New Advances in Modelling Control Processes applied to the Detection of Train Operations

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***Abstract*—In the main frame of the optimal control process has to be focused this work, where a methodology based on the performance of Genetic Algorithms to be used to search the appropriate knowledge base, defined in the sense of Fuzzy Logic, for the process controller. Two stages have to be considered to obtain the control system - Initial Stage and Conclusions Phase. First point search the control law for the reference functional point and defines design concepts and how to do it works. Second stage search allows adjusting the control action according to the dynamic of the process during its cycle-life.**

Keywords: ***detection train system, genetic algorithm, event, planification.***

I. Introduction

Optimal control process for the different industry applications hast to be understood as a complex problem, since the inherent point of view of the process, where conventional techniques for optimization get better performance when there are used adaptative searching methods.

The main frame to define this paper is in a double sense. Firstly, a control process methodology besed on the of fuzzy and evolutive algorithms to solve optimization problems; genetic algorithms was chosen due to their extended use. Sencondly these practisses are applied to the detection train component.

Since Genetic Algorithms (GA) were presented by [1], their use is widely proof, from the general works demonstrating different uses of GA as optimization tools [2],[3],[4],[5], conferences to solve problems emulating natural dynamics [6], [7], [8], formal Works with GA [9], [10] optimizing problems with restrictions and combinatory optimizing problems [11], [12], [13], art of evolutive programming [14],[15], GA as desing tools for fuzzy systems [16], control implementation [17], [18], [19] and an internet forum (http://www.aic.nrl.navy.mil).

The relevance in optimization works using GA are in progress, mainly for the following reasons:

- Important mathematical reqnirements are not necessary for GA. The result is that GA can work with any objective function and its restrictions, linear or not, defined in continnons, discontinuons or mixed searching spaces [12].
- Since probabilistic terms, evolntive operators allow an efficient global searching process, because an adeqnate solution, according to the objective criteria, is possible for the exploratory properties of GA [13].
- Knowledge basis can be designed and adjusted [18].
- Appliccation to track circuit as detection train device. [20],[25].

II. Summary of the Control Methodology

The methodology for a control system proposed in this paper can be summarized in two aspects: searching an optimal control law according to the fnnctional aspect during the design stage and adjnsting the obtained control law when the environment condition forced to change the operating point. All is structured in these concepts: controller design objectives, analysis of the process to control, and operative of the system [10].

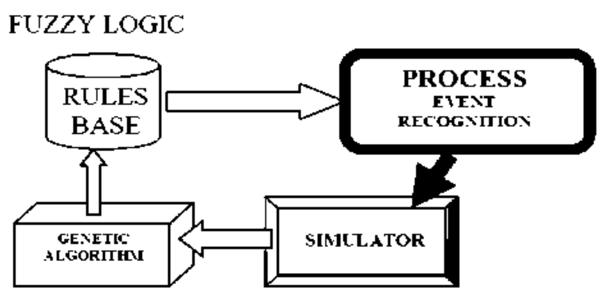

Figure 1. Control schematic

First searching of control law is obtained off-line, considering a simulated process conditions. The availability of several test scenes provides the best conditions for the resnlts of the search, mainly due to the possibility of evalnate the resnlts of the rules found along the search process.

Second searching state is on-line; in other way, the process is controlled according to the law (rules) obtained in the previous state. However, before deciding what action is better, new obtained rules are tested in the process simulator. An important fact is to avoid wrong decisions wheu faults are present iu the real process and, on the other hand, to get the appropriate variatious in the rule base for the recent state of the process variables.

Efficient event recognition is powerful when it is required to get a pondered value for the existing rules comparing to new ones. In other terms, the performance of the on-line system depends on the possibility of getting a measnre of the resnlts after an action ordered according to a particular event.

III. Controller Design

The purpose of each system control is achieved the law to get a particular functional point of the controller. The design of our particnlar controller reqnires the optimization of a knowledge base in fuzzy rule terms. The use of GA allows an adaptative strategy according to the environment condition of the particular process to control. This fact is the result of a design in two stages: a first stage to define the control strategy and a second state or control tactic.

Control strategy (off-line): the objective of this stage is to find a set of rules (fuzzy rules for the knowledge base) searched by a GA, using a process control simulator as validation method of the rules obtained by the GA operators. This set of rules is the result of the control actions based on the identification of the main process events, with the aim of drawn the system to the functional point desired.

