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METHODS AND TOOLS FOR DEVELOPMENT A HYBRID AND INFORMATION CONTROL SYSTEMS OF TECHNOLOGICAL COMPLEX

Abstract. The relevance of the development of software complexes for the control of technological complex is determined by such trends as the emergence of innovative technologies for the development of computer programs.

The power management control system development and vehicle test results for a medium-duty hybrid electric truck are reported in this paper. The design procedure adopted is a model-based approach, and it was based on the dynamic programming technique. A vehicle model is first developed, the optimal control action that maximizes fuel economy, then it is solved by the dynamic programming method. A near-optimal control strategy is subsequently extracted and implemented in the MATLAB XPC-Target rapid-prototyping system, which provides a convenient environment to adjust the control algorithms and accommodate various I/O configurations. Dyno-testing results confirm that the proposed algorithm helps the prototype truck to achieve an impressive 45% fuel economy improvement over the benchmark vehicle

This article discusses the possibilities of creating a hybrid system for the possibility of optimal control over the process of burning fuel in a vehicle using intelligent technologies.

Keywords: hybrid control system, information system, mathematical model, technological complex, synthesis, supervisory powertrain controller.

Introduction. Nowadays, most systems can be modelled by the mathematical and analytical methods developed over the last two decades. Therefore, control engineers can have good understanding of any systems and the desired behaviour can be achieved [1]. Also during the last two decades, the exponential drop in price of computing power made computers widely available. Computers are used in most control systems today.

A computer which acts as a logic decision unit processes input provides output in digital form, ie 0 and 1. It is also known as a discrete-time system. It is easy to see that a system which processes only continuous-time data is called a continuous-time system, that is, it can be represented by mathematical functions [2].

Moreover, it is common to have a mixture of both logic and continuous systems. While all the generators produce continuous-time data, the computer receives those data and processes them in discrete form. This kind of systems is known as ***hybrid control system*** [3].

A typical hybrid system is arranged in two (or more) layers. Different levels of abstractions of the plant model are used at each layer of the hierarchy. In the bottom layer, the plant model is usually described by means of differential and/or difference equations. This layer contains the actual plant and any conventional controllers working at the same level of abstraction. In the top layer, the plant description is more abstract. Typical choices of description language at this level are finite state machines, fuzzy logic, Petri nets, etc. Typically, the controllers designed at this level are discrete event supervisory controllers. The two levels communicate by means of an interface that plays the role of a translator between signals and symbols [4].

The control architecture described above appears in a wide variety of applications and forms the heart of most hybrid system formalisms. This results from the requirement that control systems are expected to be autonomous (e.g., in case of highway automation, the vehicles are supposed to be driven automatically without human intervention), requiring the controller not only to calculate feedback control laws for specific tasks, but also to plan the sequence of actions in order to achieve the specified goal [5]. Planning is inherently a discrete process, which is represented by the higher layers of the hierarchy whereas the continuous time control laws that execute each action constitute the lower layers. Switching controllers, Intelligent Control, Expert Control, and Motion Control, among others [6].

In general, a hybrid system denotes a system composed of two unlike components. A hybrid control system is a control system with both analog and digital parts. Such a system generates a mixture of continuous and discrete signals, which take values in a continuum (such as the real numbers R) and a finite set (such as{a,b,c}), respectively.

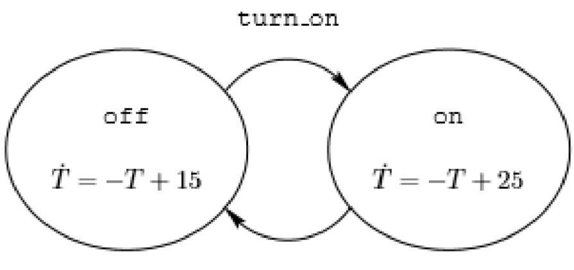
A continuous-valued signal typically takes values in the set of real numbers (e.g., a temperature T taking values in the interval [−20,100] degrees Celsius), while a discrete-valued signal takes value in a discrete (often finite) set (e.g., a thermostat valve V taking the values{on,off}). The signals can either depend on time or be event-driven. A continuous-time signal is updated continuously through a differential equation (e.g., $T(t) = -T(t) + 1$) while a discrete-time signal is updated through a difference equation (e.g., $T(t + 1) = T(t) + 1$). An event-driven signal, on the other hand, is updated when an internal or external event happens (e.g., the switching on of the thermostat, $V + :=$ on, could be driven by the event that the temperature goes below 15 degrees, $T < 15$). Note that a discrete-time signal can be interpreted as an event-driven signal being updated when the event "sampling" takes place [7].

