Design of Self Organizing System Controller for Industrial Application

Sepehr M.H.Jamarani, and M.R.Hashemi Golpayegani

Abstract**—**This paper present an approach for the self organizing manufacturing control, by presenting the algorithm that can control the complex systems. The general block diagram for self organizing controlling system has been shown and the detail of self organized controller is presented. We have used the probability state variable (PSV) for determining the system parameters. The system must have the predictor to able us knowing the situation of it. The performance assessment block used as a "punishment" or "encouragement". We have tested the controller on different types of systems such as chaotic, linear, nonlinear and got the satisfactory results.

Keywords**—**Self organize, plant, cybernetic, control, industrial.

I. INTRODUCTION

DURING the last few years, the theory of Self-Organizing Systems has spread over various different fields of science. It is applied in Computer Science, Mathematics, Physics, Chemistry, Biology and even Psychology.

Today's manufacturing industry is facing a major shift from a supplier's to a customer's market. The growing surplus of industrial capacity provides the customer with a greater choice and increases the competition between suppliers Aware of their power, customers have become more demanding and less loyal to a particular product brand. As a result, companies must shorten product-life cycles, reduce time-to-market, increase product variety and instantly satisfy demand, while maintaining quality and reducing investment costs. This is a great challenge to the manufacturing process itself; it must be more flexible and robust as well as demonstrate enhanced scalability [1]. There have been many notions and definitions of self-organization, useful in different contexts [10]. They have come from cybernetics [2, 3, 4, 5], thermodynamics [6], mathematics [7], information theory [8], synergetics [9], and others. Many people use the term "self-organizing", but it has no generally accepted meaning, as the abundance of definitions suggests.

Also, proposing such a definition faces the philosophical problem of defining "self", the cybernetic problem of defining "system", and the universal problem of defining "organization". As a most basic example, we can look at swarming or herding behavior, in which a disordered array of scattered agents gathers together into a tight formation. Intuitively, it seems that the system of agents has become more "organized".

In this study, we present the intelligent self organize system which can control the complex system through disturbances. The system contains probability state variable for identifying the system parameters. As the PSV can identify one parameter of system, so we have to use several units of them. Interesting part of our study is the performance assessment is located directly on the circle loop. The base design of the correlation logic units incorporates the probability state variable (PSV) search algorithm. This algorithm is suited for simultaneous adjustment for two or more parameters, providing the performance assessment unit has capability for resolving the very small performance differences which are obtained in the proximity of the optimum in the space of parameters.

II. SELF-ORGANIZATION

Self-organization has definitions of varying specificity. We can define that as follows

1. The evolution of a system into an organized form in the absence of external constraints.
2. A move from a large region of state space to a persistent smaller one , under the control of the system itself. This smaller region of state space is called an attractor.
3. The introduction of correlations (pattern) over time or space for previously independent variables operating under local rules.

These definitions are equivalent, the first being the most intuitive. Simply, a system self-organizes if it requires no external force to organize it.

III. CONDITIONS FOR SELF-ORGANIZATION

Obviously, not all systems will self-organize. A system must meet a number of conditions, or constraints, to be able to move from a disordered state to an ordered one.

These constraints can be any number of things, and depend upon the system being studied. It could be the number of elements in the system. For example, convection cycles of heat transfer, such as Benard rolls [3] need to have some minimum number of molecules (near 1032) to achieve spontaneous organization. The convection cells also need a sufficient heat source. In fact, all systems that move to an organized state from a disorganized state need to make use of some free energy, as is specified by the laws of thermodynamics. As more complex systems are studied the constraints become more numerous. For example, most biological life on earth requires the right levels of certain gases, such as oxygen, and the right temperatures.

The creation of problem solving and computation systems can be seen as the act of constructing a system that has no

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inherent or explicit organization, but one that will self organize when given the right conditions. This may be more difficult than construction the organized system from the start, but self-organizing systems have characteristics that are beneficial to many computational environments, as will be explored in the next section.

