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An example of intelligent greenhousing synthesis based on modern digital systems, neuro-fuzzy technologies and IoT

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Abstract. Challenges in development of new generation modern control systems based on discrete logic are reviewed in this article. System analysis of the current characteristic and properties of data processing systems is given: the problem of conversion accuracy and categorization of new criteria of new system effectiveness. The research experience of reviewed subject is summarized, a processing algorithm for greenhousing hardware control system with support for decision-making on monitoring the operation of sensors, taking into account the neuro-fuzzy technologies and graph theory, in the context of the algorithm theory and solving the problem of calculating the critical path for the quantifier of interaction with the subsequent processing in a neuro-fuzzy application in a quantitative ratio is given. There is description of generalizable algorithm for the constructed software control model with six sensors and a general assessment of the effectiveness of the traditional way for formal model of the greenhouse automated control system and the proposed way based on the balance model in the article.

1. Introduction

The creation of "ambient intelligence" control systems is determined by a different categorical apparatus of the properties and characteristics inherent both for ergodic Markov systems and for complex systems that do not belong to this class, and, in a particular case, for some dynamical systems, where autochthonous (inherent to them and only to them properties), effecting on the process of information entropy removing from the object of research are occurred.

Current control and processing systems express a posteriori format for controlled effect, i.e., a range of testable hypotheses (experiments) is determined, on the basis of which a specific, unambiguous, particular or general decision is made in a strict range of reference values. However, in some cases, this leads to a decrease of economic or practical effect of system usage in difficult, poorly controlled conditions, i.e., it does not allow ensuring a high response of systems to possible threats directed towards the work stability (the process of life activity) of studied constituents.

The need of new requirements specialization for the development of hardware and software solutions in the economy fields, particularly, in research on improving the efficiency of the agroindustrial complex, is both a necessary and sufficient condition for specifying the range of tasks for new control systems and data processing of different composition in the network -oriented, or, simply speaking, cluster, key. That is for systems in which scalability and the most accurate (balanced) interaction are a priority.

2. Problem statement

Achievement the highest degree of integration of compatible information technologies in the context of using the mathematical apparatus in control systems and decision support, taking into account the fact that certain elements of the created control and information processing systems can be ergodic, i.e. characterizing with special property inherent in the class of dynamical systems, which consists in the fact that in the process of behaviour evolution, almost every state with a certain probability passes near any other state of the system, is a goal as a criterion for justifying the need to develop and use new approaches to the design and operation of digital systems in this study [1].

3. Research questions

The mathematical expectation expressed through empirical experience, that is confirmed both by the super additive effect of using joint and compatible technologies for complex adaptive systems, and by more reliable and fail-safe behaviour for the future is a rationale for the trend for network-oriented or distributed cyber-physical systems. We will review the formalization of the design approach of digital control systems taking into account this circumstance and existing ideas for the analysis of the requirements of control loops [2].

However, it should be mentioned that implementation of the synthesis mechanism of modern decision support systems in large agricultural complexes, commonly, based on the processing of discrete signals and further internetwork influence, is associated with a number of mathematical problems. First of all, the problem of measurement accuracy adherence due to the need for their primary and secondary transformation should be mentioned.

In other words, any analog signal describing the nature of the observed or recorded physical state or behavioural function has additional entropy in the process of discretization and quantization. Said another way, discrete noise, difficult to detect during analysis of big data in multithreaded information processing systems [3].

Of course, these are minor adjustments in the most cases. However, concerning the development trends of modern digital systems, first of all, they come down to the optimization of already existing mechanisms of control, data recording and transformation.

4. Materials and methods

The solution of the problem of full conformance of a discrete signal to a continuous signal is currently not possible. Increasing the bit capacity of the converters, in particular versions, minimizes the problem, however, endows the control system with additional elements that solve the agreement issue. Gaining for the control system the nodes and additional elements that are not typical for it also indirectly effects on the quality of system functioning as a whole. Secondly, there is a rather rigid attachment to hardware and peripherals, that complicates the process of revision, and universalism (the possibility of using different architectural patterns in the formation of data suitable for processing) makes it resistant to the formal approach of systems development, in systems that take into account the different nature of performance, for example, in control systems built on the principle of a central controller (with partial or complete centralization at the global control level) [4,5].

