CONTROLLED FUZZY OSCILLATORS

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Abstract: Several configuration of controlled fuzzy oscillators are described and their behaviour is discussed. Computer simulation are presented.

Keywords: fuzzy systems, fuzzy waveform, controlled unstabilities

1. Introduction

In the field of electronics and communications, the controlled crisp oscillators play an important part as basical block on which complex devices rely. Considering fuzzy systems as the counterpart of crisp systems in future technology, the natural question arises if the crisp oscillators, and the controlled crisp oscillators can be generalized to get fuzzy oscillators (FO), and controlled fuzzy oscillators (CFO) respectively.

A positive answer to this question was given in /1/. In that paper, the background of the fuzzy systems presenting oscillators which are periodical was presented and several configuration of feedback fuzzy systems behaving as FO were discussed.

The aim of this paper is to further discussion of this topic, emphasizing on CFO.

2. Feedback in fuzzy systems

Two types of feedback loops in fuzzy systems with discrete time were introduced in /1/. The first loop (see Fig. 1) can be used in conjunction with a multiple input, discrete-time fuzzy system. The second loop (Fig. 1b) is based on the concept of "fuzzy node" (a 'join' fuzzy node is used in Fig. 1b) and does not need multiple-inputs systems. In fact, only the second loop is a true counterpart of feedback

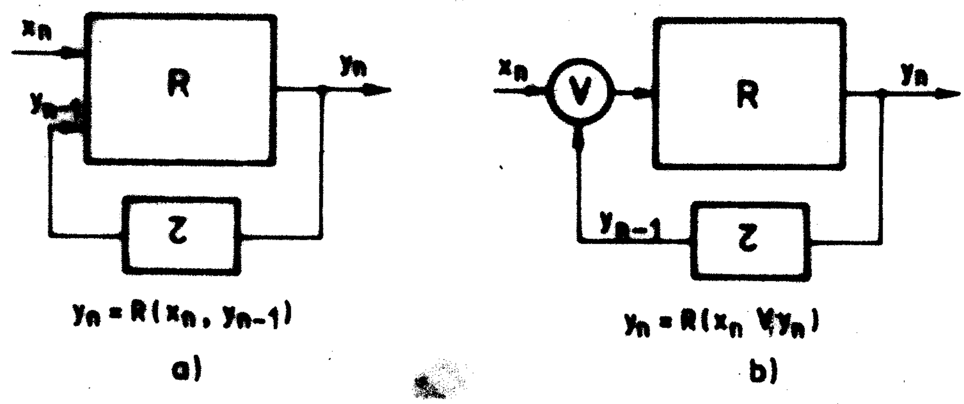

Fig. 1: Basical discrete-time feedback loops

loops in crisp systems.

Continuous-time feedback loop similar to those sketched in Fig. 1 are easy to be conceived, and will be discussed in another paper. Here we will be interested in the feedback loop configurations sketched in Fig. 2, and in Fig. 3.

Fig. 2: Continuous-time crisp system with fuzzy feedback loop

The loop in Fig. 2 can act as a positive feedback to the crisp system. Note that the overall loop is in fact a crisp one. If the usual oscillating conditions are satisfied, the systems with feedback will behave as any well

well known crisp oscillator. If the crisp system in Fig. 2 represents a crisp controlled oscillator, with appropriate interpretation of the operator "+" in Fig. 2, one gets the block diagram of a phase-locked loop (PLL) based on fuzzy loop control. This application was already discussed in /2/ and /3/.

The different approach sketched in Fig. 3 uses a crisp loop to feed back the defuzzified output to the input. Avoiding the use of an input (denoted by x in Fig. 3),

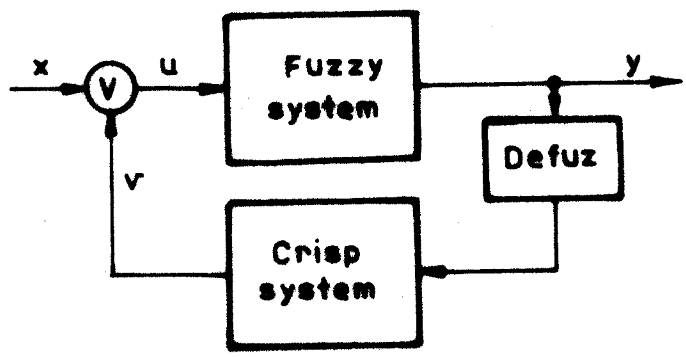

Fig. 3: A crisp loop controlling a fuzzy system

one gets the block diagram of a (possibly) oscillating fuzzy system. On the other hand, the use of an external input x allows for the external control of the oscillating behaviour, i.e. one gets a FCO. Note that if x is a crisp control signal, then the join node in Fig. 3 can be replaced by a simple summing node.

