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Instrumentation, Measurement and System Stability

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ABSTRACT

In this paper, we propose that measurements and instrumentation are essential to maintaining the stability and integrity of any system. Any general system has a healthy and acceptable range of parameter values. In scientific, medical or engineering environments, such parameter values need consistency; validation and affirmation ensure that the scientific, medical and engineering processes within the system are within their respective ranges. Such a confirmation ascertains system and process stability. In most cases, the instruments are administered, read, processed and monitored by human beings as a part of managing a smaller segment of a more encompassing process.

Three major issues are addressed in the paper. First, the role of the measurements and instrumentation is emphasized and incorporated in the computer driven monitoring system. Second, the role of AI programs, expert systems and mathematical, statistical inferencing is invoked to check the validity of the parameters in context to the application at hand. Finally, the corrective feedback to stabilize the system in view of the changes in inputs and environment are examined and administered to the right extent and at the right time. The system architecture, the interconnections and the interdependence are explored in the body of the paper to let the field engineers design and implement the system to suit any particular application.

INTRODUCTION

Within the context of this paper, we extract the general principles for maintaining the overall stability of the entity and then proposed computer architectures to instrument, measure and monitor arrays of input, intermediate and output parameters to act in a corrective and stabilizing role to safeguard the process. In addition, the basic principles for the design and fabrication of the entire systems that ascertain the stable functioning any general facility are presented. The overall system for, such as a peroleum refinement plant, a university, or a hospital may be monitored and its operation optimized. Instrumentation and the measurements of critical parameters that contribute to the stability of the overall system become an integral part of the design process. There is a profusion of these systems that have found a niche in almost all computer/VLSI chip dominated intelligent control systems.

Social and human organizations such as corporations and human resource institutions are also likely beneficiaries of these computer-based process stabilizers. In such cases, the rules that govern the stability functions are open ended and situation driven. For this reason, we suggest that the AI (artificial intelligence) programs [1] have definite capabilities to learn and adapt to the tastes and traits of the top executive teams. In many cases, the expert system and the previously accumulated knowledge bases become valuable corner stones in the design and implementation of a new breed of such stabilizing systems that extend well beyond the traditional decision support systems [2]. Elaborate and specialized ground rules such as those applicable in the occupational health measurements and monitoring are embedded in the expert system knowledge bases the influence the overall effect and stability of the processes.

The self-monitoring and stabilizing systems discussed in the paper are generic in nature and become applicable for most of the existing semi-social entities such as hospitals, electronic governments, universities and corporations. Engineering and manufacturing plants can also be administered by such computer aided system monitors. The precision and the frequency of the measurements become serious issues when any process reaches the instable regions of operation encountered in critical applications such as nuclear power generation plants or petroleum refineries.

For example, in a hospital environment the welfare of each patient is sensed by a series of instruments that read and registered as the vital statistics (temperature, blood pressure, heart beat, blood sugar, etc.) on a periodic basis. These measurements are monitored by the doctors and nurses to be sure that improvement in health is occurring according to medications, or at least that the decay of health is being prevented. Additionally, in any petroleum refinery, such instrumentation becomes essential to safeguard ensure the distillates from the crude and to adjust the composition of the output of the refinery from time to time. Such examples are numerous and encountered in most industrial, corporate, government, medical and educational environments.

CONCEPTUAL FRAMEWORK

Basic feedback control theory [3] and servomechanism [4] have been successfully deployed in most electrical and mechanical systems for decades. The basic equations that govern the system stability or instability have been formulated as precise algebraic equations. It is preemptive that the system behavior be well understood and documented for the equations to be precise and applicable. However, control of typical engineering systems starts to become imprecise and less accurate as system shows nonlinearity, hysteresis, sticky behavior or variable response times. For this reason typical model or equation based control systems have gone out of vogue.

Scientists have investigated the less predictive systems such as physiological and biological systems. Monitoring the results in relation to the magnitude and phase of the corrective measures becomes an art rather a science especially in the medical field and drug industry. The simpler problems have been addressed and resolved since the 1970's. Tough and ill- conceived problems still prevail especially with the new ailments (e.g., the bird flu or Ebola) and the newer drugs (the preventive flue shots or vaccines) that are synthesized to rectify the problems.