There is a problem of formal approach implementation to the creation of fundamentally new mechanisms for the synthesis of hardware-software control systems through the introduction of neuro-fuzzy algorithms for a complex of control effects in this study. The relevance of the research lies in the availability of hardware and software rationale for improving the existing schematic developments in the subject area of the research. The novelty of the research lies in the formalization of the model for the complete development of the "smart greenhouse" system.

5. Results

To solve the problem, a system analysis was applied: a schematic diagram of the organization of the hardware platform of an intelligent system for a greenhouse was formalized, an algorithmic component was indicated.

A mathematical model of a fuzzy set A as an example of the states of a temperature sensor was used as methods for device operation algorithm implementation (see figure 1 and figure 2).

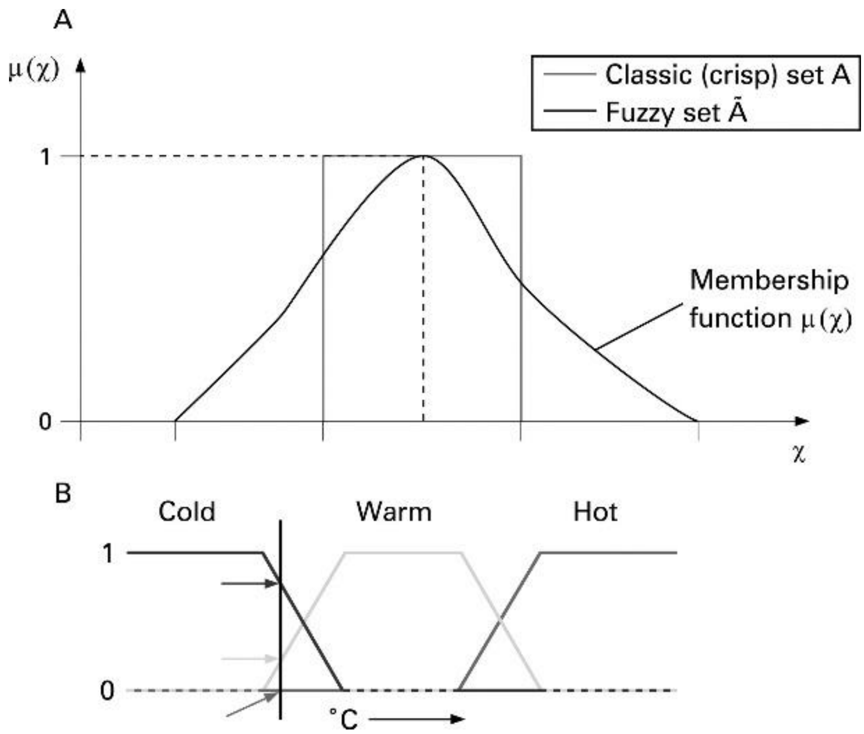

Figure 1. Fuzzy set as an element of analysis in an intelligent control system.

