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MODELS AND FUZZY MICROCLIMATE CONTROL SYSTEM IN THE STORAGE OF ARCHIVAL DOCUMENTS

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Abstract: *In this article, the main object of research is the creation of appropriate microclimatic conditions to ensure reliable and high-quality storage of archival documents, as well as automatic control of the optimal values of the main parameters of the external and internal environment that directly affect the quality of storage. To control the microclimate, three categories of models for automatic control of these parameters are considered separately in the archives: the "white box", "black box" and "gray box " models. The results of the analysis of the advantages and disadvantages of the considered models are presented. The generalized structure of the microclimate management system is also given, as well as a list of controlled and changeable parameters of the microclimate management system of archives. It is proposed to use the fuzzy logic apparatus to create microclimate control systems in archival repositories, which allows synthesizing stable algorithms for its functioning in conditions of uncertainty. The specific steps that need to be performed when designing and using fuzzy inference systems and which are implemented based on the rules of fuzzy logic are listed. When designing and using fuzzy inference systems, it is necessary to observe certain stages that are implemented based on the rules of fuzzy logic. A generalized algorithm for forming a rule base with a technique for implementing the fuzzy inference procedure is presented. The tasks that need to be solved when designing a fuzzy control system are indicated. A system of automatic temperature control in archival repositories with a fuzzy logic controller is presented.*

Keywords: *microclimate in archival storages, influencing factors in storages, fuzzy control, fuzzy analysis, fuzzy logic, fuzzification, fuzzy regulator, fuzzy logic controller.*

Аннотация: *Ушбу мақолада тадқиқотнинг асосий объекти бўлиб архив ҳужжатларининг ишончли ва сифатли сақланишини таъминлаш учун тегишли микроиқлим шароитларини яратиш, шунингдек сақлаш сифатига бевосита таъсир кўрсатадиган ташқи ва ички муҳитнинг асосий параметрларининг оптимал қийматларини автоматик бошқаришдир ҳисобланади. Архивлардаги микроиқлимни бошқариш учун ушбу параметрларни автоматик бошқаришнинг уч тоифадаги моделлар алоҳида кўриб чиқилган: "оқ қути", "қора қути" ва "кул ранг қути" моделлари. Кўриб чиқилган моделларнинг афзалликлари ва камчиликларини ўрганиш бўйича таҳлил натижалари келтирилган. Шунингдек, микроиқлимни бошқариш тизимининг умумлаштирилган структураси ҳамда архивларнинг микроиқлимини бошқариш тизимининг бошқариладиган ва ўзгартириладиган параметрлар рўйхати тақдим этилган. Архивли сақлаш хоналарида микроиқлимини бошқариш тизимини ишлаб чиқиш учун ноаниқликлар шароитида ишлашининг турғун алгоритмларини синтезлаш имконини берадиган ноаниқ мантиқ аппаратдан фойдаланиш таклиф этилган. Ноаниқ чиқиш тизимларини лойиҳалаш ва ишлатишда бажариладиган ва ноаниқ мантиқ асосида амалга ошириладиган қадамлар санаб ўтилган. Ноаниқ чиқиш тизимларини лойиҳалаш ва ишлатишда ноаниқ мантиқ асосида амалга ошириладиган бир қатор босқичларга риоя қилиш керак. Ноаниқ чиқишпроцедурасини амалга ошириш техникасига эга қоидала базасини шакллантиришнинг умумлаштирилган алгоритми келтирилган. Мантиқий бошқариш тизимини лойиҳалашда ҳал қилиниши керак бўлган вазифалар кўрсатилган. Архивли сақлаш хоналарда ноаниқ мантиқий ростлагичга эга ҳароратни автоматик бошқариш тизими тақдим этилган.*

Таянч сўзлар: *архивли сақлаш хоналаридаги микроиқлим, сақлаш хоналаридаги таъсир қилувчи омиллар, ноаниқ бошқарув, ноаниқ таҳлил, ноаниқ мантиқ, фаззификациялаш, ноаниқ ростлагич, ноаниқ мантиқий ростлагич.*