IV. CHARACTERISTIC OF SELF ORGANIZING SYSTEMS

The characteristics of self-organizing systems have much to do with modern computational systems. Heylighen lists seven characteristics, the first few being fundamental to all self-organizing systems, and the later few applying mainly to more complex systems.

A. Global Order from Local Interactions

Organized systems are those that have global order, or correlation between the elements of the system. By definition, a self-organized system is not controlled by some external force. So, the interactions of the elements on a local level are those responsible for the organization.

B. Distributed Control

This is a corollary to the first characteristic. Because the local interactions are responsible for global order, the control of the organized system is also distributed among the elements.

C. Robustness and Resilience

The distributed control of the system contributes to it's robustness and resilience. That is, the system is resistant to perturbations and has a strong capability to restore itself after damage.

D. Non-linearity and Feedback

Many complex self-organizing systems are complex because of their non-linear nature. That is, even if the elements themselves are very simple their interaction and relationships can become complex. Small changes can have large effects (through positive feedback), and conversely, large changes can have relatively small affect (through negative feedback).

E. Organizational Closure, Hierarchy and Emergence

Like many artificially constructed systems, self organizing systems form a hierarchy of levels. Each of these levels can be seen as having a boundary, an inside and outside, and is therefore organizationally closed. Very often, the higher levels can not be described or understood by examining the properties of the lower levels and are said to be emergent.

F. Bifurcations and Symmetry Breaking

Very often a self-organizing system will have more than one stable organized state, or attractor. While moving from the initial, disorganized state, the system must make some "decision" as to which organized state it will seek (these decisions typically being made by random differences or perturbations in the initial state). These decision points are called "bifurcations" and are a form of symmetry breaking.

G. Far-from-equilibrium Dynamics

For a sufficiently complex system to maintain its organization it must be constantly presented with a source of free energy and be able to make use of that energy. Consequently, the system can not be at equilibrium with its environment. It has a constant flow of resources moving through it to rebuild the organization it has constructed and to build new organization in an effort to adapt to new environmental conditions.

V. ARTIFICIAL SELF-ORGANIZING SYSTEMS

Independently of the definition of self-organizing systems, if we see them as a perspective for studying systems, we can use this perspective for designing, building, and controlling systems. A key characteristic of an artificial self-organizing system is that structure and function of the system "emerge" from interactions between the elements. The purpose should not be explicitly designed, programmed, or controlled. The components should *interact* freely with each other and with the environment, mutually adapting so as to reach an intrinsically "preferable" or "fit" configuration (attractor), thus defining the purpose of the system in an "emergent" way [13]. Certainly this is not the only approach for designing and controlling systems, and in many cases it is not appropriate. But it can be very useful in complex systems where the observer cannot *a priori* conceive of all possible configurations, purposes, or problems that the system may be confronted with. Examples of these are organizations (corporations, governments, communities), traffic control, proteomics, distributed robotics, allocation of ecologic resources, self-assembling nanotubes, and complex software systems [13], such as the semantic web.

VI. MATERIALS AND METHODS

In the self organizing systems the initial conditions are not important As we see (Figure 1) the input X and the sensor is compared with each other and results the error vector, which goes to the self organize controller. The out put of controller goes to the system which must be controlled. The self organize controller presented here uses the probability state variables (PSV) for identifying the system parameters and the result, is signal that correspond to the parameter.

PSV can only define one parameter so we have to use several units of them. The interesting point is, the performance assessment is located in the direct path of the control loop (Figure 2).

The predictor which acts as a pre- phase compensator is modeled as a derriviator (1). Presence of the predictor in the self organize system is essential so we are able to determine the situation of the system. After prediction, we have a performance assessment which performs the error function (*ep*), and the output will be as an "encourage" or "punishment" to the system. The performance assessment based on the *ep* which is the future predict of *e*.

