numerical processing environment. An example is shown in Figure 2.

The data is imported into Matlab using the function xlsread, resulting in a data vector structure used to identify the position controlled system.
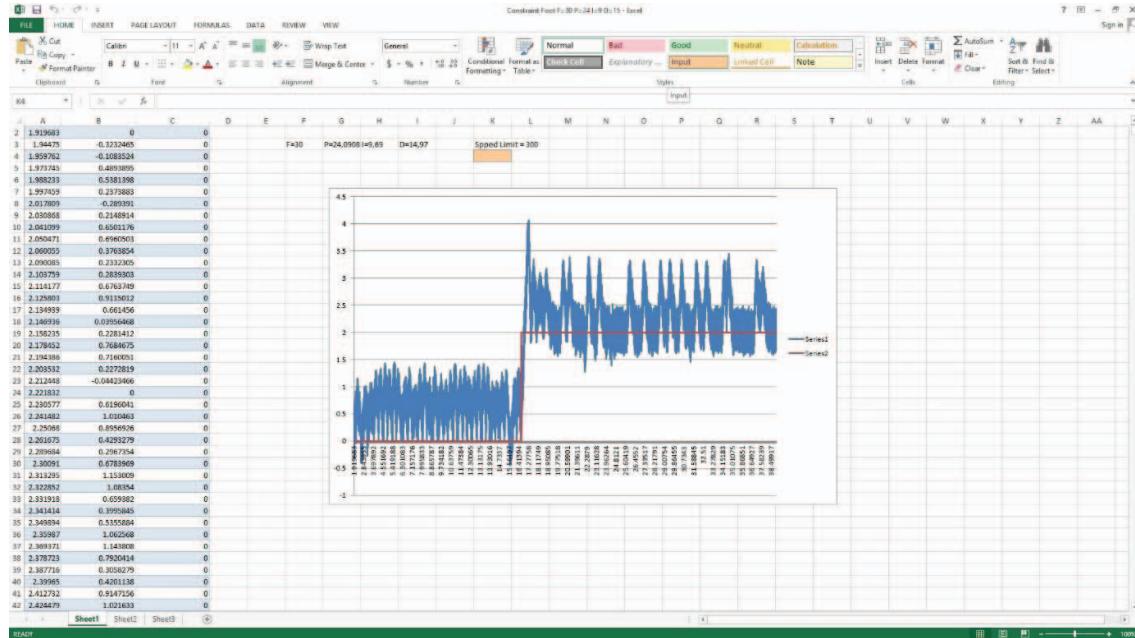


Figure 2. Data structure exported from Unity to a *.csv file

With the help of the native xlsread function, the file obtained in the Unity 3D tests can be imported into the Matlab environment for processing.

The result is shown in Figure 3, in which the data is structured as two vectors representing the reference (input variable) and the system output.
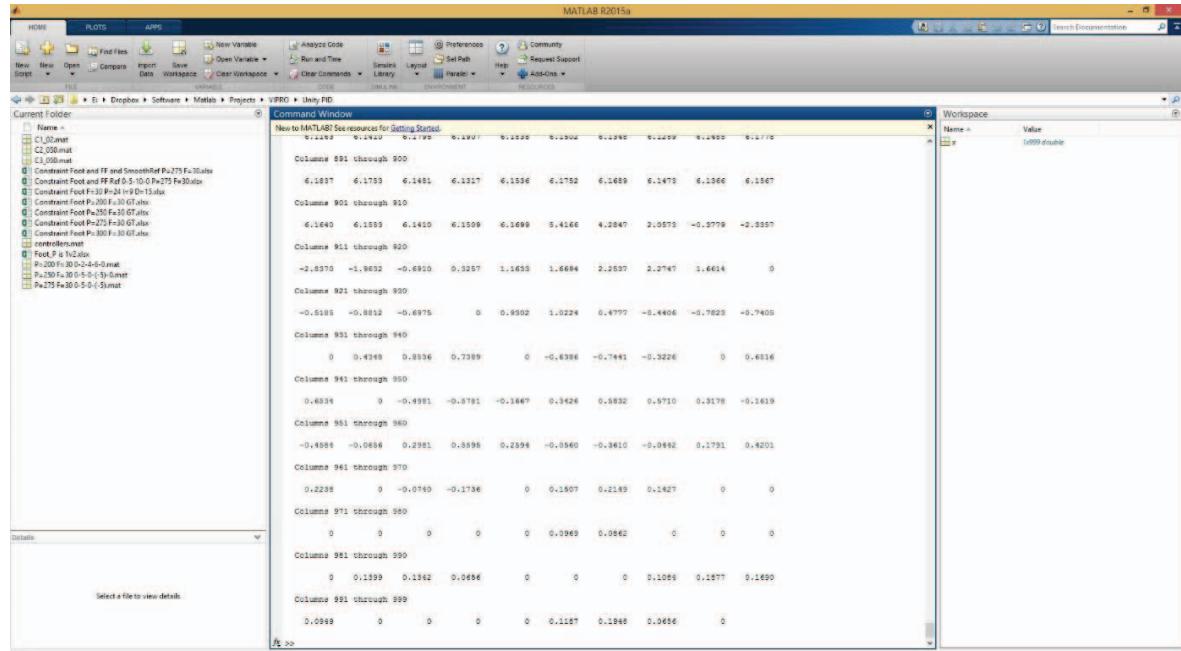


