ON THE SAMPLING PERIOD IN FUZZY CONTROL ALGORITHMS FOR SERVODRIVES
A Strategy for Variable Sampling

Dan Mihai
University of Craiova, Decebal Blvd, 107, Craiova, Romania

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Abstract: The paper deals with a variable control sampling period for the fuzzy control algorithms implemented on low inertia servodrives. The robustness of the fuzzy control strategy is extended on the sampling period values and hence an adaptive sampling algorithm is proposed. The author analyzes the possibility to vary continuously the sampling frequency upon a basic process variable. Principles, models and simulation results inserted here give reliance in this technique and an enhancement of the fuzzy control implementation. The distribution of the sampling moments in different adaptive conditions and the behaviour of the servodrive are obtained by means of some models and simulations in accordance with the real-time target hardware system.

1 INTRODUCTION

The author found (Mihai, 2001) that the fuzzy logic has the ability to drive the system in good conditions for very different control sampling period - T values over more than a magnitude order. In such a context, the idea to vary continuously the T value, in accordance with a dynamic parameter of the system, finds a suitable application area. The standard digital models become non-linear because the variable coefficients and the classical algorithms are very sensitive to T. A variable T means, in almost all the approaches, acquisitions with a variable frequency. Less studies and experience concern the real-time control with a variable cycle. Most of the involved authors and equipment use several pre-computed constant values T. Computer graphics applications refer to an adaptive sampling in term of an adjustment of the sampling resolution in exploiting the image (Adamson, 2005). The adapting sampling in the fuzzy control could also provide means to reduce noise in computer graphics, like for global illumination algorithms (Xu, 2006). Also some other special or non-conventional application fields implement an adaptive sampling (radio telemetric system for missiles, drying processes in food industry). Although some papers still prove the natural idea that a sampled-data fuzzy controller recovers the performance of the continuous-time fuzzy controller as the sampling period approaches zero (Do Wan, 2007), several authors have noticed that the fuzzy control is flexible and reliable for a low rate control sampling (Popescu, 1997; Mihai, 2001). Using an adaptive sampling frequency for the control of a servodrive is a complex task because of the fast reaction speed of such a system and its high associated performance.

2 THE FUZZY CONTROLLER AND T VALUES

Although T seems, apparently, not being an essential variable for the main characteristics of a FLC (fuzzy sets and the rule base), this parameter is involved in a fuzzy loop in two ways:
- as a real - time “integration step” of the system, (acquisition–processing–control cycle;
- as an input FLC variables generator by:

$Va_k = V(kT)$; $\Delta Vb_k = V_k - V_{k-1}$; $Vck = (V_k - V_{k-1}) / T$ (1)

The author considered a low inertia servodrive with DC motors. The figure 1 gives the essential structure for the drive with disk rotor motor and an encoder. The FLC entries are the normalized position error and the normalized variation of the position error:

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$$\varepsilon_{\alpha n\,k} = \varepsilon_{\alpha n\,k} \cdot (\alpha^{*}-\alpha_k) \,/\, \alpha^{*} \tag{2}$$

$$\Delta\varepsilon_{\alpha nk}=\varepsilon_{\alpha nk}-\varepsilon_{\alpha nk-1}= [T \cdot(-\omega_k)]_n=\omega_k \cdot \Delta\varepsilon_{\alpha nk\ max} /\Omega_{max} \tag{3}$$

α^*/α_k - the position set point/ the actual position; $N_\alpha^*/N_{\alpha k}$ – same, in encoder pulses; $\Delta N_{\alpha k}$ - pulses encoder during T; c_k, c_{kout} - the computed control and its outputted value; $Norm_i$: normalization blocks; CPB: Control Processing Block; PS - Power supply; T_{gen} - torque generator; M - motor; En - encoder. The encoder has $N_{p/r}$ pulses per revolution and the speed is computed with:

$$\omega_{ks} \approx \frac{\alpha_k - \alpha_{k-1}}{T} = \frac{2\pi \cdot k_{div} \cdot \Delta N_k}{N_{p/r} \cdot T} = c_{sp} \cdot \Delta N_k \tag{4}$$