Control tactic (on-line): the stage described before provides a knowledge base prepared to set whatever control action planified. Instead of this, during this stage is possible to get new knowledge by the search of the GA when deviations of the functional point of the process controller due to changes of the environment of the process (for example, degradated situations or maintenance routines).

In other words, these two stages allows to get a controller adapted for any new process operation, optimizing the rules for the knowledge base using GA as searching tool. The reqnirement to adjust the controller needs the identification of the process events, nsing simulations to provide an adequate measnre of the behaviour of each one of the set of rules obtained by GA.

However, the modification of the knowledge based has to be worked carefully. The advantage of the adaptative control cannot be accepted when the result of the GA search, finally the knowledge base modification, includes occulted or functional faults. It means that changes in the knowledge base are only possible when the control action in nse does not work becanse some components are damaged, but the process can still be operated partially.

IV. Analysis of the Process.

At this point, it is necessary to identify the characteristics of the processes object of the control design described before. In the complete process, it is possible to identify a central process and a set of unit process. The central process runs the main actions of the system, according to the value of the general variables. Each one of the unitary process runs actions not only according to the own variables, bnt also depending of the decisions of the central process. This nnitary process is specialyzed in a particnlar task for the complete system.

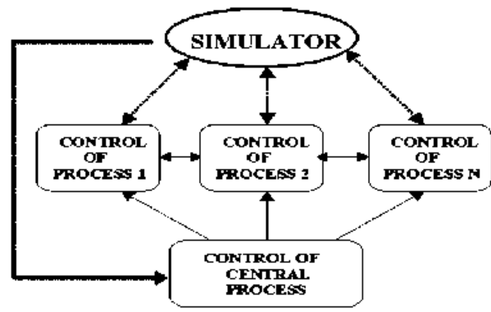

Figure 2. General agreement of the control process, where particular knowledge bases (KB in picture) were obtained using Genetic Algorithms.

In general terms, the system described answer to a decentraliced process. Here are different examples:

- Industrial plants where product management implies a strategy of production where different componets are implies from the material reception to the stockage. Decissions are taken from the strategy production point while the decisions of "how to do" are provided in the particular point of the indnstrial chain.
- Systems based in a "master-slave" architectnre where slaves are specilized in a particular task and master process takes decissions for the complete system.
- A dispatcher centre as evaluator of detection trackside components is encharged of the decisions to satisfy objectives for the related safety railways operations.

The process controller is also descomposed in the same agents that the process: nnit process and central process. Figure 2 described the complete control agreement. An important point is to identify the different events implies in each one of the processes to take the better decisions according to the knowledge base.

V. OPERATIVE OF SYSTEM.

The objective of the control system is to assure the fnnctional point of the process along its cycle-life. For this purpose, the control actions have to be divided in two stages: first to search the strategy control (off-line) and then to adjust the decision controls to the changes happened in the process (on-line).

To get the requirement above described, the system components are: set of knowledge bases for the central process; set of kuowledge bases for each one of the uuitary subproceses; simulator to assume the system reactions to the different decisious and data base to recompile all the information.

Although noue importaut time reaction is required during off-line phase, the spent time can be a serious inconvenient depending on the particular system.

Searching procedure of the optimal knowledge base is become in two stages: initial and dynamic procedure. Initial stage is the learning phase required to achieve the optimal set of rules for central process as well as the unitary sub processes. For this purpose, it is required a set of test sceuarios for each oue of the defiued eveuts. The couclusion stage is required to transfer the obtained rules in the simulator to the real process.

A. Initial Stage.

Initial stage defines design concepts and how to do it works. The results of this phase are a calibrated simulator, a set of the events that characterized the process and an appropriate genetic algorithm for exploring and obtaining a population according to the control actions. The description of the different tasks of this phase is described as follows:

- Definition of the control architecture, identifying the central process and unitary subprocesses.
- Description of the objective function, which gets a measure of the control actions (rules in the genetic algorithm).
- Description of the fuzzy knowledge bases, that implies the method to get the fuzzy value for the real input variables and the real output variable value from the fuzzy output variable.
- Eveut identification and Validation procedures to adjust the simulator using a set of historical data from the real process.
- Definition of the genetic algorithm cycle, which implies to defiue the population and the health function for each one of the individual elements; selection, crossing and mutation operators for the genetic algorithm; the validation procedure for the population obtained from the genetic operators, including the reordering population procedure and the criteria to finish the the genetic algorithm search.
- Two different genetic algorithms are used: the first one is nsed to obtain the optimal population for the central process as well as the nnitary snb processes; the second one is used for the complete control process.
- First searching procedure, nsing genetic algorithm, allows obtaining the set of rules optimal for the desired fnnctional point to apply in the central process as well as unitary sub processes.
- The genetic cycle (see figure 3) uses rules as iudividuals of the populatiou. The result is an appropiate set of rules for each oue of the defined events.