Figure 3. Vector imported into the workspace

## C. Data pre-processing

The obtained data is pre-processed, as can be seen in Figure 4, to ease the task of system identification by eliminating nonessential areas and their respective noise. For example, the reference has a null value for the beginning of the test in order to calibrate the system. However, the acquired data shows nonzero values due to the existing noise in the simulation environment and the inexactness assumed in representing the mechanical system.
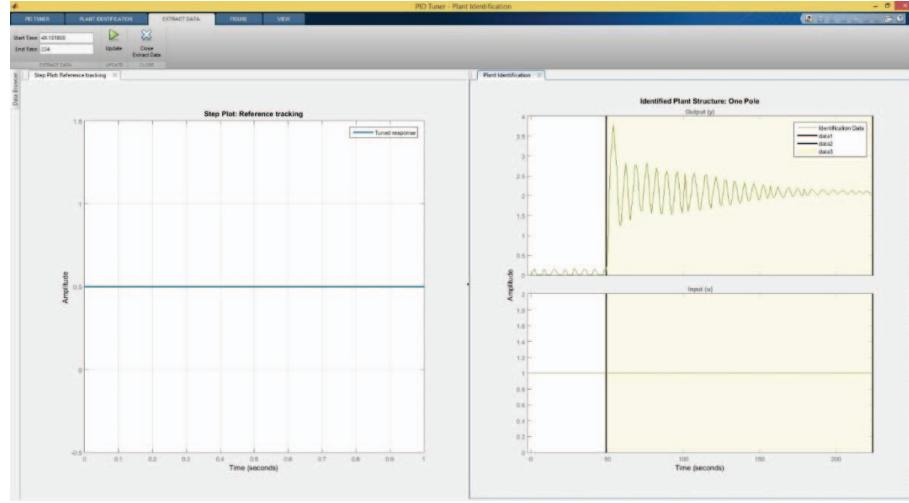


*Figure 4. Pre-processing the obtained data*

## IV. SYSTEM IDENTIFICATION

System identification using the automated identification function from the Matlab toolbox is tried for a number of various order systems.

After the input data has been brought to a desired form and the possible noise components removed, system identification can begin in earnest. In the respective application in the Matlab programming environment are investigated a number of possible system models, with the program handling the automatic parameter identification.

Given a certain model chosen for representation, the interface optimizes automatically the model parameters using the samples from the input and output vectors (Figure 5).
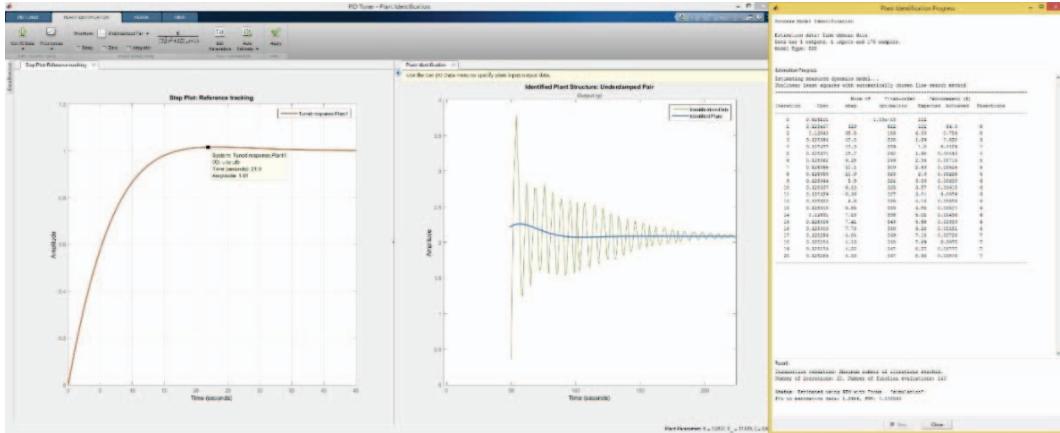