3. Fuzzy waveforms

In any application, the waveform of the crisp signal outputed by crisp oscillators is carrefuly considered. For sake of correctness, in this Section the definition of fuzzy signals (previously introduced in /4/, /5/) will be briefly discussed.

A fuzzy signal is defined -- in the one-dimensional case-- as a mapping from the real-valued time instances set T to a set of fuzzy sets. Thus, a fuzzy signal can be regarded as a set of fuzzy sets indexed upon R (or an interval of R, or even a numerable subset of R -- for a "sampled" fuzzy signal). Suppose that all fuzzy sets are normalized. Then, a fuzzy signal can be reprezented as in Fig. 4.

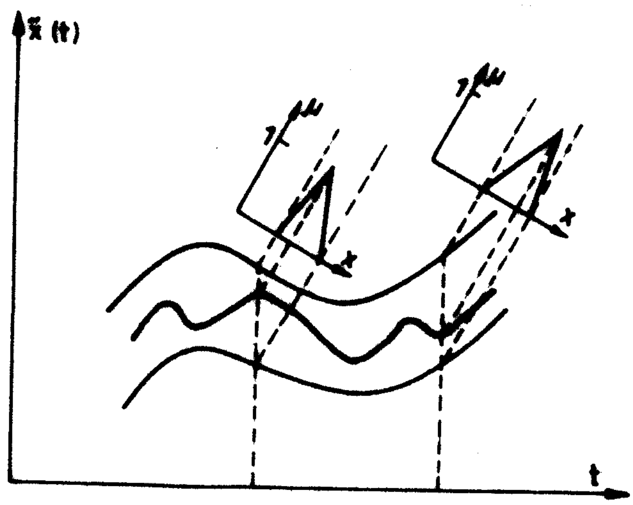

Fig. 4 : A grphical representation of a continuous fuzzy signal. The signal is continuous-time type.

Note that the concept of waveform --which applies only to 1-D signals -- can not be directly applied to fuzzy signals. In fact, the fuzzy signals are similar rather to the bi-dimensional crisp signals (image signals) than to usual 1-D signals. However, once it is a usual practice to defuzzify fuzzy signals, a waveform could be assigned to them, namelly the defuzzified signal waveform. Another way of assigning waveforms to fuzzy signals is suggested in Fig. 4.

4. Structures of controlled fuzzy oscillators

All the CFO discussed below are discrete-time systems. In fact, only these systems can conveniently be modelled on computer. The block diagram of these CFO is sketched in Fig. 5 and is the direct extension of the block diagram plotted in fig. 3. (The fuzzifier at the input of the fuzzy system is not represented for sake of clarity). In Fig. 6, the controlled crisp feedback is realised as a discrete-time linear control. (Here, the sense of linear is : "the output of the feedback system is a linear function of its input").

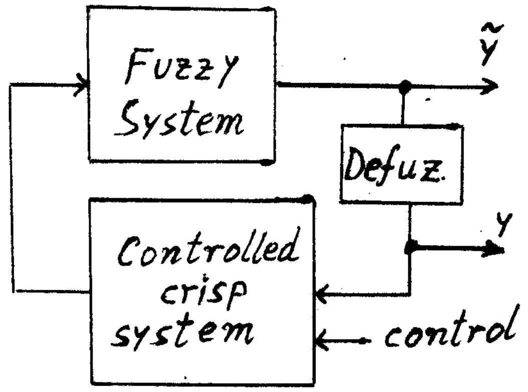

Fig. 5: Basical block diagram of the controlled fuzzy oscillator with crisp feed-back and loop control.