The simulation results from figure 2 are obtained using a FLC from Fuzzy Toolbox (Guley, 1995), with fuzzy sets and rules presented in (Mihai, 2008). The quality of the results is proved by the final position error (null) and the fuzzy state-space trajectory, between the initial point (10, 0) and the final point (0,0)–last window. When T increases, the FLC task becomes more difficult. Although for the whole range the controller succeeds in bringing the system to the final point, some internal ringing or steps appear. It is obviously also that for low sampling frequencies, the speed (quite well filtered by the mechanical system) is far from the position error variation. Another model is designed as a fuzzy position / speed loop for the same system but with a Look-Up-Table (LUT) FLC-figure 3. An additional argument for the adaptation of T is given by the real-time recordings presented in figure 4, for an on-line inference fuzzy control (Mihai, 2006). During every T (SPER), each falling edge of the encoder pulses (PULSE) leads to a fast hardware interrupt routine (INTO) that up-dates the FLC entries. FUZZ is the fuzzyfier task, INFER-the on-line inference task, DEFUZ-defuzzification task and AUX concerns other processing tasks, like savings. The 2 diagrams were recorded for different conditions, revealing the ability of the FLC to manage the microcontroller resources even at maximum speed, when the processing algorithm is interrupted at maximum rate. However, the available time is very depending on the motor speed. A higher speed could lead to the situation when the control processor is no more able to fulfil the real-time task inside T. Its adaptation to the speed would be the solution. For adding robustness related with the load variation, a special strategy was proposed by the author keeping the same reference LUT. Additional procedures were implemented for on-line adaptation of the control to the load value, both by an estimated current and some external computations and decisions blocs.

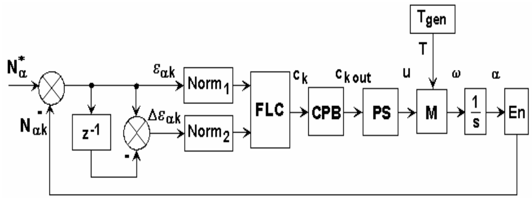
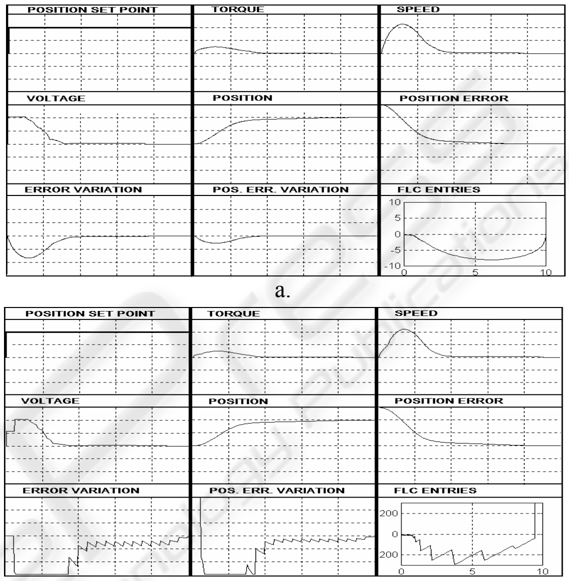


Figure 1: The servodrive with FLC.



a.

b.

Figure 2: Results: T=2.456 ms (a) and T=50 ms (b).

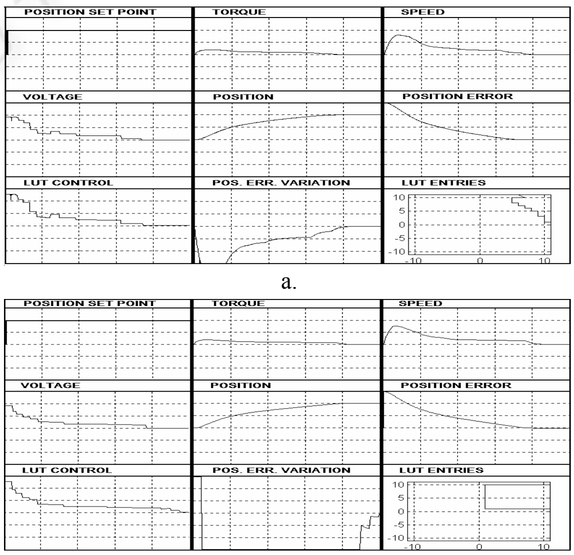


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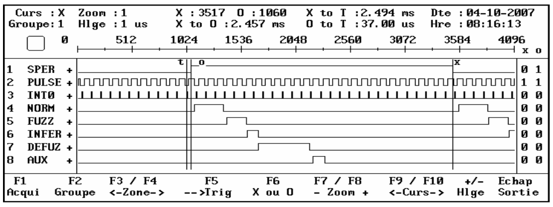
Figure 3: Results for T = 2.456 ms (a) and T= 50 ms (b) with a LUT based FLC.