Аннотация: *В данной статье основным объектом исследования является создание соответствующих микроклиматических условий для обеспечения надежного и качественного хранения архивных документов, а также автоматического контроля оптимальных значений основных параметров внешней и внутренней среды, непосредственно влияющих на качество хранения. Для управления микроклиматом в архивах отдельно рассматриваются три категории моделей для автоматического управления параметрами: модели "белого ящика", "черного ящика" и "серого ящика". Представлены результаты анализа по изучению преимуществ и недостатков рассмотренных моделей. Приведена обобщенная структура системы управления микроклиматом, а также перечень контролируемых и изменяемых параметров системы управления микроклиматом архивов. Предлагается использовать аппарат нечеткой логики при создания систем управления микроклиматом в архивных хранилищах, что позволяет синтезировать устойчивые алгоритмы его функционирования в условиях неопределенности. Перечислены конкретные шаги, которые необходимо выполнить при проектировании и использовании систем нечеткого вывода и которые реализуются на основе правил нечеткой логики. При проектировании и использовании систем нечеткого вывода необходимо соблюдать определенные этапы, которые реализуются на основе правил нечеткой логики. Представлен обобщенный алгоритм формирования базы правил с техникой реализации процедуры нечеткого вывода. Указаны задачи, которые необходимо решить при проектировании системы нечеткого управления. Представлена система автоматического регулирования температуры в архивных хранилищах с контроллером нечеткой логики.*

Ключевые слова: *микроклимат в архивных хранилищах, влияющие факторы в хранилищах, нечеткое управление, нечеткий анализ, нечеткая логика, фаззификация, нечеткий регулятор, контроллер нечеткой логики.*

INTRODUCTION. In archival institutions, the object of close attention is archives, where archival documents are stored, transferred to state storage.

At the same time, a main factor of attention is maintaining optimal values of air parameters and a stable microclimate in the storage.

For productive functioning of the microclimate control system, regular adaptation to unstable requirements of the internal state and the external environment is required with ability to short-term and medium-term prediction of the status of controlled object under the influence of changing environmental factors.

It is possible to predict the state of microclimate by control system using a variety of models capable of detecting changes in the parameters of the external and internal environment. Many models, due to their originality, take into account only a small number of parameters affecting the feeling of comfort, and their use is considered narrowly focused. The most widespread model is PMV model because of its flexibility and complexity, considering a huge number of parameters, (The Predicted Mean Vote) introduced by Ole Fanger[1] and taking into account the influence of microclimate parameters (temperature, humidity, ambient temperature, etc.) [1; 2].

MATERIALS AND METHODS. Traditional management methods ("white box" models) are used constantly at this time due to their relative ease of implementation. However, when these methods are applied, costs associated with maintaining the system and energy consumption are relatively high.

Therefore, nowadays there are more and more so-called "black box" models, which are based on methods of intellectual calculus (fuzzy logic, genetic algorithms, neural networks, etc.) [2].

Most indoor climate control models can be divided into 3 categories (Fig. 1):

1. <u>So-called white box models</u> are based on the physical foundations of thermodynamics, hydrodynamics and gas dynamics. All these models are calculated from the order of complex differential equations, in which numerous coefficients are applied, considering the geometry of the room, thermal characteristics of enclosing structures, insolation, etc. All parameters and coefficients of the models are known, they are either calculated or measured.

Such models are cumbersome, computationally intensive and time consuming. Some types of models take into consideration the susceptibility of documents and humans to thermal and humidity requirements on the principle of a comfort index (PMV / PDD values). And the last type of models is

[1] Prof. P. Ole. Fanger (1934 - 2006) - Danish scientist-engineer, the founder of the modern theory of the microclimate of residential and public buildings. His scientific developments and experimental studies have formed the basis of many international and national regulatory documents and standards, and are also included in all reference books for designers and researchers.
Recourse:. *https://zen.yandex.ru/media/id/5d70c9fbfe289100ad64d6b4/pole-fanger-5d70de4e78125e00af311e8d*

based on electrothermal similarity, which is determined by the identity of the equation of electrical conductivity and the equation of thermal conductivity [2; 3; four].