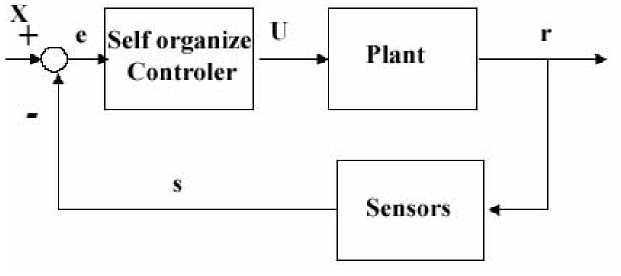


Fig. 1 Block diagram of system contain self organizing controller

$$\frac{ep(s)}{e(s)} = 1 + Ts \tag{1}$$

For more investigation in performance assessment we uses the laplasian transform (2)

$$ep = e + Te' \tag{2}$$

Our goal is decreasing predictor error to zero *(ep = 0)* or *(e=-- Te)* this equation gives us a switching line in the state space of error. The time that crossing from switching line we can find the error from (3)

$$e(t) = e^{-t/T} \tag{3}$$

So the first job of the self organizing controller is that, locate around the switching line, and minimizing the integration of predication error in the time is a good performance (4).

$$p(t) = \int_{t1}^{t1+\Delta t} |ep| dt \tag{4}$$

The simple performance assessment (Figure 3) which can minimize the above equation, uses the *(+1)* for encourage and *(-1)* as punishment.(5)

$$\mathrm{V = -sgn(ep) \,.\, sgn(e''p)} \tag{5}$$

At the time the sign of error and sign of second derivation of error are different, error is moving through the switching line. After achieving *V*, the correlator compares the Δt of previous *y* with the *V* for encouragement or punishment.

The procedure is, output of $y(t-\Delta t)$ is multiplied to *-1* or *+1* (output of performance assessment) and the mean correlation is passed through the low pass filter. Correlation logic units of the self-organizing controller implement the parameter search under the guidance of the performance assessment unit for optimum engine areas or other parameter values being optimized.

The base design of the correlation logic units incorporates the probability state variable *(PSV)* search algorithm. This algorithm is suited for simultaneous adjustment for two or more parameters, providing the performance assessment unit has capability for resolving the very small performance differences which are obtained in the proximity of the optimum in the space of parameters. In practice, this may requires the correlation logic units be employed in alternating adjustments of the parameters for which the problem of performance resolution is greatly alleviated. A two-stage search strategy can be used, in which simultaneous parameter adjustments are first made to bring the system close to its optimum state in very little time, after which alternating adjustments are made to effect fine tuning. The correlation logic units receive the value signal *V* calculated in the performance assessment unit and correlate this signal with information as to the polarity of the immediate past search experiment. In the *PSV* search mode, a correlation logic, correlation signal biases a centered (zero-mean) random variable, the polarity of the resulting biased random variable being detected to find a sense of the next experiment, and all correlation logic units generate output changes simultaneously at a prescribed frequency or asynchronously. The break point of derriviator in the performance assessment depends on the time delay in correlator and able to minimize the noise effect of the deriviator. The goal of *PSV* is to produce the input signal of the controlling system (plant), respect to separating the high frequency parameter of the system and the noise of sensors. The PSV signal can find the system parameter through random search. So the correlated and smoothed signal is passed through smoothing limiter so the dynamic area in response to the amplitude of signal noise become limited and the probability voltage control *(PCV)*is produced. This limiting action will not let the *PCV* parameter to become zero or one and will guarantee the behavior of system. Then *PCV* is mixed with high frequency noise so the output signal has a stochastic sign. The distribution of *-1* or *+1* in the output of PSV becomes stochastic. The high frequency noise added to *PCV* will results in decreasing correlation between the output signal and the sensor noises so using the high gain controller become possible.

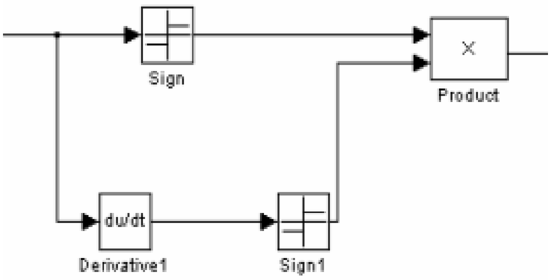


Fig. 3 Performance assessment system

In the end the hard limiter in the PSV is used as a decision maker, which has a +1 in the output if PSV summed with noise signal greater than zero. So probability of *-1* or *+1* in the output of *PSV*, is direct function of *PCV*.