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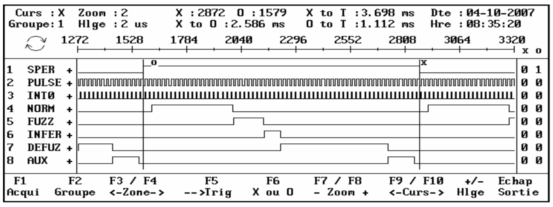


b.

Figure 4: An on-line T in fuzzy control.

3 A FUZZY CONTROLLER WITH ADAPTIVE T VALUES

The idea is to relate T with the variation rate of the main variable of the system. During the intervals with small variations (or in steady state regimes), T is greater and during the high rate dynamic regimes, T decreases. The variation for the (generic) variable v from the step t induces an adequate adaptation of T at t+δt. The figure 5 gives an image of the principle and helps for obtaining some relations. A first possibility is to evaluate the amplitude variation for the main variable during a constant time interval (easily in real-time). Another idea is to use an amplitude quantization of the v variable using a constant step Δ and to evaluate then the time intervals associated with this variation. They can be directly assimilated with the adapted T. Next relations make connects the derivative value and Δ.

$$v = f(t);\ \Delta = f(t_{i+1}) - f(t_i)\ ;\ \mathrm{tg}\,\alpha_i = \Delta / T_i \qquad (5)$$

$$T_i = \Delta / \mathrm{tg}\,\alpha_i \cong \Delta / \left(\left| df/dt \right|_{ti} + \varepsilon \right) \qquad (6)$$

Δ could be chosen by practical considerations. If ***f*** is known, (5) is useful for evaluate T. If not, t_i result by detecting the amplitude thresholds and by that the next T value is available. ε is for a limitation of max.T. A limitation is also necessary for minT, (systemic, on-line processing constraints):

$$T_{min} \le T \le \Delta / \varepsilon \qquad (7)$$

For a servodrive where the main variable is the position, let be the speed ω the variable v (the variation of the position). It is more suitable to use a T adaptation in accordance with the variation rate not after the amplitude of the v variable. Indeed, for that last case, even in a steady-state regime, the sampling rate is high and for a low speed during a strong dynamic regime the sampling has a slow rate. If the main characteristic variable of the system is the speed, v could be the acceleration. The next idea is to adapt also the step value Δ upon another characteristic variable of the controlled system. The results for two Δ (constant) values are depicted by figure 6, with the distribution of the sampling moment. Position 1 is the sampled position with an adaptive period. "State space FLC path" is the trajectory of the system. The global behaviour is good for both variants, the final position error being null and the system response in speed and position being a smooth one. Figures 7a and 7b give the variations of T for Δ=2.456 and Δ=20, during the whole regime. The max/min rate values are almost 100/Δ=10 and 35/Δ=50. Figures 7c, 7d make visible the large variation range of the max/min T along 3 magnitude ranges (logarithmic scale).

The next idea is to use a variable quantization step for adapting T as a double adaptive sampling strategy. Another adaptation parameter is involved. The fig. 8 gives the elements for that, considering the speed as an additional modulator (by its change rate) for the adaptive sampler of the position. In this way, it is no more necessary to make different experiments in order to adopt the best step value Δ (Q). The distribution of the sampling moments is different (fig. 8a) and the step value is variable (fig. 8b). The image of the new sampled position is given by fig. 8c. The results from 8d concern another values range for the modulator of the adaptive sampler (a larger one – see Q_ad). It is depicted also the quantified speed – Speed 1, as the source of the modulator for the quantization step necessary for the sampler with double adaptive T. The overshoot for the position is related with its quantized final values.

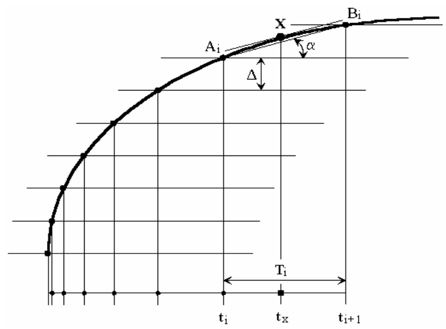
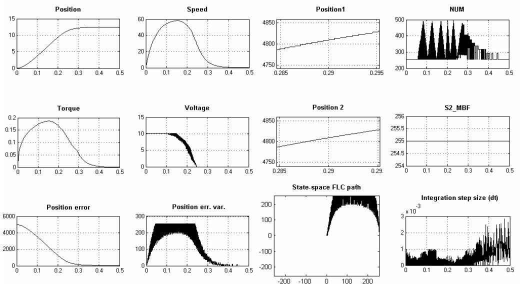


Figure 5: For adaptation of T values.