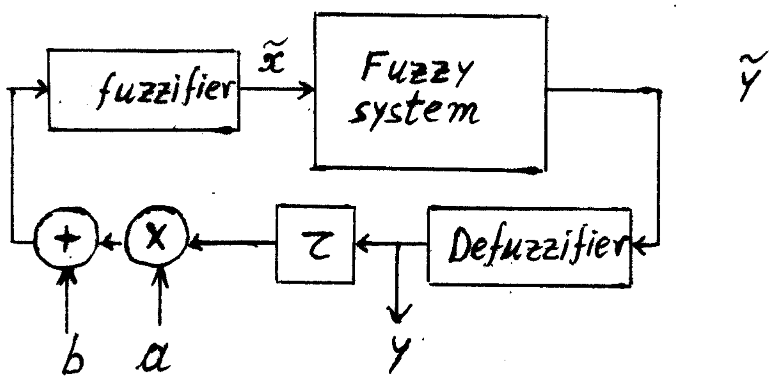

Fig. 6: Discrete-time, linear control crisp feed-back

As proved by computer simulations, the control prov - ided by the loop in Fig. 6 sometimes does not cover a large enough frequency range, or waveforms spectrum. To alleviate this drawback, a non-linear loop was found useful. The sim-plest to implement nonlinearity is the truncation operation. The CFO thus obtained is plotted in Fig. 7. Here, only an

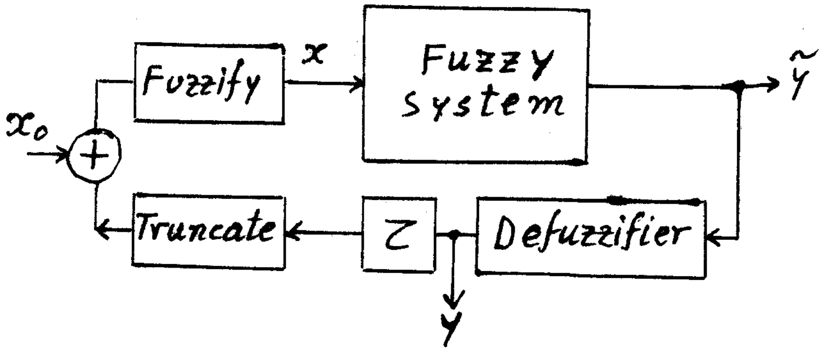

Fig. 7: Truncating feedback loop

additive external control is provided to simplify the diagram, although in simulations an multiplicative control was also used).

Only CFO as presented in fig. 6 and 7 will be discussed below.

5. Dynamical behaviour of CFO

As it was stated in /1/, the feedback fuzzy system sketched in fig. 1 - 3 behave as oscillators iff their state-transitions graph is cyclic. This condition is not generally fulfilled. In fact, assymptotically stable or even chaotic behaviours often occur in such systems.

To build up a CFO, probably the simplest way to follow is to use a 'linear' fuzzy system in the main path and then to derive the oscillating conditions by means of the algorithm presented in /1/.

Unfortunatelly, to check by hand-made computation that the state transitions graph is cyclic can be an impossible task. If the behaviour of the system is not transparent, a chaotic behaviour often occurs -- at least, so we found in our computer simulations. A simple way to prevent chaotic behaviour and to do the behaviour of the CFO more transparente is to use the truncation operation,as in fig. 7.

An important dynamical parameter of the CFO is the lock-in time. As a general rule, this parameter is related to the period of the crisp output signal (y, in fig. 6 and 7). In our simulations, the lock-in time was found to range between about one and about ten periods. The lock-in time is also much dependent on the initial conditions choosed in defining the system (see /1/).

Also note that the period of oscillation and the waveform can be conveniently changed in a quite large range by acting on the truncation length, as can be seen in fig. 8 and fig. 9. Fig. 8 presents the result for a computer simulation of CFO that uses a simple linear, five linguistic degrees input and output system in the direct path. Figure 9 presents the results obtained by computer simulation on the same CFO, but with different truncation length.