Let us develop a simple hybrid control system, which illustrates how continuous and discrete signals may interact. The example describes the problem of maintaining the temperature T of a room at some desired level (about 19 degrees Celsius, say). If the radiator is off, the temperature dynamics is given by

$$T = -T + 15$$

and if it is on the temperature, dynamics is given by

$$T = -T + 25.$$



Hybrid control system modeling the heating of a room

When the thermostat turns on the radiator, the hybrid system jumps from the off to the on state through the discrete transition turn on. It jumps back again when the thermostat turns off the radiator. The temperature T, which is a continuous-time variable, is governed by one of the two differential equations depending on the current discrete state.

It is convenient to represent a hybrid system by a graph. The hybrid system describing the heating of the room can be modeled as the graph shown in figure. The two vertices of the graph represent the two discrete modes of the system: the radiator is either off or on. As long as the radiator is off, the temperature T will follow the dynamics specified in the left mode, i.e., T will tend to 15. When the event marked turn_on is triggered, the discrete state of the system jumps from the off to the on mode. The transition is represented by the upper edge of the graph. In the on mode, the temperature follows the dynamics given by the differential equation specified in the right vertex, i.e., T will tend to 25. When turn_off is triggered, the system returns to the off mode. The events turn_on and turn_off can be triggered by either external or internal signals. An external trigger can be that an operator manually turns the radiator off, that a failure causes the switch, or that a separate system (e.g., a heating system in another room) communicates the trigger. An internal trigger signal is depending on the hybrid state of the system. As an example, suppose that a thermostat is used as a heat controller. Then, an internal trigger can be created by identifying the event turn_on with the logical condition $T \leq 18$ and the event turn_off with the condition $T \geq 20$. For such a hybrid control system, the discrete transitions can take place only when these boolean expressions are true.

For the thermostat controlled system, it is easy to see that regardless of the initial state of the system (i.e., for all initial discrete state in{off,on}and initial continuous state $T(0) \in R$), the temperature tends to an oscillate between 18 and 20 degrees. For more complicated hybrid control systems, such a conclusion is not obvious, but one need theoretical and computational tools to analyze properties of hybrid control systems [8].

Methods. Hybrid control systems are typically found when continuous processes interact with, or are supervised by, sequential machines. Such systems frequently arise from computer aided control of continuous processes and such hybrid systems arise in varied contexts such as manufacturing, communication networks, autopilot design, computer synchronization, traffic control, and industrial process control, for example [9]. Another important way in which hybrid systems arise is from the hierarchical organization of complex control systems. In these systems, a hierarchical organization helps manage complexity and higher levels in the hierarchy require less detailed models (discrete abstractions) of the functioning of the lower levels, necessitating the interaction of discrete and continuous components. Examples of such systems include flexible manufacturing and chemical process control systems, interconnected power systems, intelligent vehicle highway systems, air traffic management systems, and computer communication networks [10]. More generally, hybrid systems arise from the interaction of discrete planning algorithms and continuous control algorithms. As such, hybrid systems provide the basic framework and methodology for the synthesis and analysis of autonomous and intelligent systems [11]. Examples of this type not already mentioned above include biological motor control models, robotic systems, data base retrieval systems and medical informatics systems.