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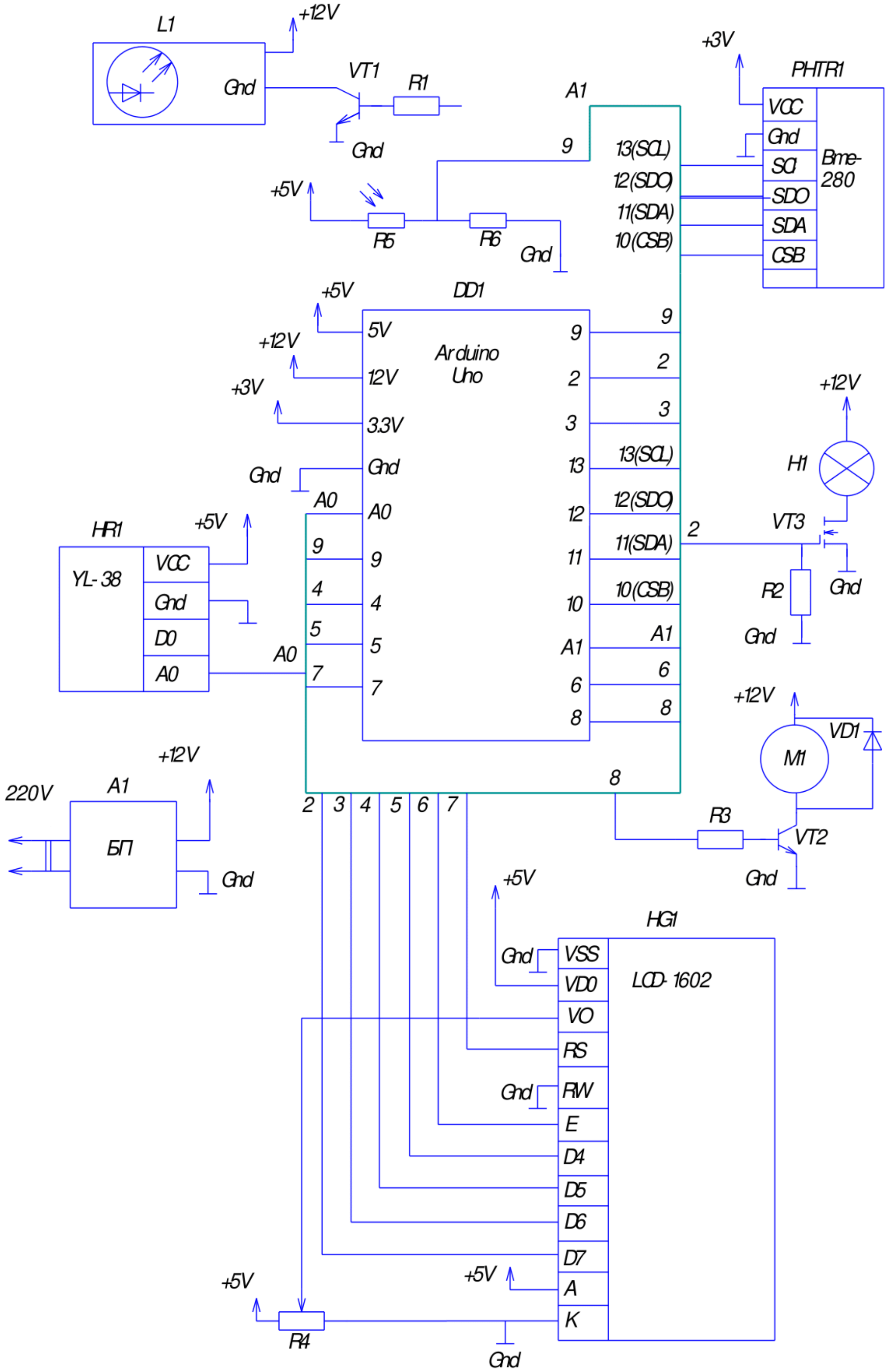

Figure 2. Basic diagram of a developed specialized computer system - an independent node of a distributed system of an intelligent greenhousing.

Under implementation of basic diagram of the hardware platform, structural synthesis, particularly, was used as a solution to the discrete optimization problem. Arduino UNO R3 controller and information output devices: sensors, indicators (LCD-1602) were used as material base.

The analysis of graph theory in solving the structural analysis problems in the context of algorithm theory, in particular, the study of orgypergraphs based on a certain number of nodes (q_n-q_{n+1}) "connections" was based on the device interaction algorithm [6].

6. Findings

The method of organizing the orgypergraph of connections based on a finite automaton (see figure 3) through the calculation of the critical path (which can be considered as a tool for connection monitoring), that is produced with direct and the reverse course of the basic algorithm: moving from the initial to the final event, the early date of event occurrence is calculated (it is indicated next to the event under the decimal line), was used as method for integral functioning of the sensor piping and decision making base creation. Then, moving from the final event to the initial one (reverse move), the late date of the event occurrence (it is indicated above the fractional line) is calculated [7,8].