In respect to the block diagram of self organize controller (Fig.2) the output of PSV is sampled periodically and holed *-1* or *+1* for Δt seconds so the response of the controlling system to the PSV unit is performed in Δt so the controlled system have enough time to respond to control signal. As the rate of sampling time is greater than rate of response of the controlling system, we use the low pass filter for smoothing the output of correlator, so the final output of correlator *u'* is produced and prevent the system from instability in response to fast reaction. The input signal of plant is achieved by multiplying the output of correlator and nonlinear function on the predicted error *(ep)*. The nonlinear function keeps the sign of ep while coming close to zero and if the switching line is cut the sign is immediately change. Cause of the delay in correlator (approximately big) this path is predicted. So if the error and the output of correlator agree with each other the sign of the control system will be positive.

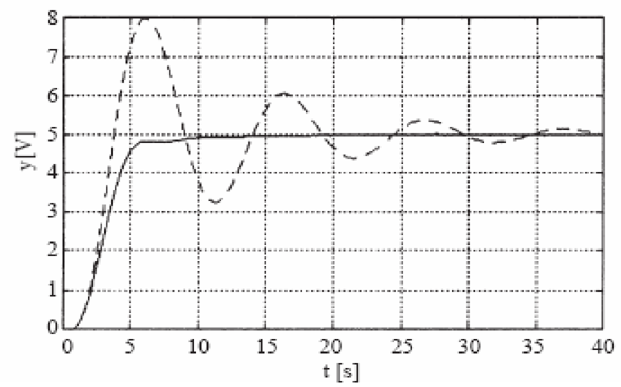
The general behavior of the self organizing controller is, at first there is no information about the sign of output controller for the correct response to the system. Noise signal produce the stochastic control signal which will be performed in the controller and if there is any correlation in signal and the application of system, it will be continued, if not system will start searching to find the correlator amount with same probability in any direction.

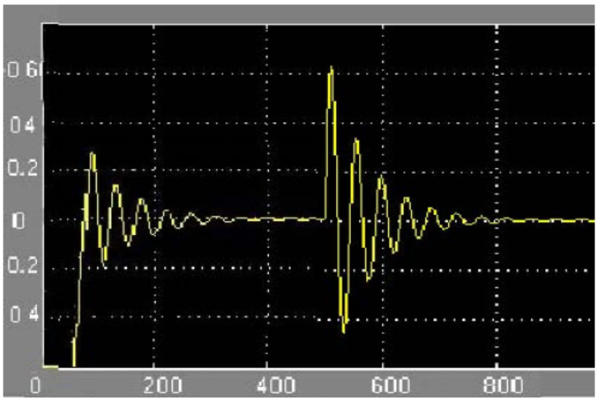
VII. SIMULATION RESULTS

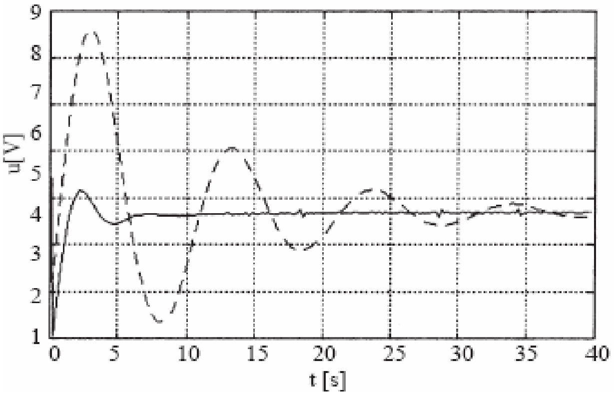
In the below we have presented the simulation result that we obtained from the self organizing controller. For observing the performance of controller we disturbed the system after reaching to the steady state of it with different amplitudes and as we can see the system try to reach to its attractor and by crossing the switching line the performance assessment guide the system to equilibrium state (“ punishment” and “encouragement”)(Figure 4)

VIII. DISCUSSION

The self organizing controller has been introduced which can be used for controlling different types of simple or complex systems. As we can see the results are satisfactory and the performance of the system is acceptable. The most important issues in controlling manufacturing and industrial plant is the time and cost. So in our future work we will try to reduce the time of recovery after disturbances and by doing that we can decrease the cost and increase the capability and reliability of the system.