The control of hybrid powertrains is more complicated than the control of ICE-only powertrain. First, one needs to determine the optimal operating mode among five possible modes (motor only, engine only, power assist, recharge, and regenerative). Furthermore, when the power assist mode or the recharge mode is selected, the engine power, motor power and transmission gear ratio all need to be selected to achieve optimal fuel economy, emissions reduction, charge balance, and drivability. With the increased powertrain complexity and the need to achieve multiple objectives, we adopted a two-level control architecture. A supervisory powertrain controller (SPC) sits at the top to manage the operation of the hybrid powertrain system. The supervisory powertrain controller is designed to include the following functions: power management strategy, transmissions shifting control, smooth operation logic, I/O communication, and system monitor and diagnosis. At every sampling time, the supervisory powertrain controller sends commands (set points or desired states) to each sub-system control module and receive sensor signals and diagnostic status from each sub-system. The low-level control systems manipulate the local-level inputs to follow the SPC commands as long as other local constraints were not violated [12].

To ensure that the SPC achieves a guaranteed level of performance and robustness, a model-based design process was adopted. First, models and look-up tables for all sub-systems are developed or documented. A vehicle model, based on the MATLAB/Simulink/ State flow platform was then developed for vehicle performance analysis and control algorithm development. The SPC control was developed based on the dynamic programming technique, which aims to maximize fuel economy without sacrificing drivability. A near-optimal control strategy is then extracted and implemented in the MATLAB XPC-Target rapid prototyping system, which provides a fast and easy way to adjust the control algorithms and accommodate various I/O configurations. More importantly, the entire development process of the control system provides a seamless environment of control algorithm design, implementation, and testing for flexible hybrid powertrains.

IT application allows us to solve similar problems at once and as experience has shown quite successfully. The fact that artificial intelligence methods involve the using of knowledge, experience and intuition of human experts who are familiar with the subject [13]. So, it uses the so-called effect of "ready knowledge." In contrast, the development of a mathematical model (the main component of the system) is the process of creating of "new knowledge", and therefore requires a sufficiently long time to carry out theoretical studies, as well as high material and labor costs for experimental studies and model identification. In addition, experienced process-operators during long-time work learned to process under optimal conditions at different initial situations (and they often get success). The transfer of "ready knowledge" of human-experts to the knowledge base of intelligent system greatly simplifies the creation of intelligent systems and their operation eliminates the effect of the "human factor" in process control (these are properties of the human body such as: fatigue, not fast enough reaction, not enough psychological stability, drowsiness during monotonous work, little experience of young operators, and other causes) [14]. Using the basic idea of the work (development of process control models instead of a process model) and by development of the existing IT methods, we propose the following three-stages of process on creation of the optimal control systems of technological processes (see figure 1). At the first stage, it is produced a priori investigations of technological characteristics of controlled object on literary source, publications in periodicals, and factory technical documentation. As a rule, the existing processes had had to go through a long phase of research, experimental -industrial and industrial tests before they would be adopted into production. Surely, there are still available materials of those researches, as well as attempts to create mathematical models of creation of mentioned process. It is necessary to carry out careful analysis of all this information in order to use it in the development of intelligent control systems. This is especially important during potential creation of hybrid control systems (HCS). At this stage it is necessary to analyze the researched process as object of control with identification of input and output, controlled and uncontrolled, ruled and not ruled variables. Meanwhile, it is necessary to estimate object persistence through various channels, the object class (continuous or discrete), completeness degree of information on instance variables, operational range of instance variables and etc. After careful analysis of the available information, it is necessary to make the structure of the future control system, which will significantly simplify further work. At the second stage, it is developed a process control model. With assistance of experienced experts (process operators, or engineering and technical personnel of workshop or factory) the main goal of control (equivalent of target function in optimization tasks) is being determined, which used to be familiar as rule, and which is usually trying to be reached by experienced operators. Then by the method of ranking from the general list of all types of the variables it is determined those, which are considered as main for the mentioned object (process) according to the opinion of the experts [15].

