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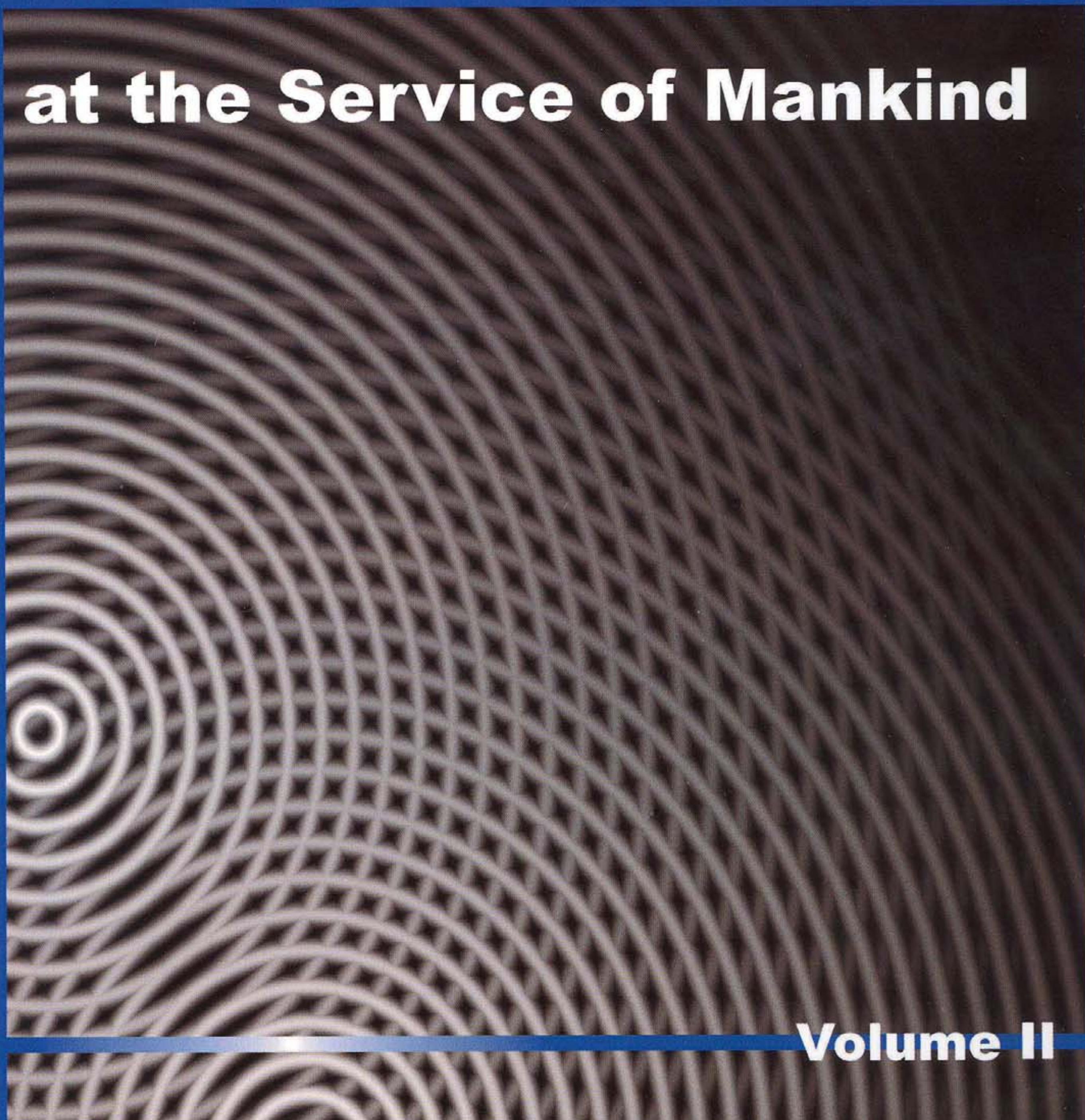

Volume II

Improved Numerical Simulation for a Novel Adaptive Control Using Fractional Order Derivatives

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Abstract — *A novel control technique is investigated in the adaptive control of a typical paradigm, an approximately and partially modeled cart plus double pendulum system. In contrast to the traditional approaches that try to build up "complete" and "permanent" system models it develops "temporal" and "partial" ones that are valid only in the actual dynamic environment of the system, that is only within some "spatio-temporal vicinity" of the actual observations. This technique was investigated for various physical systems via "preliminary" simulations integrating by the simplest* 1^{st} *order finite element approach for the time domain. In 2004 INRIA issued its SCILAB 3.0 and its improved numerical simulation tool "Scicos" making it possible to generate "professional", "convenient", and accurate simulations. The basic principles of the adaptive control, the typical tools available in Scicos, and others developed by the authors, as well as the improved simulation results and conclusions are presented in the contribution.*