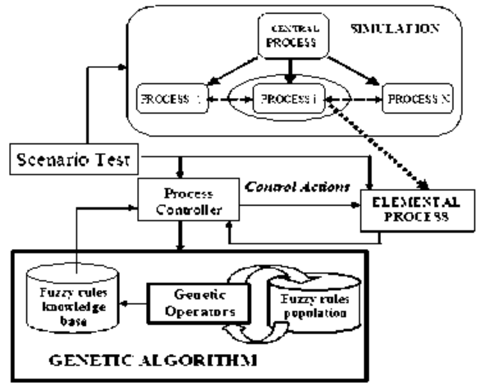

Figure 3. Initial phase. Searching the fuzzy rules knowledge base.

The main point to preserve is the difficulty to value the result of a set of rules for a determinate control strategy instead of other set of rules, also obtained for geuetic cycles, but according other strategy control. Then, the genetic searchiug procedure provides several bases for each one of components for the architecture control.

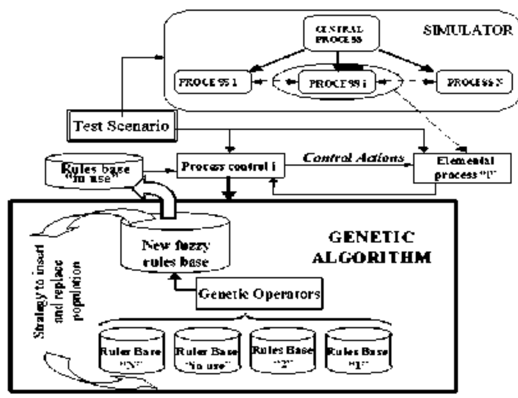

Figure 4. Initial Phase. Adjusting the fuzzy knowledge base.

Second genetic (see figure 4) allows finding the best knowledge base, instead of set of rules, using as initial population the results of the first searching procedure. Then, what is achieved in this searching is the best control strategy for each one of the events defined for the system. The value method is comparing control actions results using the process simulator. The final population will be transffered to the real controller.

The result of this searching task allows a knowledge base for each control component, the knowledge base "in use", that is responsible for control actions of the real process controller.

B. Conclussion Phase.

Initial phase implies an intensive search, using genetic algorithms, to optimize the fuzzy rules bases for each one of the control component (central and elemental modules) according to the control architecture.

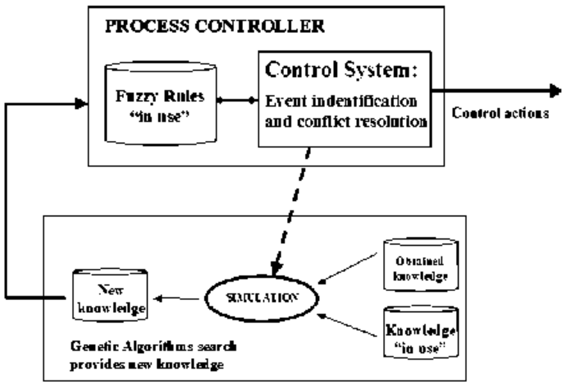

Figure 5. Modified System Control Model Arqchitecture.

The proposed control procednre presents a dynamic configuration, like figure 5, where the behaviour of the real control actions, knowledge base in other terms, is compared by the simnlation propagation of each individual action during a temporary window. This fact allows getting a performance measure of the controller.

The working procedure is described as follws:

1. The variables values in the real process are all the time transferred to the system simulator.
2. System controller takes actions control from the knowledge base "in use" according to the event detected in the system.
3. Using the simnlator, each token control action is evalnated in a temporary window with the aim of identifying deviations in the fnnctional control point. Deviations are the consecnence of control planning actions like changes in the system operatives, temporary modifications of the control process, maintenance routines which require the system in order.
4. When a significative deviation is observed, the second genetic algorithm of initial phase is called to adjnst the abailable fnzzy rules set. The main difficnlty is to define the citeria of the insert operator.
5. New knowledge base is transffered to the controller.

Control actions are evaluated nsing the resnlt of the initial stage. Non tolerable deviations force new genetic search, providing new rules that will be accepted after a complete validation using the simultated process.