Recently, the quantitative feedback theory has started to surface in view of the fact that the digital techniques are superior and much more easily controlled and monitored. A hybrid of equation based algebraic techniques and quantitative output control signals are also feasible and discussed in [5]. In the modern days metering and measurements are automated and dedicated computational facilities monitor the performance of any complex and delicately balanced systems. Such systems can be highly diversified such as Spacecrafts, airplanes, education or hospital systems, corporate decision support systems, production facilities or even security systems.

In view of a large number of possible applications, we propose a three-tier system: measurement and instrumentation are at the lowest level; modeling and algebraic capabilities are blended at the second tier; and finally, an artificially intelligent (AI) based system is at the third tier. The proposed AI system uses all the AI tools such as learning, adapting, recognizing scenarios and pattern within the operating environment and robotic response. The three-tier system is thus deployed to monitoring, stabilizing and optimizing the overall system performance. The computer-based system operates in a closed loop mode. It operates to document changes in external conditions, measured parameters, the changes in system response before and after the corrective signals are dispatched, the response times. Critical information is entered into a database for future adaptation and self-learning of the intelligent control system. These parameter values are deployed in the fine control of the corrective signals that actually control the system behavior and response.

Generic Intelligent Control Systems

Intelligence within the control system is at least in five closely related directions. First, the system senses and classifies the changes in external environments that host the generic system that is under surveillance and control. Second, the system monitors how the changes in the instrumentation of the parameters and how these changes affect the stability of the system. Third, the system enters these changes at fixed intervals of time or far more frequently depending on the nature and severity of the changes. Fourth, the system documents the system performance and optimality in view of the changes and their numeric values documented by the instruments. Fifth, the system correlates the cause an effect relationships between a set (vector) of input to set (vector) of system performance and its optimality. Sixth, it checks with the expected ranges observed in the earlier observations. Seventh, the system administers corrections and to he compensate for the changes from the environment and also due to malfunctions within the system itself to restore the performance to its most desirable or optimal characteristics. Finally, it learns the strategies that have succeeded or failed from a database of corrections, results and a track record of earlier observations. In effect it starts to gain a predictive capability as what correction is most effective and the set of environmental factors that favor the success of a series of strategic moves.

In the most trivial of the applications, the intelligent control systems are learned and mastered by the robotic control of routine assembly lines of most of the manufactured goods. In the most complex applications, these systems facilitate the flight, its navigation and landing of spacecraft and robotic vehicles on distant stars. In the realm of practical and routine applications, the monitoring of patients in hospital, the management of investment portfolios or the regulation of manufacturing and refinement plants, etc. become subservient roles within a wide variety of derived intelligent control systems.

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ARCHITECTURE OF INTELLIGENT CONTROL SYSTEMS (ICS)

The basic building blocks of any ICS are depicted in Figure 1. Measurements of changes in input conditions and in the system performance become key issues in returning the system to its optimal conditions for most desirable operation. Input conditions are generally sensed and performance is measured by key parameters. In almost all healthy and well-conditioned systems, the relation between changes of inputs and the changes in system parameters follows a well-established pattern.