1 Introduction

A new approach for the adaptive control of imprecisely known dynamic systems under unmodeled dynamic interaction with their environment was initiated in [1]. In the family of the adaptive control methods this new one is situated between the linear PID/ST and the parameter identification approaches. Instead of the supposed analytical model's parameters the controller is tuned as in the PID/ST control, but it uses several parameters of some abstract Lie groups fit to the needs of the "non-linear control". In the same time these parameters may be considered as that of the system-model, though they do not belong to a detailed, analytical system-description. This "non-analytical modeling" is akin to the Soft Computing philosophy, too. In this approach adaptivity means that instead of simultaneous tuning of numerous parameters, a fast algorithm finding some linear transformation to map a very primitive initial model based expected system-behavior to the observed one is used. The so obtained ”amended model” is step by step updated to trace changes by repeating this corrective mapping in each control cycle. Since no any effort is exerted to identify the possible reasons of the difference between the expected and the observed system response it is referred to as the idea of ”Partial and Temporal System Identification”. This anticipates the possibility for real-time applications. Regarding the appropriate linear transformations several possibilities were investigated and successfully applied. For instance, the ”Generalized Lorentz Group” [2], the ”Stretched Orthogonal Group”, the ”Partially Stretched Orthogonal Transformations” [3], and a special family of the ”Symplectic Transformations” [4] can be mentioned.

The key element of the new approach is the formal use of the ”Modified Renormalization Transformation”. The ”original” version of this transformation was widely used in the seventies to investigate the properties of chaos. This (originally scalar) transformation modifies the solution of an $x = f(x)$ fixed-point problem. Since the adaptive control can be formulated as a fixed-point problem, too [5], this transformation was considered to be a possible candidate for the solution of the task of the adaptive control. The modification of the original transformation was necessary due to phenomenological reasons. Satisfactory conditions of the complete stability of the so obtained control for Multiple Input-Multiple Output (MIMO) systems were also highlighted in [5] by the means of perturbation calculation. This means the most rigorous limitation of the circle of the possible applications of the new method. To release this restriction to some extent ”ancillary” but simple interpolation techniques and the use of ”dummy parameters” were also introduced in [5]. The applicability of the method was investigated for electro-mechanical and hydrodynamic systems via simulation [6, 7]. In this paper a quite simple but lucid typical paradigm, a cart conveying a double pendulum is chosen to be the subject of the adaptive controller.

2 The Control Problem in General

From purely mathematical point of view the control problem can be formulated as follows: there is given some imperfect model of the system on the basis of which some excitation is calculated for a desired reaction of the system used as the input of the controller $\mathbf{i}^d$ as $\mathbf{e} = \varphi(\mathbf{i}^d)$. The system has its inverse dynamics described by the unknown function resulting in a realized $\mathbf{i}^r$ instead of the desired one, $\mathbf{i}^d : \mathbf{i}^r = \psi(\varphi(\mathbf{i}^d)) = \mathbf{f}(\mathbf{i}^d)$). (In Classical Mechanics these values are the desired and the realized joint accelerations, while the external free forces and the joint velocities serve as the parameters of this temporarily valid and changing function.)

Normally any information on the behavior of the system can be obtained only via observing the actual value of the function $\mathbf{f}()$. In general it can considerably vary in time. Furthermore, no any possibility exists to ”directly manipulate” the nature of this function with the exception of the direct manipulation of its actual input from $\mathbf{i}^d$ to certain $\mathbf{i}^{d^*}$, that is a ”deformed” input. The controller’s aim is to achieve and maintain the $\mathbf{i}^d = \mathbf{f}(\mathbf{i}^{d^*})$ state. [Only the nature of the model function $\varphi(\mathbf{i}^d)$ can directly be determined.]