4 CONCLUSIONS

A variable sampling frequency could give a better control. This approach leads to some serious robustness problems for the classical algorithms but not for the fuzzy control. A good robustness regarding the sampling period for the fuzzy control induced the idea to try a control with adaptive sampling period. This idea is applied for a servodrive - a fast and precise system. Several variants were considered: adaptive sampler with a constant quantized step, with a multi-step modulation and with a continuous variation.



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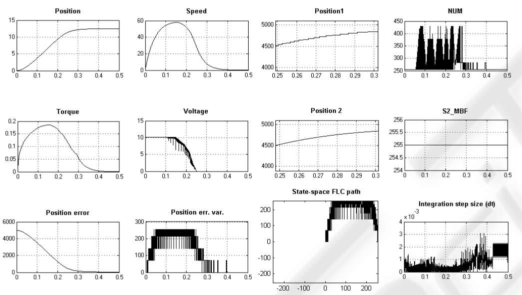
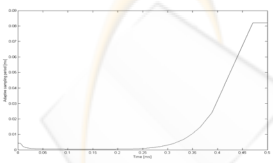


b.

Figure 6: Main variables of the system for a step Δ = 2.5 (a), Δ = 20 (b) and T evolution.



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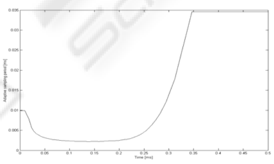

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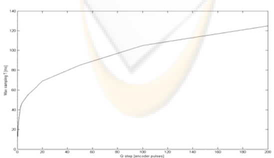
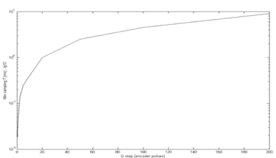
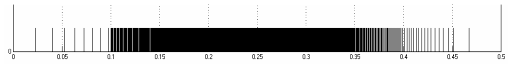


c.



d.

Figure 7: T evolution in time and upon Δ.



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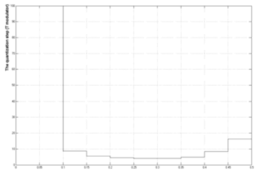

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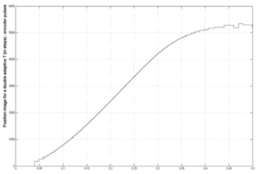

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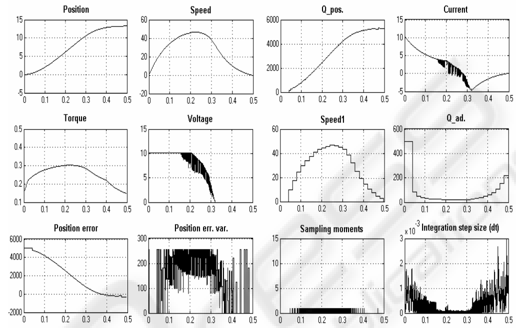

d.

Figure 8: Adaptive FLC /variable step.

REFERENCES

Adamson, A., Alexa, M., A. Nealen, 2005. Adaptive sampling of intersectable models exploiting image and object-space coherence, *Symp. on Interactive 3D graphics and games I3D '05*, ACM Press.

Do Wan, K., Jin Bae, P., Young Hoon, J., 2007. Effective digital implementation of fuzzy control systems based on approximate discrete-time models, *Automatica (IFAC Jour.)*, Volume 43 , Issue 10, pp. 1671-1683.

Gulley N., Jang,J.S. R., 1995 *Fuzzy Logic Toolbox for use with Matlab*, The Mathworks, Inc.

Mihai, D., 2001. Robustness of the Fuzzy Digital Control Regarding the Sampling Frequency for a Servodrive System, *ELECTROMOTION '01*, Bologna, pp. 431-435.

Mihai, D., 2006. An Optimized Fuzzy Control Algorithm for Servodrives. Some Real-Time Experiments, *IS '06*, London Proc., pp. 192-197.

Mihai, D., 2008. On the Sampling Period in Standard and Fuzzy Control Algorithms for Servodrives. A multicriterial design and a timing strategy for constant sampling, *INICO 08*, Funchal - Madeira, Portugal.

Popescu, G.S., Pastravanu, A., Bogdan, I., 1997. PWM AC/DC converter with reduced sampling frequency fuzzy control, *Proc. of the IEEE International Sym. on Industrial Electronics*, Vol. 3, pp. 1228 – 1231.

Xu, Q., Xing, L., Wang, W., Sbert M., 2006. Adaptive sampling based on fuzzy inference, *Proc. of the 4th int. conference on Computer graphics and interactive techniques in Australasia and Southeast Asia* GRAPHITE, ACM Press.