Black box models - Do not explicitly exploit physical principles when developing a model. Only the input and output parameters of the model are defined. This model is a separate approximation of controlled processes. These models include various models based on artificial neural networks, models based on fuzzy logic and neuro-fuzzy modeling.

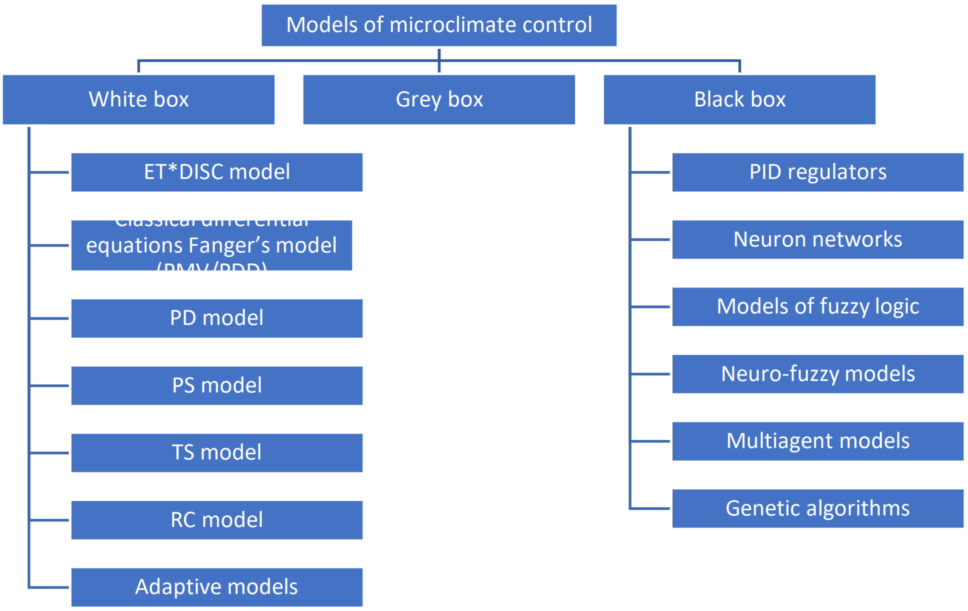

Fig 1. ***Types of microclimate control models in a building.***

Gray box models - Created partly on physical bases. Not all parameters of such a model are known, they cannot be calculated or measured. They are hybrid models, combining the characteristics of the first and second types.

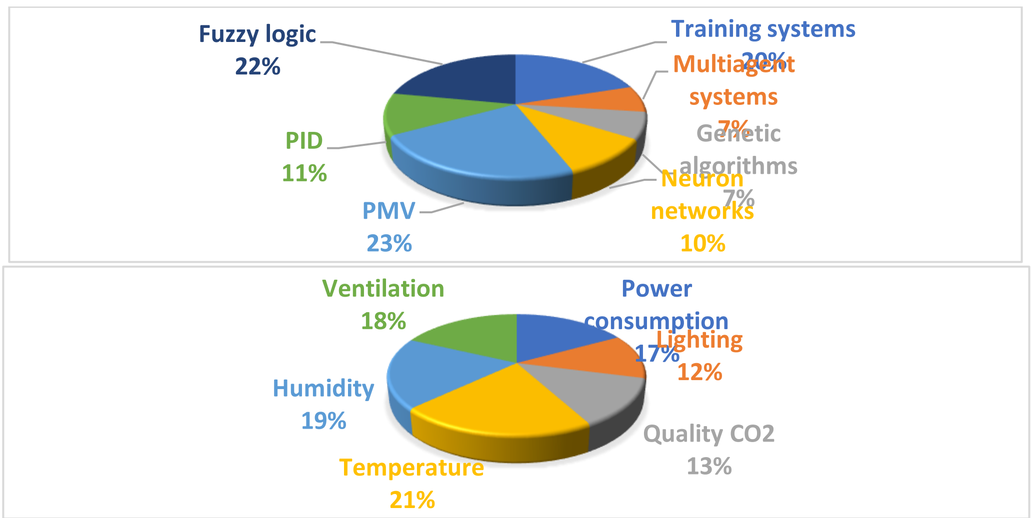

Fig. 2. ***Diagram of the controlled parameters of microclimate.***

A choice of calculation model and dataset may depend on specific tasks and conditions of use. Control in heating, ventilation and air conditioning (HVAC) systems is mainly carried out according to the parameters shown in Fig. 2.