The Modified Renormalization Algorithm consists in seeking a series of linear transformations as:

$$\mathbf{i}_0; \mathbf{S}_1\mathbf{f}(\mathbf{i}_0) = \mathbf{i}_0;\ \mathbf{i}_1 = \mathbf{S}_1\mathbf{i}_0; \ldots; \mathbf{S}_\mathrm{n}\mathbf{f}(\mathbf{i}_{\mathrm{n}-1}) = \mathbf{i}_0;\ \mathbf{i}_{\mathrm{n}+1} = \mathbf{S}_{\mathrm{n}+1}\mathbf{i}_\mathrm{n};\ \mathbf{S}_\mathrm{n} \xrightarrow[\mathrm{n}\to\infty]{} \mathbf{I} \tag{1}$$

in which the $\mathbf{S}_\mathrm{n}$ matrices denote some linear transformations to be specified later. As it can be seen these matrices map the observed response to the desired one, and the construction of each matrix corresponds to a step in the adaptive control. It is evident that if this series converges to the identity operator just the proper deformation is approached, therefore the controller "learns" the behavior of the observed system by step-by-step amendment and maintenance of the initial model. Since (1) does not unambiguously determine the possible applicable quadratic matrices we have additional freedom in finding appropriate ones. The most important points of view are fast and efficient computation and the ability for remaining as close to the identity transformation as possible. For making the problem mathematically unambiguous (1) can be transformed into a matrix equation by putting the values of $\mathbf{f}$ and $\mathbf{i}$ into well-defined blocks of bigger matrices. Via computing the inverse of the matrix containing $\mathbf{f}$ in (1) the problem can be made mathematically well-defined. Since the calculation of the inverse of one of the matrices is needed in each control cycle it is expedient to choose special matrices of fast and easy invariability. Within the block matrices the response arrays may be extended by adding to them a "dummy", that is physically not interpreted dimension of constant value, in order to evade the occurrence of the mathematically dubious $0 \to 0$, $0 \to$ finite, finite $\to 0$ transformations. In the present investigations the special symplectic matrices announced in [4] were applied for this purpose. In general, the Lie group of the Symplectic Matrices is defined by the equations

$$\mathbf{S}^T \Im \mathbf{S} \equiv \left[\begin{array}{c|c} \mathbf{0} & \mathbf{I} \\ \hline -\mathbf{I} & \mathbf{0} \end{array}\right], \det\mathbf{S} = 1. \tag{2}$$

The inverse of such matrices can be calculated in a computationally very cost-efficient manner as $\mathbf{S}^{-1} = \Im^T \mathbf{S}^T \Im$. In our particular case the symplectic matrices are constructed from the desired and the observed joint coordinate accelerations corresponding to the response of the mechanical system to the excitation of torque and force by the use of the columns of the matrix

$$[\mathbf{m}_1, \mathbf{m}_2, \mathbf{m}_3, \mathbf{m}_4, \mathbf{m}_5] = \begin{bmatrix} \ddot{q}_1 & -\ddot{q}_1 & e_1^{(3)} & e_1^{(4)} & e_1^{(5)} \\ \ddot{q}_2 & -\ddot{q}_2 & e_2^{(3)} & e_2^{(4)} & e_2^{(5)} \\ \ddot{q}_3 & -\ddot{q}_3 & e_3^{(3)} & e_3^{(4)} & e_3^{(5)} \\ d & -d & e_4^{(3)} & e_4^{(4)} & e_4^{(5)} \\ D & \frac{\ddot{\mathbf{q}}^2 + d^2}{D} & e_5^{(3)} & e_5^{(4)} & e_5^{(5)} \end{bmatrix} \tag{3}$$

in the block of a more complex one defined as

$$\mathbf{S} = \left[\begin{array}{c|c} \mathbf{0} & \frac{-1}{s}\mathbf{m}^{(1)}\ \ \frac{-1}{s}\mathbf{m}^{(2)}\ \ -\mathbf{e}^{(3)} \ldots -\mathbf{e}^{(5)} \\ \hline \mathbf{m}^{(1)}\ \ \mathbf{m}^{(2)}\ \ \mathbf{e}^{(3)} \ldots \mathbf{e}^{(5)} & \mathbf{0} \end{array}\right] \tag{4}$$

in which the $\mathbf{e}^{(3)} \ldots \mathbf{e}^{(5)}$ symbols denote unit vectors in the orthogonal sub-space of the first two columns, d is the "dummy" parameter used for avoiding singular transformations, and