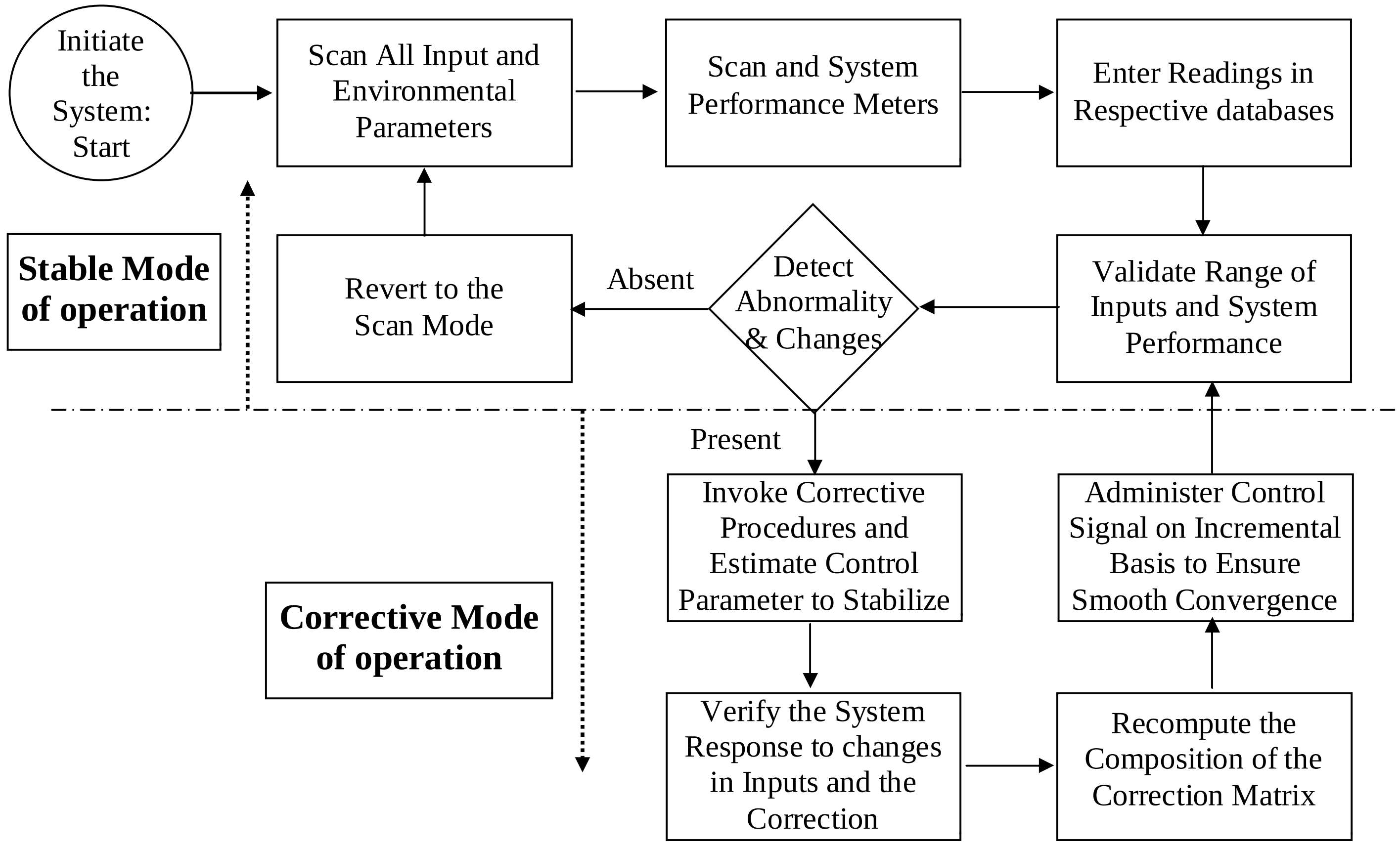

Figure 1. Block diagram of a rudimentary control system to respond to slow changes in the environmental conditions hosting a simple production line. The instruments are sensed periodically and classified. The stable mode of operation continues as long as the parameters sensed lie within the ranges for normal functioning for the production facility. When correction is deemed by altering the system control signals, then the preprogrammed steps to restore the system equilibrium are invoked. All the variations of the controls fall within the programs/software.

The "error function" between the parameters for best system performance and the instantly measured parameters initiates the corrective matrix that re-stabilizes the system and its performance. The error function has two primary characteristics: the magnitude of change in each parameter and the rate of change in the parameter values. In a sense, each of the corrective measures also needs two constituents: the magnitude and its rate of its administration in to the system. Bye and large, for most complex system, the changes and corrections comes as numerical arrays rather than single numbers. Additionally, the timing and the rate administration of each of the corrective parameters are necessary to ensure the smooth transition from operating point to the next due to changes in the environmental conditions. Such transition strategies and procedures are most commonly seen during flight of commercial airline when changes in weather conditions are encountered or during take off and landing.