ANALYSIS OF MODELS. Analysis showed that the modeling of the influence of illumination and air pollution (CO2) is taken into account in the models less often than such factors as temperature, humidity, energy consumption [4; 5]. Table 1 provides a brief analysis of the advantages and disadvantages of the considered models.

Table 1.

Analysis of the advantages and disadvantages of microclimate control models

Model	Model advantages	Model disadvantages
Classic differential room heat balance equations	Reliability and validity of the results, the possibility of taking into account additional factors (humidity, etc.)	Complexity and cumbersomeness of calculation, need to identify a large number of parameters
model PMV	Uses a large number of parameters. take metabolic factors into account	Cannot be used when fluctuating many variables. Main parameters must fit in the specified intervals
Models ET-DISC and SET	Models emulate the thermoregulation system of the human body	Do not take into account the habituation of the body, apply the established factors
Models TS, PD, PS	Allows you to discover the comfort conditions for factors affecting the quality of life in a building	Local convenience models, low accuracy, difficult to explain results
Adaptive model	Consider outdoor climate variation, good resistance	Complexity and laboriousness during implementation
Control on base of fuzzy logic	High accuracy, stability, speed, makes it possible to control nonlinear systems with dynamically changing parameters	Complexity of the formation and configuration of the base of fuzzy rules.
Artificial neural network control	BigData processing, good prediction, no preliminary building or climate information required	A large sample is required for high-quality forecasting, training process time
Artificial neural network control	Control of complex nonlinear dynamic objects and synthesis of nonlinear control rules for them	Long learning process

Microclimate of the premises during the changing climatic seasons, depending on the weather and day-night changes, and its parameters can have a detrimental effect on health and well-being. In this regard, the task of automatically maintaining comfortable and safe values of climatic parameters in the premises of buildings becomes urgent. A list of monitored and changeable parameters of the indoor climate control system as shown in Fig. 3.

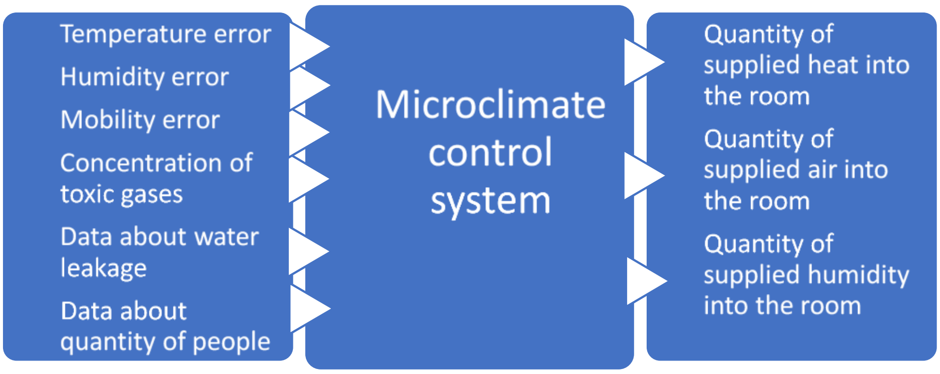

Fig. 3. ***Generalized structure of the microclimate control system.***

To control and change the parameters shown in Fig. 3, appropriate measuring and actuating devices are needed, an approximate layout of which is shown in Fig. four.

Management of such objects is a difficult task in the applied sense, since the construction of a traditional control system requires a formal description of the control object, as well as the refinement of control criteria formed on the basis of a mathematical apparatus operating in quantitative categories.