$$D^2 \equiv \ddot{\mathbf{q}}^T\ddot{\mathbf{q}} + d^2,\ s = 2D^2 \tag{5}$$

The unit vectors can be created e.g. by using El Hini's algorithm [3], which, while rotates vector $\mathbf{b}$ into the direction of vector $\mathbf{a}$, leaves the orthogonal sub-space of these vectors invariant. So if the operation starts with an orthonormal set $\{\mathbf{e}^{(1)} \dots \mathbf{e}^{(5)}\}$ and at first it is rigidly rotated until $\mathbf{e}^{(1)}$ becomes parallel with the 1st column of $\mathbf{M}$, its 2nd column will be in the orthogonal sub-space of the 1st one spanned by the transformed $\{\mathbf{e}^{*(2)} \dots \mathbf{e}^{*(5)}\}$ set. In the next step this whole set can rigidly be rotated until the new $\mathbf{e}^{**(2)}$ becomes parallel with the 2nd column of $\mathbf{M}$. (This operation leaves the previously set $\mathbf{e}^{*(1)}$ invariant because it is orthogonal to the two vectors determining this special rotation.) With the above completion the appropriate operation in (1) evidently equals to the identity operator if the desired response just is equal to the observed one, and remains in the close vicinity of the unit matrix if the non-zero desired and realized responses are very close to each other. Since amongst the conditions for which the convergence of the method was proven near-identity transformations were supposed in the perturbation theory, a parameter ξ measuring the "*extent of the necessary transformation*", a "*shape factor*" σ, and a "*regulation factor*" λ can be introduced in a linear interpolation with small positive ϵ_1, ϵ_2 values as

$$\xi := \frac{|\mathbf{f} - \mathbf{i}^d|}{\max(|\mathbf{f}|, |\mathbf{i}^d|) + 1},\ \lambda = 1 + \epsilon_1 + (\epsilon_2 - 1 - \epsilon_1)\frac{\sigma\xi}{1 + \sigma\xi},\ \hat{\mathbf{i}}^{\mathrm{d}} = \mathbf{f} + \lambda(\mathbf{i}^{\mathrm{d}} - \mathbf{f}) \tag{6}$$

This interpolation reduces the task of the adaptive control in the more critical sessions and helps to keep the necessary linear transformations in the vicinity of the identity operator. In the forthcoming simulations the following numerical data were used: $d = 100$, $\sigma = 22$, $\epsilon_1 = 0.2$, $\epsilon_2 = 0.1$. They were selected "experimentally".

3 The Dynamic Model of the Cart - Double Pendulum System

Let the cart consist of a body and wheels of negligible momentum and inertia having the overall mass of *M [kg]*. Let the pendulums be assembled on the cart by parallel shafts and arms of negligible masses and lengths L_1 and L_2 [*m*], respectively. At the end of the arms balls of negligible sizes and considerable masses of m_1 and m_2 [*kg*] are attached, respectively. The appropriate rotational angles are q_1 and q_2 [*rad*], and the linear degree of freedom describing the translation of the cart pus pendulums system is denoted by q_3 [*m*]. The Euler-Lagrange equations of motion of this system, in which g denotes the gravitational acceleration $[m/s^2]$, Q_1 and Q_2 [*Nm*] denote the driving torque at shaft 1 and 2, respectively, and Q_3 [*N*] stands for the force moving the cart in the horizontal direction, are given as follows:

$$\begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \end{bmatrix} = \begin{bmatrix} m_1L_1^2 & 0 & -m_1L_1\sin q_1 \\ 0 & m_2L_2^2 & -m_2L_2\sin q_2 \\ -m_1L_1\sin q_1 & -m_2L_2\sin q_2 & (M + m_1 + m_2) \end{bmatrix} \begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \\ \ddot{q}_3 \end{bmatrix} + \tag{7}$$

$$\begin{bmatrix} -m_1L_1\cos q_1\dot{q}_1\dot{q}_3 - m_1gL_1\cos q_1 \\ -m_2L_2\cos q_2\dot{q}_2\dot{q}_3 - m_2gL_2\cos q_2 \\ -m_1L_1\cos q_1\dot{q}_1^2 - m_2L_2\cos q_1\dot{q}_2^2 \end{bmatrix}$$

On the basis of (7) it is easy to express the inverse dynamical equations of motion in closed analytical form used for simulation purposes.

4 The Fractional Order Derivatives

In the case of a normal PID-type controller the desired trajectory reproduction can be prescribed in a purely kinematics based manner. For the second time-derivative of the actual coordinate errors vector e the desired relation can be formulated as:

$$\ddot{\mathbf{e}}^d = -P\mathbf{e} - D\dot{\mathbf{e}} - I\int_0^t \mathbf{e}(t')dt' \tag{8}$$

A possible modification of (8) consists in replacing the local 1[st] order derivative by a "global" term also having some "memory" as

$$\ddot{\mathbf{q}}^D = \ddot{\mathbf{q}}^N + P\left(\mathbf{q}^N - \mathbf{q}^R\right) + DA\frac{d^\beta}{dt^\beta}\left(\mathbf{q}^N - \mathbf{q}^R\right) - I\int_0^t \left(\mathbf{q}^N - \mathbf{q}^R\right)dt' \tag{9}$$

in which A is a constant depending on β, and the symbol d^β/dt^βdenotes the fractional order derivative constructed on the basis by Caputo's definition as

$$\frac{d^\beta}{dt^\beta}u(t) := \frac{1}{\Gamma(1-\beta)}\int_0^t \left[\frac{du(\tau)}{d\tau}\right](t-\tau)^{-\beta}d\tau,\ \beta \in (0,1) \tag{10}$$