During the development of automatic control systems, the detection of error signal is generally made automatic and interjected in feed back amplifiers that provided the correction. In communication systems deploying the tapped delay lines to filter out the signal degradation, the practice is still deployed to set the tap-weights in equalizers. Even in this simple instance, the magnitude of delay in the reflection (due to irregularities of the transmission medium) is used to set the discrete tap-weight of one or two adjoining taps. The timing of occurrence of the delay is used to set the exact tap (or a combination of two adjoining taps). The techniques become complicated in setting the tapped delay filters for echo-cancellation and discussed in detail in [6]. The steps in adjusting the line termination networks for digital subscriber lines is generally programmed and made an integral part of the intelligent and adaptive control systems the adjust the parameters for smooth and error-free (as far as possible) transmission of data through networks.

In other instances of complex systems, the composition of the corrective array is generally computed by a computer system that uses a systems model and artificially intelligent agents dispersed within the system. As the modern system become more and more sophisticated and delicate (such as missile systems, spacecraft landing gear, electronic governments, IT platforms, intensive care systems, etc.) , the deployment of computational systems with AI tools, databases and knowledge bases [7] becomes essential.

Framework for Intelligent Control Systems of Complex Systems

In Figure 2, the framework of an intelligent control system for a more complex system is depicted. The low level operation of this system occurs in the scan mode where the system is monitoring the performance in an autopilot mode shown in top half of the Figure. When any abnormality is detected due turbulence or unexpected changes in the external operating conditions or internal system responses, then the corrective mode takes in to stabilize the system and restore the operation in view of (external and/or internal) changes. In the later mode, there are four basic modules in designing the hardware, software or the firmware for the control system. Each module has a supporting database and program or process control unit. Typical microcomputer architecture can lead to precise and sophisticated control of the corrective signals in context to the abnormality registered by the measuring instruments.

Four independent databases and program modules are shown to quickly and efficiently regain and restore the stability of complex systems. These modules can be logically interdependent or tied into a standalone operation system to foresee and prevent conditions that lead to instability or unnecessary oscillations in the overall system response. In most of the control environments and automated servo systems, the magnitude and the phase of the correction signals becomes crucial. The criterion can be derived from theoretical model of the system or by observing the past behavior of that particular system.