The modeling process to select a powertrain is the first stage in this research. Several viable powertrains and the respective vehicle technical specifications (VTS) are evaluated. The P3 parallel configuration with a V8 engine is chosen because it generated the set of VTS that best meet design goals and EcoCAR 3 requirements. The V8 engine also preserves the heritage of the Camaro, which is attractive to the established target market. In addition, E85 is chosen as the fuel for the powertrain because of the increased impact it has on GHG emissions compared to E10 and gasoline. The use of advanced methods and techniques like model based design (MBD), and rapid control prototyping (RCP) allow for faster development of engineering products in industry. Using advanced engineering techniques has a tremendous educational value, and these techniques can assist the development of a functional and safe hybrid control system. HEVT has developed models of the selected hybrid powertrain to test the control code developed in software [15].

The strategy developed is a Fuzzy controller for torque management in charge depleting (CD) and charge sustaining (CS) modes. The developed strategy proves to be functional without having a negative impact of the energy consumption characteristics of the hybrid powertrain. Bench testing activities with the V8 engine, a low voltage (LV) motor, and high voltage (HV) battery facilitated learning about communication, safety, and functionality requirements for the three components. Finally, the process for parallel development of models and control code is presented as a way to implement more effective team dynamics [15].

By hybrid systems we mean dynamic systems that are a combination of analog systems and finite digital systems. In a typical hybrid system a digital unit controls the behavior of continuous processes. The digital subsystem is usually modeled as an FSM, while the analog subsystem is modeled by differential and/or difference equations. The behavior of the digital part of the system can be described using the state transition rules related to the corresponding FSM, while the analog part changes over time as a derivative/integral function. Graphically, the digital part is represented as a state diagram, while the analog part is usually represented as a stock-flow diagram (both types of diagrams will be described later). The architecture of a hybrid system forms a two-level control structure. On the low level, feedback loops are used for local control as part of the analog system. On the high level, meta-control logic function switches between modes of the analog systems behavior according to a predefined logic of the FSM's state transition rules (Bencze & Franklin, 1995; Branicky, 1995; Mosterman & Biswas, 2000). The properties of analog and digital systems are summarized in table.

Properties of the digital and analog system

	Digital	*Analog*
Mathematical model	Final state machine Algorithmic state machine	Differential/difference equations
Behavior	State transition according to input and transition rules	Change as a derivative/integral function
Graphical model	State diagram	Stock-flow diagram
Type of control	Event driven control	Local feedback loops

The concept of hybrid system has been known since the early days of dynamic systems theory (Branicky, 1995), but its importance in the modern man–made digital world is still on the rise. Implementations of hybrid systems modeling methods are recognized mainly in the two following contexts:

1. In a local context, in cases when microprocessors control physical and technological processes.
2. In a global context, when human decision making systems may be modeled by means of hybrid techniques.

The first group consists of modern technological real-time systems (Antsaklis & Lemmon, 1998). Cars, robots, cell phones, medical devices, home climate systems, microwaves, computer disk drives, washing machines, intelligent transportation systems, and production lines are all technologies where a digital controller interacts with continuous processes (Branicky, 1995; Johansson, 2000). Most of today's sophisticated controlling systems use the computer as a mean of control, though their full potential is still to be revealed (Kamil & Chui, 1996). The presence of these systems in everyday life – from consumer electronics to traffic control – is constantly growing [15].

Active, semi-active and hybrid structural control systems are a natural evolution of passive control technologies such as base isolation and passive energy dissipation. The possible use of active control systems and some combinations of passive and active systems, so called hybrid systems, as a means of structural protection against wind and seismic loads has received considerable attention in recent years. Active/hybrid control systems are force delivery devices integrated with real-time processing evaluators/controllers and sensors within the structure. They act simultaneously with the hazardous excitation to provide enhanced structural behavior for improved service and safety. Remarkable progress has been made over the last twenty years. The First and Second World Conferences on Structural Control held in 1994 [Housner et al, 1994b] and 1998 [Kobori et al, 1998], respectively, attracted over 700 participants from 17 countries and demonstrated the worldwide interest in structural control.

As will be discussed in the following sections, research to date has reached the stage where active systems have been installed in full-scale structures. Active systems have also been used temporarily in construction of bridges or large span structures (e.g., lifelines, roofs) where no other means can provide adequate protection.