For $t > 0$ (10) physically has the following simple meaning: the full 1[st] order derivative in the integrand removes the constant component from the signal, and this derivative is "causally reintegrated" by the use of a Green function like expression that has slowly forgetting nature (the contribution of the far past becomes more and more negligible in it), while its singularity in $\tau = t$ enhances the relative weight of the contribution of the $\tau \cong< t$ instants. Furthermore, the relatively slowly decreasing "tail" of this function also acts as a frequency filter that rejects the high-frequency components of the traditional 1[st] derivative. Due to the singularity of the Green function in (10) common finite-element numerical integration cannot accurately be done. Instead of that we can suppose that at least $u'(\tau)$ is relatively slowly varying in time, therefore it can approximately be treated as a constant during the integration over a small time-interval, while the variation of the Green function can be taken into account accurately. Furthermore, to introduce symmetry against the translation of the signal in time we can omit the very long tail of the Green-function and we can go back in time only to some time t-T instead of 0. The proposed approximation of (10) in this paper was taken as

$$\frac{d^{\beta+1}}{dt^{\beta+1}}u(t) \cong \frac{u''(t)\delta^{-\beta+1}}{\Gamma(2-\beta)} + \sum_{0<s \text{ while } s\delta<\mathrm{T}} \frac{\delta^{-\beta+1}[(s+1)^{-\beta+1} - s^{-\beta+1}]}{\Gamma(2-\beta)}u''(t-s\delta) \tag{11}$$

The original form of (10) is inconvenient from the point of view that the "maximum" of the Green function always occurs in the "present" moment. For numerical simulations its components can be stored in an array variable as well as the u' values can be stored in a shift-register in the case of a discrete time approximation. It is interesting to highlight the connection between the "fractional" and the "integer" order derivatives on the basis of (11) that can trivially be written in the form as

$$\frac{d^\beta}{dt^\beta}u_k \cong \sum_{l=0}^{-N} a_l u'_{k+1} \tag{12}$$

implying that if the conventional 1st derivative is constant then the appropriate fractional order derivative also is constant, and their ratio is set by the sum of the coefficients. The so obtained factor $A := (\sum_{s=0}^{-N} a_s)^{-1}$is taken into account in (9). It is also evident that by prescribing constant fractional order derivative in a discrete time-resolution a causal series of the 1st order derivatives can be obtained as

$$\left(\frac{d^\beta}{dt^\beta}u\right)_{k+1} = a_0 u'_{k+1} + \sum_{l=-1}^{-N} a_l u'_{k+1+l} = \sum_{s=0}^{-N} a_s u'_{k+s} = \left(\frac{d^\beta}{dt^\beta}u\right)_k \tag{13}$$

leading to

$$\left(u'_{k+1} - u'_k\right) = -\sum_{s=-1}^{-N} \frac{a_s}{a_0}\left(u'_{k+1+s} - u'_{k+s}\right) \tag{14}$$

In a discrete-time approach this seems to prescribe the 2nd conventional derivative of the signal in each discrete time instant. It is interesting to see if the "initial condition problem"

$$\frac{d^\beta}{dt^\beta}u_{k+s} = \sum_{l=0}^{-N} a_l u'_{k+s+l} \equiv const.\ s = 0, 1, \ldots \tag{15}$$

converges to constant 1st derivatives or results in some divergent series. (In this case the term "initial condition" refers to an $N+1$ elements long series belonging to $s = 0$.) According to (14) the following estimation can be done

$$|u'_{k+1} - u'_k| \leq \sum_{s=-1}^{-N}\left|\frac{a_s}{a_0}\right||u'_{k+1+s} - u'_{k+s}| \leq K \times N \times \underset{s=-1,\ldots,-N}{Max} |u'_{k+1+s} - u'_{k+s}| = \tag{16}$$

$$= KN|u'_{k+1+s_1} - u'_{k+s_1}|, \text{ where } K := \underset{s=-1,\ldots,-N}{Max}\left|\frac{a_s}{a_0}\right|, \ -N \leq s_1 \leq -1$$

that is the appropriate maximum is taken at s_1. If $KN < 1$ (16) can recursively applied as

$$\begin{aligned} |u'_{k+1} - u'_k| &\leq KN|u'_{k+1+s_1} - u'_{k+s_1}| \\ &\leq (KN)^m|u'_{k+1+s_1+s_2+\ldots+s_m} - u'_{k+s_1+s_2+\ldots+s_m}|, \text{ where} \\ &\underset{z=1,2,\ldots,m}{\forall} \ -N \leq s_z \leq -1 \end{aligned} \tag{17}$$