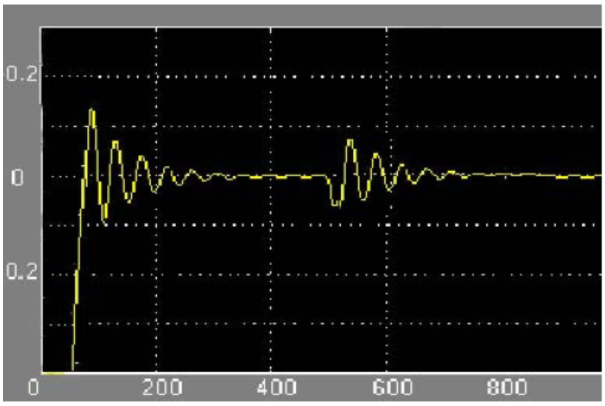


Fig. 4 The process output and control signal for different amplitude of disturbance

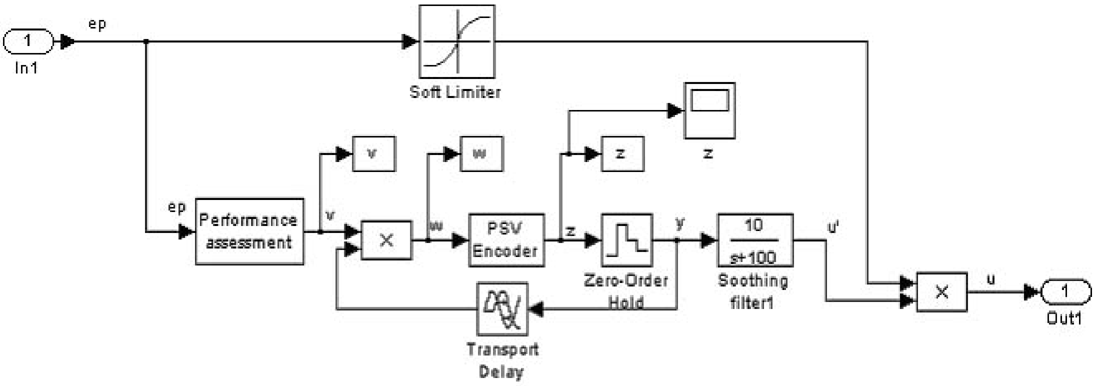


Fig. 2 Block diagram of the self organize controller

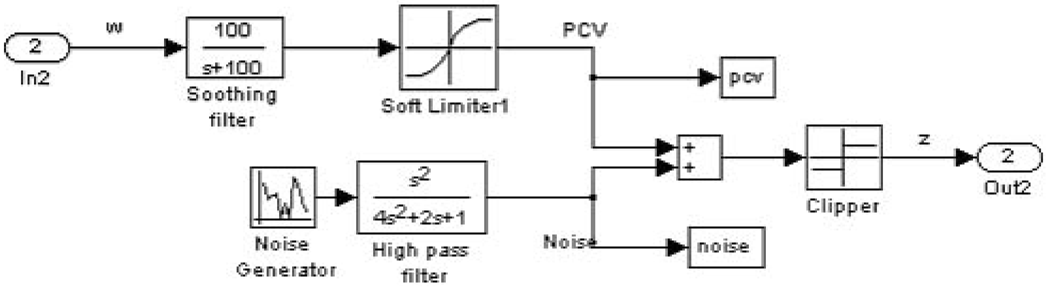


Fig. 5 Block diagram of probability state variable (PSV)

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