Indeed, the most challenging aspect of active control research in civil engineering is the fact that it is an integration of a number of diverse disciplines, some of which are not within the domain of traditional civil engineering. These include computer science, data processing, control theory, material science, sensing technology, as well as stochastic processes, structural dynamics, and wind and earthquake engineering. These coordinated efforts have facilitated collaborative research efforts among researchers from diverse background and accelerated the research-to-implementation process as one sees today [16].

An active structural control system has the basic configuration as shown schematically in figure 1c. It consists of (a) sensors located about the structure to measure either external excitations, or structural response variables, or both; (b) devices to process the measured information and to compute necessary control force needed based on a given control algorithm; and (c) actuators, usually powered by external sources, to produce the required forces.

When only the structural response variables are measured, the control configuration is referred to as feedback control since the structural response is continually monitored and this information is used to make continual corrections to the applied control forces. A feedforward control results when the control forces are regulated only by the measured excitation, which can be achieved, for earthquake inputs, by measuring accelerations at the structural base. In the case where the information on both the response quantities and excitation are utilized for control design, the term feedback-feedforward control is used [Suhardjo et al, 1990].

To see the effect of applying such control forces to a linear structure under ideal conditions, consider a building structure modeled by an n-degree-of-freedom lumped mass-spring-dashpot system. The matrix equation of motion of the structural system can be written as

$$M\ddot{x}(t) + C\dot{x}(t) + Kx(t) = Du(t) + Ef(t) \tag{1}$$

where M, C and K are the n × n mass, damping and stiffness matrices, respectively, x(t) is the n-dimensional displacement vector, the m-vector f(t) represents the applied load or external excitation, and r-vector u(t) is the applied control force vector. The n × r matrix *D* and the n×m matrix E define the locations of the action of the control force vector and the excitation, respectively, on the structure.

Suppose that the feedback-feedforward configuration is used in which the control force *u*(*t*) is designed to be a linear function of measured displacement vector x(t), velocity vector) (t_x and excitation *f*(*t*). The control force vector takes the form

$$u(t) = G_x\dot{x}(t) + G_x x(t) + G_f f(t) \tag{2}$$

in which G_x, and $G_f$are respective control gains which can be time-dependent.

$$M\ddot{x}(t) + (C - DG_x)\dot{x}(t) + (K - DG_x)x(t) = (E + DG_x)f(t) \tag{3}$$

It is seen that the effect of feedback control is to modify the structural parameters (stiffness and damping) so that it can respond more favorably to the external excitation. The effect of the feedforward component is a modification of the excitation. The choice of the control gain matrices G_x and G_f depends on the control algorithm selected.

In comparison with passive control systems, a number of advantages associated with active control systems can be cited; among them are (a) enhanced effectiveness in response control; the degree of effectiveness is, by and large, only limited by the capacity of the control systems; (b) relative insensitivity to site conditions and ground motion; (c) applicability to multi-hazard mitigation situations; an active system can be used, for example, for motion control against both strong wind and earthquakes; and (d) selectivity of control objectives; one may emphasize, for example, human comfort over other aspects of structural motion during noncritical times, whereas increased structural safety may be the objective during severe dynamic loading [16].

While this description is conceptually in the domain of familiar optimal control theory used in electrical engineering, mechanical engineering, and aerospace engineering, structural control for civil engineering applications has a number of distinctive features, largely due to implementation issues, that set it apart from the general field of feedback control. In particular, when addressing civil engineering structures, there is considerable uncertainty, including nonlinearity, associated with both physical properties and disturbances such as earthquakes and wind, the scale of the forces involved can be quite large, there are only a limited number of sensors and actuators, the dynamics of the actuators can be quite complex, the actuators are typically very large, and the systems must be fail-safe.

It is useful to distinguish among several types of active control systems currently being used in practice. The term hybrid control generally refers to a combined passive and active control system as depicted. Since a portion of the control objective is accomplished by the passive system, less active control effort, implying less power resource, is required.

Similar control resource savings can be achieved using the semi-active control scheme, where the control actuators do not add mechanical energy directly to the structure, hence bounded-input bounded-output stability is guaranteed. Semi-active control devices are often viewed as controllable passive devices [17].