The maximal difference determined by the initial conditions sooner or later will be achieved in (17). If $KN < 1$ then for $k \to \infty$ $m \to \infty$, (13) corresponds to a *Cauchy series* that is convergent in a full metric space. Therefore the differences between the elements in the initial condition slowly relax, and the series converges to a constant 1st order derivative.

That is the presence of the factor A in (9) is substantiated from this point of view, too. This means that some ”memory” or ”inertia” can be present in the system that may result in modifying its response to abrupt, noisy influences. We also note, that in contrast to Caputo’s original definition the numerical approximation (11) can be extended for $\beta > 1$, too. In the sequel we do not wish to analyze the effect and the proper place of the fractional order derivatives. The main point is the design of a simulator that gives room for the application of such derivatives.

5 Simulations by the Use of ”Scicos”

The new version of INRIA’s SCILAB 3.0 was issued about the end of the summer of 2004. This software package is freely usable for scientific research. In its basic form it corresponds to a programming language and a development system that makes it possible to develop and use user-defined functions in similar way as its own built-in functions. Scicos an application developed in SCILAB to support programming via defining block diagrams and symbolic ”wires”. Besides this graphical possibility its main virtue is the use of sophisticated program packages for solving *Ordinary Differential Equations* (ODEs) either in explicit form [$\dot{\mathbf{y}} = \mathbf{f}(t, \mathbf{x}), \; \mathbf{y}(t_0) = \mathbf{y}_0$ by the ”*lsodar*” package], or in implicit form [$\mathbf{g}(t, \mathbf{y}, \dot{\mathbf{y}}) = \mathbf{0}, \; \mathbf{y}(0) = \mathbf{y}_0, \dot{\mathbf{y}}(0) = \dot{\mathbf{y}}_0$ by the ”*dasrt*” package that calculates the time instants in which the surface defined by g is achieved]. The program defined ?graphically? at first is compiled to bring about an ODE system that is solved by the use of one of these packages automatically.

At the time being Scicos has not very extended documentation. However it has been found ”experimentally” that it is the ”run SCILAB” $\rightarrow$ ”call Scicos” $\rightarrow$ ”load diagram” $\rightarrow$ ”run the simulation defined by the diagram” sequence of steps that always leads to the same results. Most probably the ODE solver is loaded according to its default settings when it is called at the first time. Since the package has to adapt itself to solve various problems it probably adapts itself to the last task solved by it within this SCILAB session, and this modified settings remains valid when the simulation is ended or restarted, or a new diagram is loaded for simulation. Even quitting Scicos seems to leave the last settings valid.

For a beginner this behavior may seem to be troublesome because it may generate the semblance that the simulation results are not well ”reproducible”. However, it can be observed that running the simulation for a while, stopping and restarting it several times without quitting Scicos eventually results in well reproduced behavior. During this process the package well adapts itself to the particular task to be solved.

In Figure 1 the Scicos model of the simulation scheme based on the simple, kinematically designed, non-adaptive PID controller, the ”rough” model consisting of constant $1 \times \mathbf{I}$ ($\mathbf{I}$ = unit matrix) inertia matrix, and the constant Coriolis and inertial terms $[1, 1, 1]^T$. and the ”exact” system models is presented. The typical ”built in” elements as the integrator, the ”source elements” as the constants, the clock, the ”*periodic event generators*”, and the only ”sink”, that is the multiple oscilloscope simulator called ”*Mscope*” can well be identified in the figure. The other blocks contain ”user-developed functions” as the trajectory generator ”*Trajgen*”, the model of the PID controller, the rough and the exact system models and the ”*Vector Subtractors*”. These user-developed functions can be given as common SCILAB instructions that are ”interpreted” by Scicos.