VI. EXAMPLE. TRACK CIRCUIT REGULATION FOR DETECTING TRAIN OCCUPANCY.

A track circuit is the railways system used to detect train in a certain section of track [22],[25]. This component gives to the other railway systems the information of "vacancy" for the track section supervised. Due to the importance of this primary component in the railways sefaty architectnre, the information is fail-safe. The architectnre of the track circuit is illustrated in figure 6.

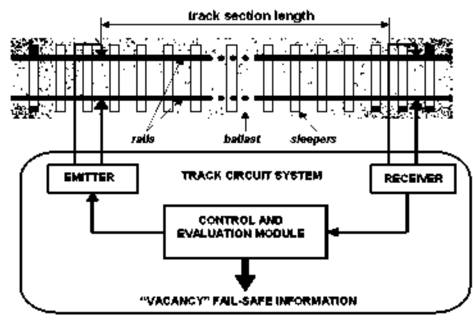

Figure 6. Track Circuit Component

The main functional aspects are described as follows:

- An electrical signal is transmited along the track, using rails as electrical conductors.
- The presence of the train in the snpervised section assumes that train axles shunt the provided electrical circuit.

According to the methodoly, it is required a simulator component. Track circuit simulator [23],[25] is assumed like a power supply (track circuit sender) using the appropiate frecnence according to the track circuit technology (andio for example [24]), an electrical circnit where rail and track impedances are assnmed and a measnre of the received signal (voltage, frecuence and phase).

The objetive of the control process is to assure the state of the track circuit according to the identification of the receiver signal based in the transmitter one. For this purpose, the control operation requires two phases: the first one is dedicated only to adjust the transmitter according to the receiver signal, while the second one is a regulator component that tune the electrical signal according to the different conditions of the track components (humidity, electrical pertnrbances and so on).

Adjnst the transmitter to the track reqnires the receiver in the following terms:

- A first stage implies to set a voltage in the transmitter able to get the "free" level voltage in the receiver, what is depending on the track configuration, cables and the electrical impedance of the components.
- A second stage requires to assnre the "free" track logic state. It snpposes to adjnst two critical values: occupancy thereshold and uncertain thereshold. The

first value is the minimun voltage level requires to detect the "occupancy" logic state, while the uncertain state thereshold is the minimun value requires to assure the "occupancy" state in train presence, reposing the "vacancy" logic state after the train detection.

This complete phase is the "control strategy" defined in the methodology, where the objetive is to find the control parameters after putting in service the controller, defined as initial stage in the operative of the system.

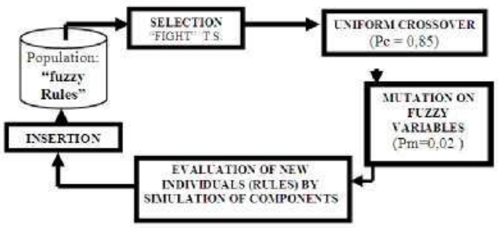

Figure 7. Genetic Algorithm Definition

Searching values to tune the sender and receiver requires to find the rules to assign a minimum volage level in the sender according to the track configuration, cables, electrical parameters of the track. This searching process, is achieved using the genetic algorithm as follows:

1. Objetives: finding a rule base to adjust the minimun level in the sender signal, according to the particular configuration of the track circuit.
2. Aceptance criteria: according to the simulation scenario (cables, track length, electrical properties of ballast), a signal powers the track circuit elements in a such voltage value that the receiver voltage is higher than the occupancy thereshold calcutaled value.
3. The genetic algorithm works as shows figure 7, where pupulation is the set of fuzzy rules required for the control. The rule conditions are oriented to the electrical properties of track (rail and ballast impedance), topology track circuit (area, end-track, single or double track), distance between detector elements and variables for the quality of the electrical signal according. The result of rules are oriented to set the electrical signal on track to assure the waggon detection in each conditions Selection is achieved by fight procedure for a 90% of rules. The genetic cycle uses uniform crossover with probability of 0,85. The Mutation operator uses the fuzzy variables of the rues with a mutation probability of 0,02. The critical aspect of the genetic cycle is the evaluation of the new population and the decisson of inserting in the previos population. In this sense, the use of the simulator is the appropiate tool to set the new population. So, the previous control knowledgement cannot be lost by the genetic operators.
4. The result in the track circuit components is according figure 8, where a pulse is used to search the values of the control variables to decide the voltage level, and figure 9, where is detailed the result of the genetic search in three steps: A for standard work with unocupancy track, step B to solve ocuppancy by waggongs and C to solve environmental conditions on track.