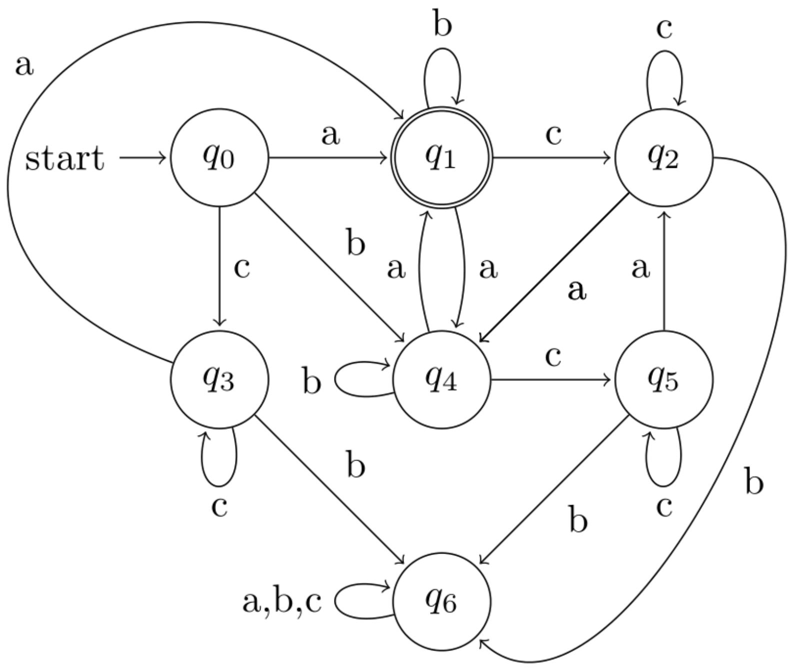

Figure 3. Finite state automation - quantifier of universality of intermodal interaction of peripheral connections (software model).

Review first the procedure of forward path. Define through ES the early start date of all operations coming down from event i. In other words, ESi is also the early date of the i-th event. If i = 0, so ES0 = 0.

In general, we have: ESi = max {ESj + Dij}, e.i., to calculate ESi for some event i, firstly, all ESj of initial events for operations (i, j) included in event j must be determined. Define through LCi the late end of all operations included in event i. For i = n we have LCn = ESn– this is the starting point for the reverse path.

In general, we have: LCi = min {LCjDij}–Dij}, j e.i., to calculate LCi for some event i, firstly, all LCj of final events for operations (i, j) exiting from event i must be determined.

In other words, for critical operations occurring in the internal loop of the control system, the early date of occurrence of event i coincides with the late date of occurrence of the same event, and the same can be said about event j. The difference between the early dates (or late dates) of occurrence of events i, j is equal to the duration of the operation (i, j) [9].

For the external control loop (i.e., for a quantitative assessment from the standpoint of the events under consideration or their predicates), a neuro-fuzzy recurrent apparatus expressed by an estimate of the accuracy of transferring information from the primary converter in pulse-width representation to the memory of the control controller (Takagi-Sugeno-Kanga method) was applied.

In addition to the above, the possibility of implementation of universal approximator for interpretability within the framework of the Mamdani model should be mentioned [10].

7. Discussion

The development of defining efficiency values was a complex and lengthy process. The existing calculations were used in the form of balance models through the created balance models of the results of approximation refinement with a reference control system (without a software algorithm and embedded neuro-fuzzy system; without discrete optimization in structural synthesis on the same controller model - K_f), and with it - K_k (see table 1).

Table 1. Econometric balance model for created decision (in short).

Assessment criteria	Criterion weight	Scores		Competitiveness	
		B_f	B_k	K_f	K_k
Technical criteria for assessment of resource efficiency					
1. Improving of labour efficiency	0.15	5	5	0.75	0.75
2. Operational convenience	0.1	4	5	0.4	0.5
3. Energy efficiency	0.13	5	5	0.65	0.65
4. Reliability	0.1	3	3	0.3	0.3
5. Safety	0.07	4	4	0.28	0.28
6. Dimensions	0.05	4	3	0.2	0.15
7. Possibility to add The various sensors	0.15	4	5	0.6	0.75
Economy criteria for assessment of smart greenhouse effectiveness					
1. Product competitiveness	0.1	4	4	0.4	0.4
2. Price (in thousand dollars)	0.05	3	4	0.15	0.2
3. Expected life (in years)	0.1	4	4	0.4	0.4
Total (coefficient)	1			4.13	4.38

Based on econometric analysis, a higher efficiency coefficient was shown for a system with a neuro-fuzzy algorithm. The efficiency of 4.38 versus 4.13, based on factoring, determined the effectiveness of the created formal control system in the process of its modelling by 6.05%.

8. Conclusion

Therefore, the creation of new control systems is determined by the ergodicity properties, i.e., it requires additional verification of the system elements. The complication of systems due to additional features of control and agreement negatively effects on sustainable control, creates additional risks for functioning. The implementation of joint and compatible methods and patterns of development in the control's synthesis and algorithmization solves the challenge in a much better way, particularly, taking into account discrete minimization, and econometric balance models allow to speak about the success of the project for development of a formal model of a smart greenhouse, and provide opportunities for further research [11,12].

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