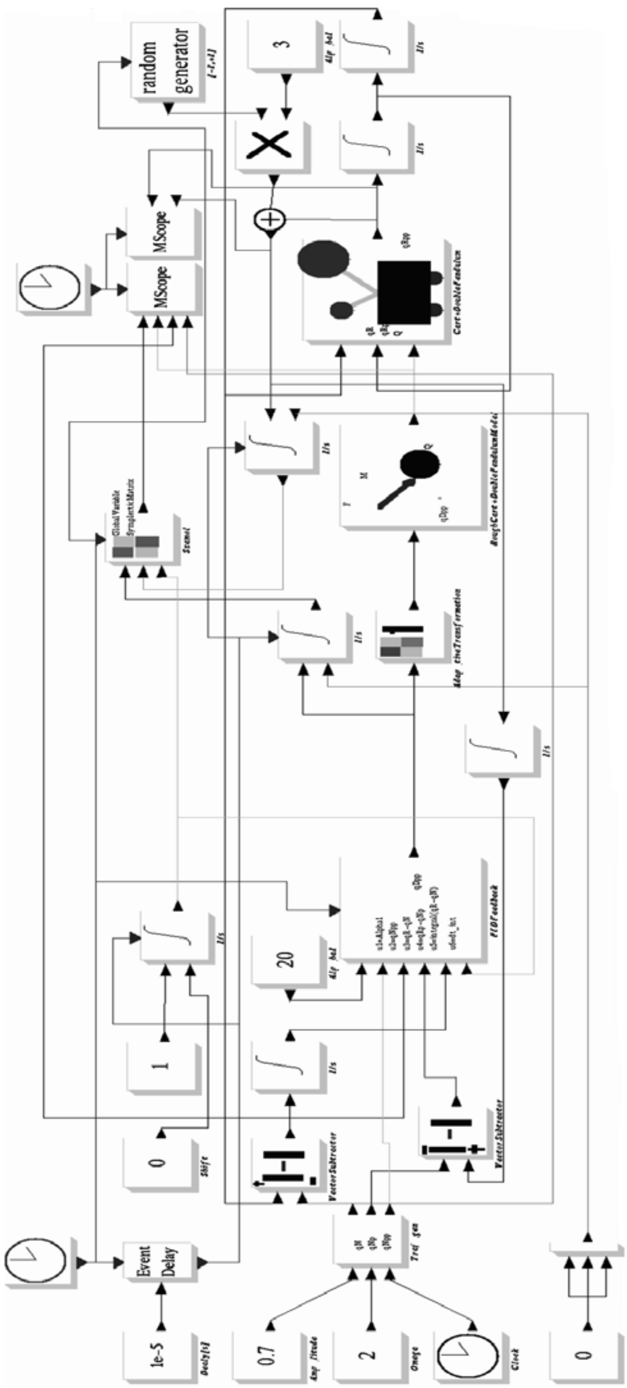

Figure 1: The Scicos model of the simulation scheme based on the simple, kinematically designed, non-adaptive PID controller, the ”rough” and the ”exact” system models

To speed up the operation of the simulator an alternative method is loading and compiling the user functions instead of directly writing them in the user blocks. (In this case the user block contains only simple calls for the compiled functions.) The compilation of the necessary user functions at the beginning can be prescribed in the so-called ”*Context*” box of the simulator. The here defined variables behave as ”*global*” ones from the point of view of the user-defined functions. They can be referred to as "global" variables in the heading (beginning lines) of the user's functions. The "wires" correspond to the traditional function calls via the stack making the use of the simulator similar to data flow programming. (The global variables can directly be modified by the functions without the use of any "wire".) The "chequered" blocks in Fig. 1 correspond to the program block making and applying the symplectic identification by the use of global matrices.

In Figure 2 typical operation of the adaptive controller without simulated measurement noise in measuring the joint coordinate accelerations is described. It can well be seen that