*Figure 5. Model identification for two paired poles*

## A. Control model adaptation

For complex black-box system identification and adaptation to the nonlinear behaviour of the data set, the separate system identification interface is used. The various available options and the parameter optimization algorithms are shown in Figure 6.

## B. Control law optimization interface

Optimization of the PID controller in a varied number of options and of the amplification factors for each of these, which control the chosen process, is developed in the virtual environment through an intelligent control interface.

Within the existing interface, the controller type was chosen (P/PI/PD/PID), as well as the desired response for a closed

loop system including this controller. The estimated result, seen within the interface in Figure 7, has allowed establishing the desired transitive response, the convergence speed and the direct adjustment of the amplification factors of the three branches of the controller.
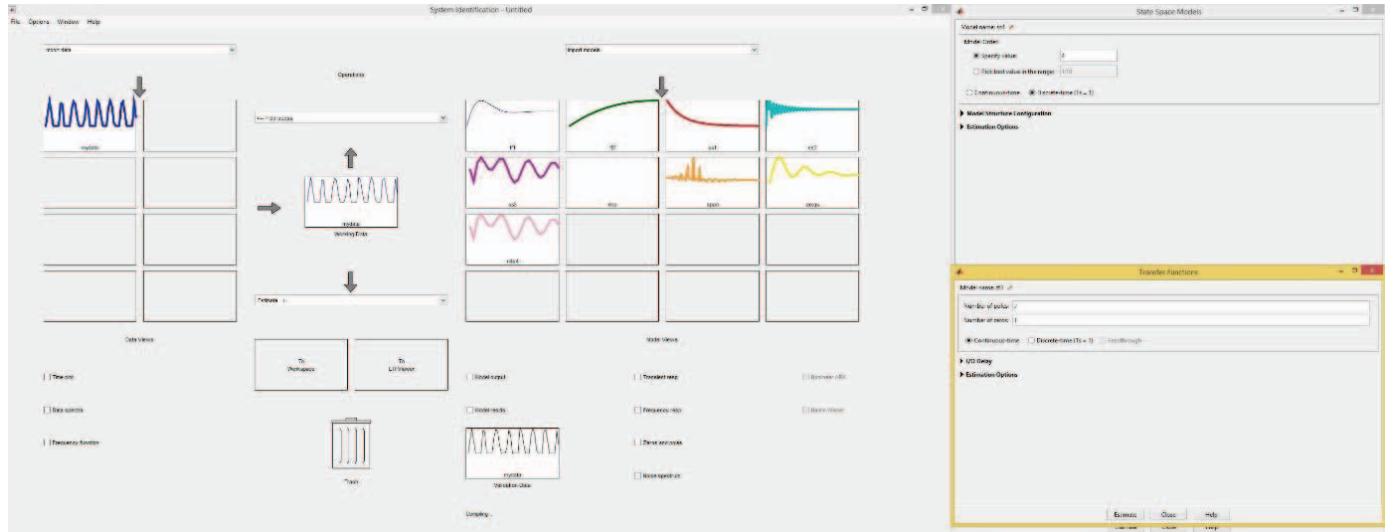