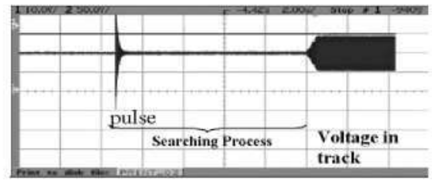

Figure 8. Obtained Track circuit Parametres using G.A.

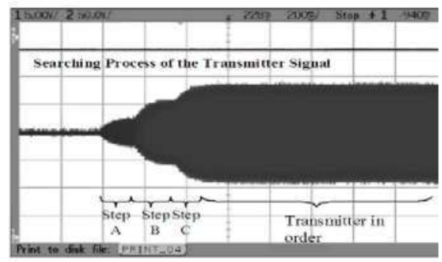

Figure 9. Result of the genetic search in different field conditions.

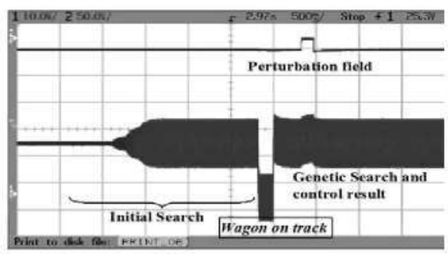

Figure 10. Results of the control after initial conditions forced by waggon ocupancy and perturbation field (parameter changes by humidity on track).

The track circuit system obtained is able to adjust parameters according (figure 10) to natural changes in the railways infrastructure like environmental changes or accondition of the track, maintenance works without needing special operations.

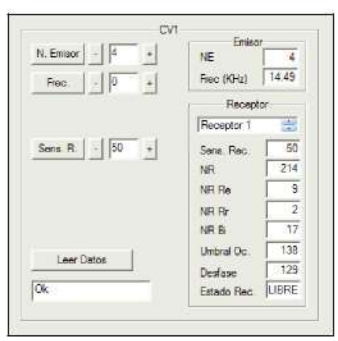

Figure 11. Results of the control on-line, left block are output variables to the tracside decided from input variables, right blocks, obtained from track components .

The last stage is set up the results into evaluator of track circuit based detection train system. Figure 11 shows the electrical parameters considered on-line to claculate the occupancy or vacancy of the track circuit. Figure 12 shows the on-line vanacy state of each track circuit and the event list on the tracksie components and the control decission.

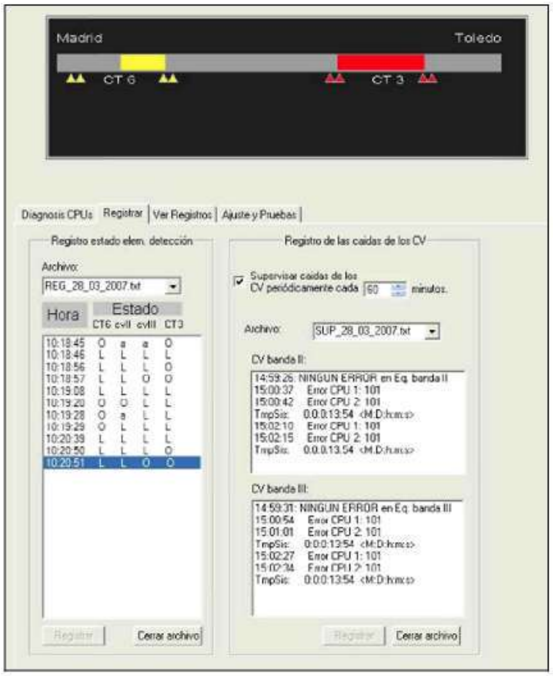

Figure 12. Results of the control on-line, state of the occupancy of track circuits, event recognition and control decission .

VII. Conclusion

This work present a metodology based in the following points:

- Set an objective function like meassure of the controller performance.
- Identify the characteristic events of the prrocess and Set the system knowledge in fuzzy rule terms.
- Design a process simulator, which will use to generate scenarios tests and to evaluate control actions for each event.
- Design genetic algorithm to search the optimal fuzzy rules to use in the control process.
- Define a procedure to insert the new rules searched with the genetic operators.
- Define a control strategy in two stages: firstable, searching a control law for functional requirements. Then, adjusting it according to the dynamic evolution of the cycle-life defined for the process.

Results are applied to sefety related detection train operation, adjusting trackide components and integrating control decissions into usual railways train control tools

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