Although there is no general consensus on the definition of advanced control, many approaches that make use of mathematical models of the process, either at a design stage or during operation, are currently called advanced. An excellent review up to 1980 is presented in [Damborg, et al. 1980]. Some references that have transcended are mentioned in what follows for completeness. Much attention has been paid to optimal control minimizing a quadratic performance index [McDonald and Kwatny 1973, Sandor and Williamson 1977]. The practical application of this technique for overall control has been limited by the complexity of the implementation, sensibility effects due to model uncertainties, the need to include reset action in the controller, and the use of linear control techniques in a highly non-linear system. Even though not an overall unit control strategy, the most relevant application of the multivariable optimal control techniques which commissioned a linear quadratic regulator for the steam temperatures in the boiler of a 500 MW unit at the Kyushu Electric Company, Japan, in 1978.

A breakthrough then, this kind of temperature control schemes, including other state-space identification and estimation, nonlinear mathematical programming, optimization and model reference adaptive control techniques, have become a standard feature in Japanese fossil power plants during the last 20 years, allowing them to operate with the highest levels of availability and thermal efficiency. Research has also been done to apply decoupling methods to reduce or eliminate interaction effects between control loops. In boiler-following unit control scheme is extended with a state feedback based compensator to reduce the system interaction effects of a 150 MW unit by Ontario Hydro in Canada [18].

The compensator generates complementary signals for the four major control inputs as the weighted sum of the main control signals and the process state vector using a pair of constant gain matrices, which are calculated from a 9th order state-space linear model of the plant. The state vector is estimated using a Kalman filter. Simulation results showed improved load maneuvering capability in the 75% to 100% load operation range with reduced process variable errors and interaction effects. No details are given regarding the number of linear models used in the load range considered, neither on the way are the gain matrices switched in that it range. In decoupling controller based on a 12th order model was implemented in the real power plant. Compared to a traditional control, the approximately decoupled scheme yielded reduced control error, improved low load stability, simple parameter adjustments, and insensitivity to plant variations. The main difficulty with the decoupling approach was pointed out to be the design of the decoupling compensator [19].

A side benefit of hybrid and semi-active control systems is that, in the case of a power failure, the passive components of the control still offer some degree of protection, unlike a fully active control system [20].

While great strides have been, and are being, made in research and development of active structural control systems for natural hazard mitigation, there remains a significant distance between the state-of-the-art of active control technology and some originally intended purposes for developing such a technology. Two of these areas are particularly noteworthy and they are highlighted below.

1. Mitigating Higher Level Hazards. In the context of earthquake engineering, one of the original goals for active control research was the desire that, through active control, conventional structures can be protected against infrequent, but highly damaging earthquakes. The active control devices currently deployed in structures and towers were designed primarily for performance enhancement against wind and moderate earthquakes and, in many cases, only for occupant comfort. However, active control systems

remain to be one of only a few alternatives for structural protection against near-field and high-consequence earthquakes.

An upgrade of current active systems to this higher level of structural protection is necessary, since only then can the unique capability of active control systems be realized. In this regard, collaboration on a global scale is essential and must be nurtured and reinforced.

2. Economy and Flexibility in Construction. Another area in which great benefit can be potentially realized by the deployment of active control systems is added economy and flexibility to structural design and construction. The concept of active structures is advanced. An active structure is defined here as one consisting of two types of load resisting members: the traditional static (or passive) members that are designed to support basic design loads, and dynamic (or active) members whose function is to augment the structure's capability in resisting extraordinary dynamic loads. Their integration is done in an optimal fashion and produces a structure that is adaptive to changing environmental loads and usage.

Discussion. Note that an active structure is conceptually and physically different from a structure that is actively controlled, as in the cases described above. In the case of a structure with active control, a conventionally designed structure is supplemented by an active control device that is activated whenever necessary in order to enhance structural performance under extraordinary loads. Thus, the structure and the active control system are individually designed and optimized. An active structure, on the other hand, is one whose active and passive components are integrated and simultaneously optimized to produce a new breed of structural systems. This important difference makes the concept of active structures exciting and potentially revolutionary. Among many possible consequences, one can envision greater flexibilities which may lead to longer, taller, slender or more open structures and structural forms.