*Figure 6. Comprehensive interface for robotic system identification*

After the theoretical validation of the model, the obtained data is exported back into the virtual reality 3D environment in Unity, in which the controller behaviour is simulated through a compiled script, which generated the amplifications determined in the Matlab control interface presented above.
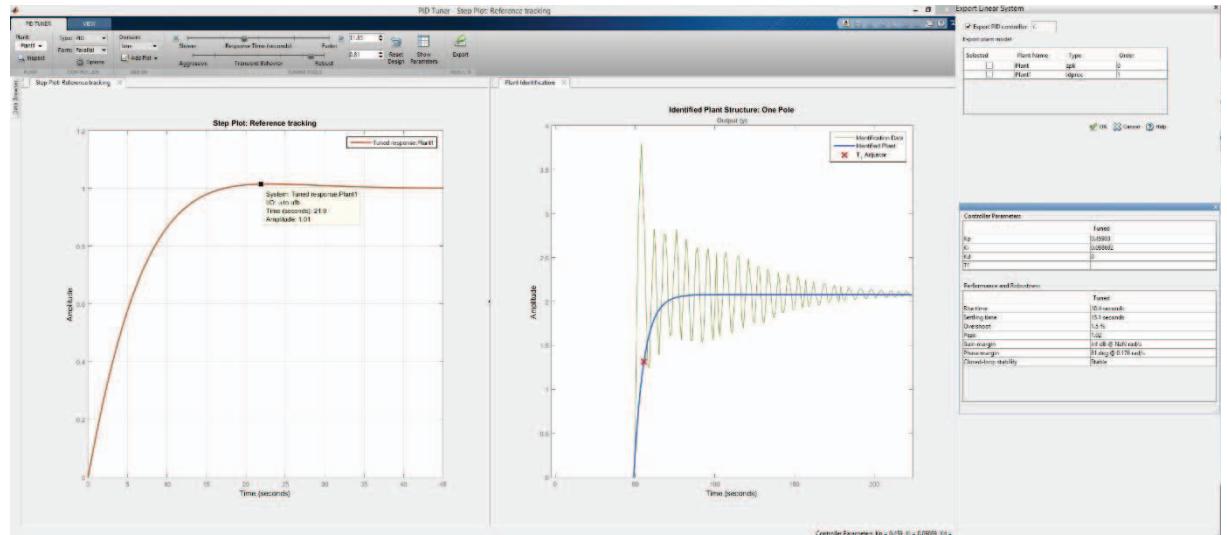


*Figure 7.  PID answer estimated*

## V.  RESULTS AND CONCLUSIONS

Identifying the control law parameters for the Nao walking robot, using the 3D simulation component of the virtual reality platform Unity 3D, through automated parameter estimation techniques, for both PID control and future implementations of intelligent control laws, allows an improvement in stability and robot motion control in a virtual reality environment.

By applying the virtual projection method, the improvement in robot performance is transferred from the virtual world of modelling and simulation to the real world of experimental models, representing a powerful experimental validation tool.

The PID parameter identification program for the Nao humanoid robot using the virtual reality platform Unity 3Dand the 3D simulation component are shown in Figure 8, are available for users of the VIPRO platform and accessible from the VIPRO interface, either locally or from a remote location.
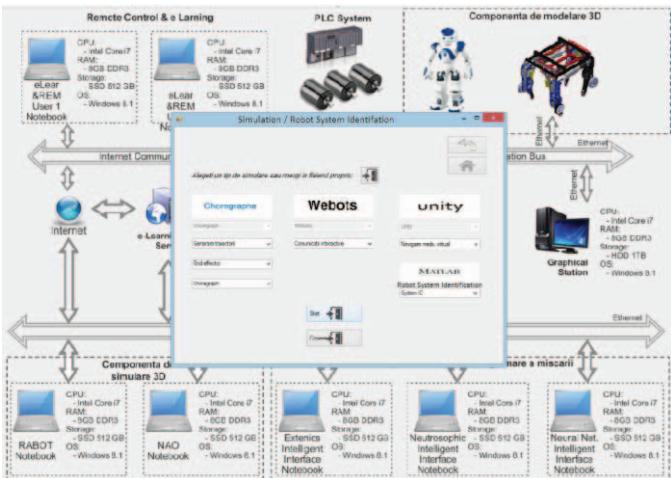
*Fig.8. Robot system identification on VIPRO Platform*

The obtained results, validated in the virtual reality environment, have led to the implementation on the VIPRO Platform in the 3D environment Unity, of the simulation component for the PID parameter identification for the NAO humanoid robot, with the possibility of extension to the RABOT search and rescue robot.

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