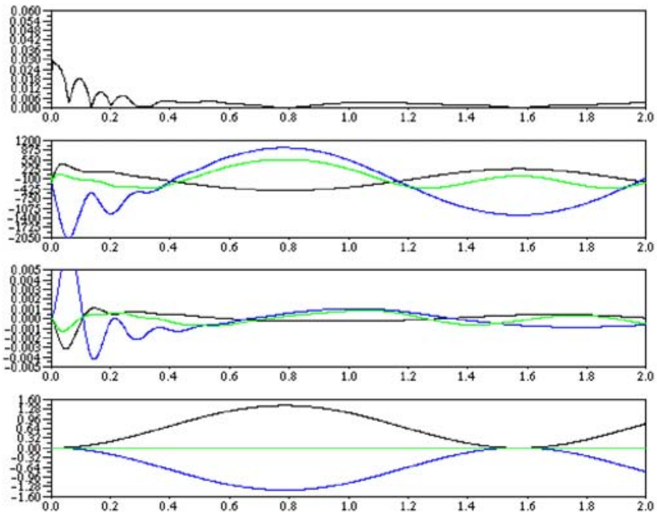

Figure 2: The operation of the adaptive controller without simulated measurement noise in measuring the joint coordinate accelerations: 1^{st} box: the norm of the $(\mathbf{Sn}_n - \mathbf{I})$ matrix (characteristic to the adaptive signal); 2^{nd} box: the generalized forces [in *Nm* for Q_1 and Q_2, *N* for Q_3]; 3^{rd} box: the joint coordinate errors [in *rad* for q_1 and q_2, m for q_3]; 4^{th} box: the nominal trajectory [in *rad* for q_1 and q_2, *m* for q_3] vs. time [*s*]. The cycle time of the external controller is 2 *ms*, $\beta = 1.6$.

the controller accurately tracks the nominal trajectory apart from a short initial learning phase. In Figure 3 the noisy counterpart of Figure 2 with evenly distributed 3 rad/s^2 or m/s^2 (quite comparable with that of the nominal motion) simulated measurement noise in measuring the joint coordinate accelerations is given. Though the tracking error increased, the control remained stable and the precision did not decline drastically. It can be seen, too, that a damped action of the measurement noise also appears in the actual motion of the system due to the coupling brought about by the controller.

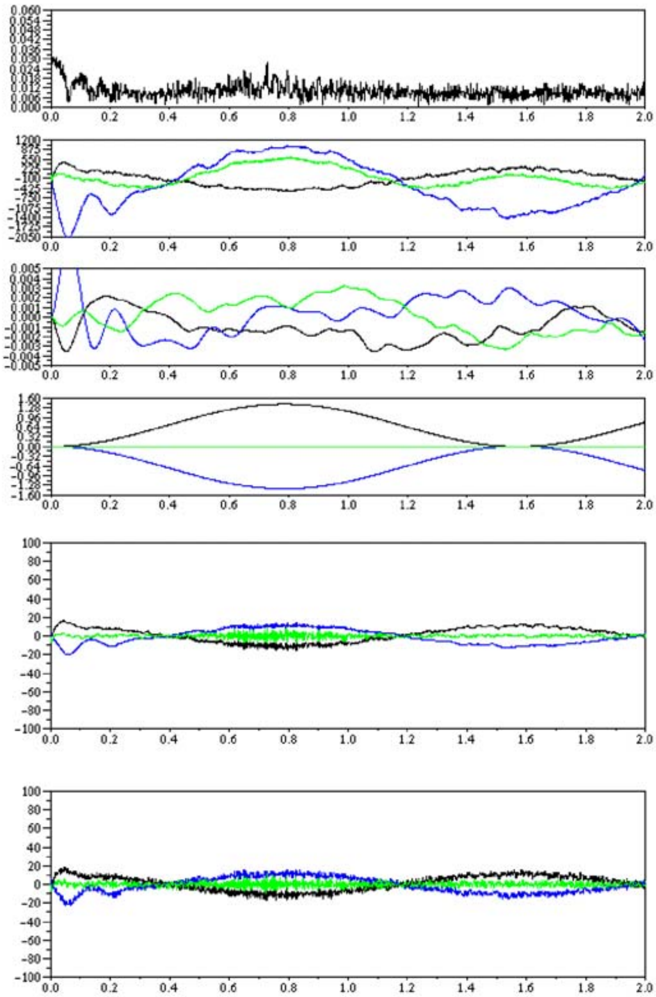

Figure 3: The operation of the adaptive controller with simulated measurement noise in measuring the joint coordinate accelerations: boxes 1 to 4 are the counterparts of the appropriate boxes in Figure 2; 5^{th} box: the actual and the "measured" (6^{th} box) joint coordinate accelerations [in rad/s^2 for q_1 and q_2, m/s^2 for q_3] vs. time [s]. The cycle time of the external controller is 2 *ms*, $\beta = 1.6$.

6 Conclusions

At the end of the summer of 2004 INRIA issued its SCILAB 3.0 containing an advanced numerical simulation tool called "Scicos". Due to it new prospects were opened for making "professional" and in the same time "convenient" simulations for studying the sensitivity of the novel adaptive control developed at the Budapest Tech in connection with the joint coordinate measurement noises. A quite simple but lucid typical paradigm, a cart conveying an asymmetric double pendulum system was chosen to be the subject of the adaptive controller. It was found that the method, though it uses joint coordinate acceleration measurements, is not very much sensitive to these noises. It can be stated that the sophisticated modeling tool of Scicos resulted in more rigorous values than the formerly applied, more primitive estimations. It became clear that in the future it is expedient to use the services of Scicos in similar modeling and simulation investigations.

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