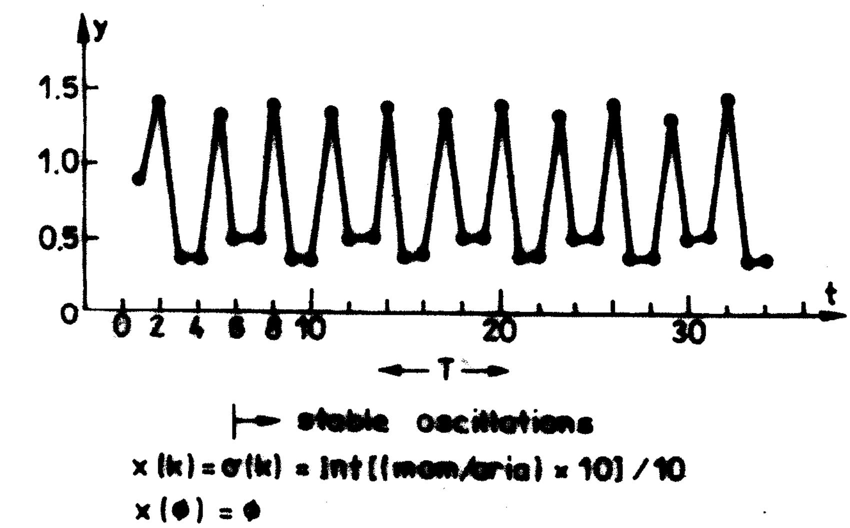

Fig. 8: Output waveform. 'mom/aria': defuzzifier output.

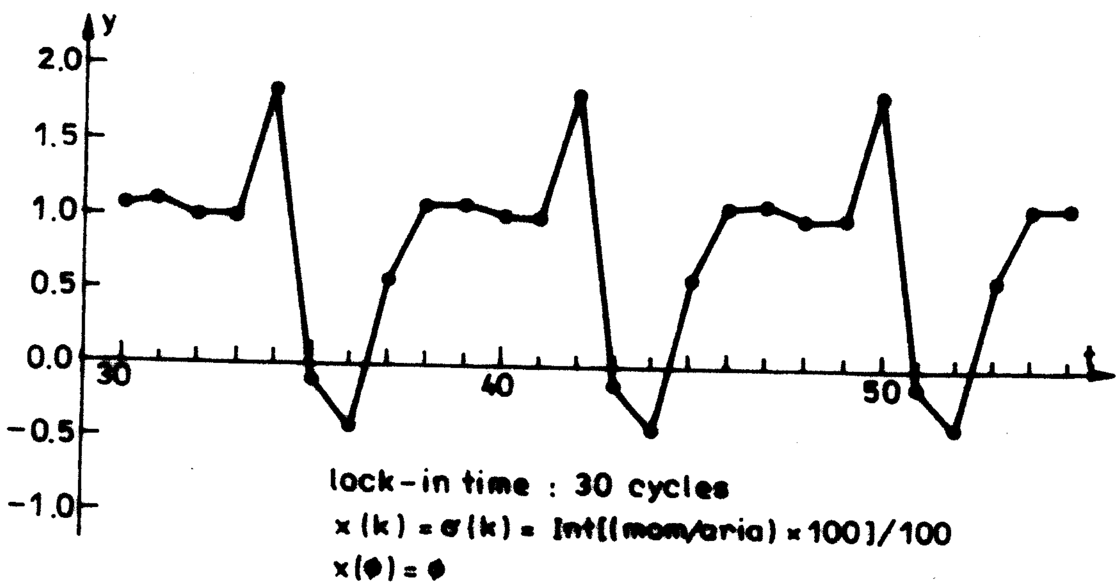

Fig. 9: Another oscillation waveform obtained by altering the truncation length.

Using various techniques of control, virtually any period and waveshape of the defuzzified output can be obtained. Finally note that the'width'of the fuzzy output signal, i.e. the length of the interval on which the output membership function does not vanish, is not a constant (as for the fuzzy signal in Fig. 4).

6. Conclusions

Controlled fuzzy oscillators, the counterpart of the well known devices named 'voltage controlled oscillators' can be realised in a great variety of configurations, all based on the concept of feedback. The discrete-time CFO are easy simulated on computer to get their dynamical parameters (period, waveform, lock-in time). Although a detailed algorithm to build CFOs was not yet developped, one can use in the design the algorithm for building a feedback system with cyclic state-transitions graph, as well as some simple rules derived from simulations.

7. References

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