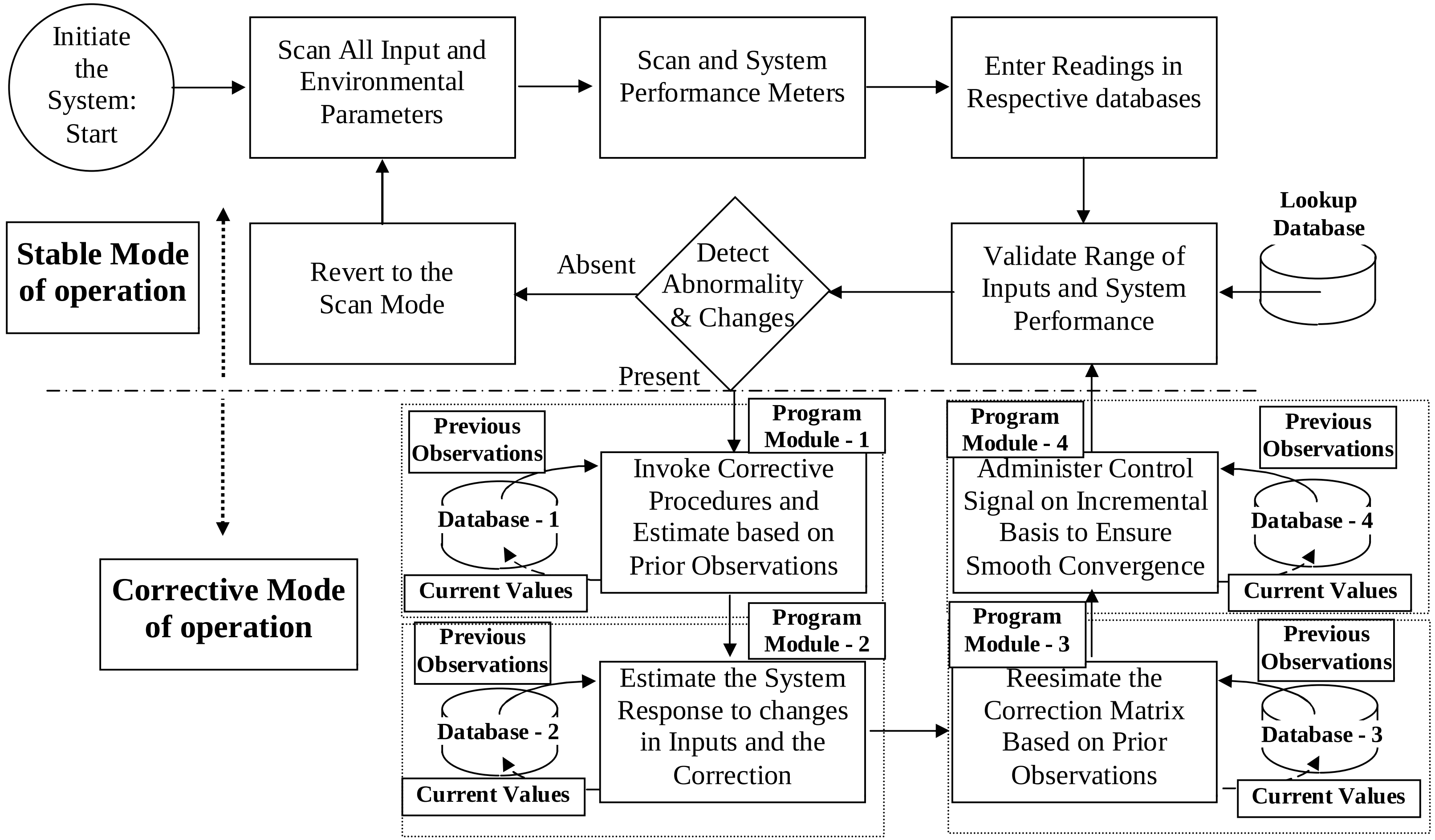

Figure 2. The use of databases and four independent program modules to regain the stability of complex systems. These modules can be logically interdependent to prevent any unnecessary oscillations in the overall system response. In most of the control environments and automated servo systems the magnitude and the phase of the correction signals becomes crucial. In addition, the interaction of different corrective measures can also cause system instability. Such interactions are noticed in patient care. Nonlinear system response also leads to unexpected system behavior.

This approach is most frequently deployed for solving the stability issues while dealing with human and social groups. Such situations arise in the management of conflictive groups, such as warring factions, labor-management negotiators, domestic violence, etc. The interaction of different corrective measures can also cause system instability. Drug interactions are noticed in patient care. Nonlinear system response also leads to unexpected system behavior. The entire system can be monitored by human beings, intelligent agents, or by constant observation. It can also be made artificially intelligent to be able to learn from prior experience(s) in the successful deployment of different strategies for stabilizing the entire system. In a purely human setting, the management teams deploy this approach in evolving the standard operating procedures (or SOP's) in corporations. In a routine production environment, the extent of automation depends on the skill sets of the designers of the intelligent control system (ICS). The hardware, software and the firmware each offers a limited amount of programmability and in combination the entire ICS can be made powerful and efficient. A certain degree of latitude exists if the designers deploy existing chip-sets for the ICS. The amount of unused memory and the cycle time of the chip-sets need careful consideration in relation to the system response times.

CONCLUSIONS

Sensing and instrumentation form the foundation of stable systems. The general principles for maintaining almost all production, human and corporate systems at optimal level have been revisited in light of the modern computations systems and AI techniques. Such systems can be designed, built and optimized for any given system operating in a variable environment. These microcomputer-based systems are lodged in chipsets and function with preprogrammed algorithms to monitor and stabilize simple systems. For the more sophisticated systems, adaptive algorithms encoded in the memory banks of chipsets are invoked. Typical example of such adaptation occurs in equalizers and echo cancellers for high-speed digital subscriber lines. For monitoring and stabilizing more complex systems all the AI techniques (pattern recognition, expert systems, learning and strategizing, intelligent agent deployment, etc.,) become necessary. The software partitioning for programs and for databases is depicted and the role of the corrective feedback is discussed to make the transition from one set of external and/or internal condition to the other smooth and oscillation free.

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