To be sure, some progress has been made in this direction. Several modes of the bridge tower, which were anticipated to be excited by wind vortex, were carefully protected by appropriate controllers during the construction phase. It therefore made it possible for the tower of this bridge to be built much lighter and more slender than one following traditional design.

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КҮРДЕЛІ ТЕХНОЛОГИЯЛЫҚ КЕШЕНДІ БАСҚАРУДЫҢ ГИБРИДТІК ЖӘНЕ АҚПАРАТТЫҚ ЖҮЙЕСІН ӘЗІРЛЕУДІҢ ӘДІСТЕРІ МЕН ҚҰРАЛДАРЫ

Аннотация. Технологиялық кешенді басқару үшін бағдарламалық жүйелерді әзірлеудің өзектілігі компьютерлік бағдарламаларды дамыту үшін инновациялық технологиялардың пайда болуы сияқты үрдістермен анықталады. Мақалада орташа қуатты гибридті электромобилі үшін қуатты басқару жүйесі мен көлік құралдарының сынақ нәтижелері туралы баяндалады. Қабылданған жобалау әдіснамасы моделдеуге және динамикалық бағдарламалау әдісіне негізделген. Біріншіден, автокөліктің моделі жасалады, содан кейін отын үнемдеуі барынша оңтайлы бақылау алгоритмі құрастырылады, содан кейін динамикалық бағдарламалау әдісін басқару есебі шешілді. Осыдан кейін оңтайлы басқару алгоритмі MATLAB жоғары жылдамдықты XPC-Target жүйесіне енгізіледі, ол басқару алгоритмдерін орнату және әртүрлі енгізу/шығару конфигурацияларын орналастыру үшін қолайлы жағдайды қамтамасыз етеді. Динамикалық тестілеудің нәтижелері ұсынылған алгоритм автокөліктің прототипіне отын үнемдеудің 45 пайызға жетуіне қол жеткізуге көмектеседі. Сондай-ақ, мақалада интеллектуалды технологияларды қолдана отырып, көлік құралында жану үдерісін оңтайлы басқару мүмкіндігі бар гибридті жүйені құру мүмкіндіктері қарастырылады.

Түйін сөздер: гибридті басқару жүйесі, ақпараттық жүйе, математикалық модель, технологиялық кешен, синтез, қадағалаушы қуатты контроллер.

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МЕТОДЫ И СРЕДСТВА РАЗРАБОТКИ ГИБРИДНОЙ И ИНФОРМАЦИОННОЙ СИСТЕМЫ УПРАВЛЕНИЯ ТЕХНОЛОГИЧЕСКИМ КОМПЛЕКСОМ

Аннотация. Актуальность разработки программных комплексов для управления технологическим комплексом определяется такими тенденциями, как появление инновационных технологий для разработки компьютерных программ. В статье сообщается о разработке системы управления питанием и результатах испытаний транспортных средств для гибридного электромобиля средней мощности. Принятая методика проектирования основана на моделировании и основана на методе динамического программирования. Сначала разрабатывается модель транспортного средства, далее оптимальный алгоритм управления, который максимизирует экономию топлива, затем решается задача управления методом динамического программирования. После этого оптимальный алгоритм управления внедряется в быстродействующую систему MATLAB XPC-Target, которая обеспечивает удобную среду для настройки алгоритмов управления и размещения различных конфигураций ввода-вывода. Результаты динамического тестирования подтверждают, что предлагаемый алгоритм помогает прототипу грузовика достичь впечатляющего улучшения экономии топлива на 45%. Также, в статье обсуждаются возможности создания гибридной системы для возможности оптимального управления процессом сжигания топлива в транспортном средстве с использованием интеллектуальных технологий.

Ключевые слова: гибридная система управления, информационная система, математическая модель, технологический комплекс, синтез, диспетчер контрольного силового агрегата.

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