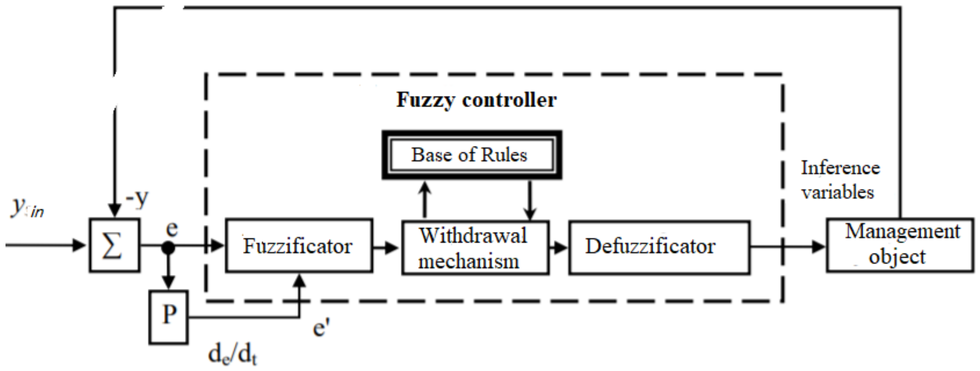

Fig. 4. ***Control system with a fuzzy controller for deviation from the set parameters.***

In practice, such objects are controlled by an operator, using experience, he makes decisions that do not have a rigorous mathematical description. Therefore, the construction of models of procedures, close to the reasoning of a specialist, and their subsequent use in automatic control systems is one of the most important areas of automation of production processes.

When managing processes that do not have an exact mathematical description, fuzzy control systems, as compared to traditional ones, have higher indicators in terms of such criteria as speed, stability, noise immunity and accuracy due to a more adequate description of real environment in which they operate. Therefore, to create microclimate control systems in archival storages, it is proposed to use the apparatus of fuzzy logic, which allows synthesizing stable algorithms for its functioning under conditions of uncertainty (Fig. 4).

Fuzzy control is carried out in two variables: deviation *e* and *de /dt* rate of change of the deviation e and de / dt of the desired output variable y_{in} control object from its actual value y.

Fuzzy inference is a procedure for making conclusions, in the so-called fuzzy form, about the characteristics of control actions on executive devices, formed with the participation of linguistic variables, which are based on information about the current state of the microclimate. When designing and using fuzzy inference systems, specific stages must be observed, which are implemented on the basis of the rules of fuzzy logic (Fig. 5) [6; 7; 8, 11, 12, 13].

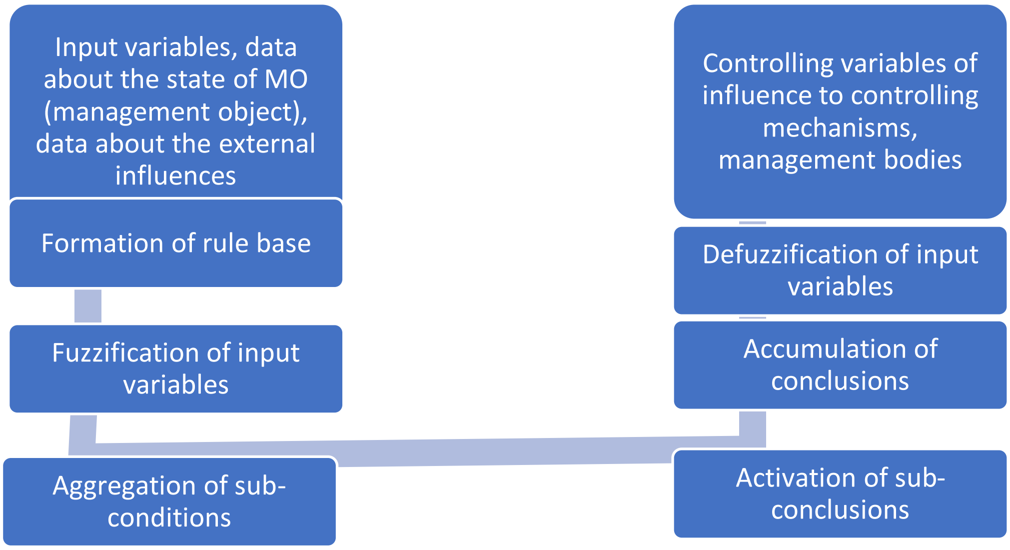

Fig. 5. ***Principle for formation of Fuzzy inference.***

A rule base is a linguistically formalized experience of experts in the form of fuzzy production rules. A rule base includes the experience of experts on methods and algorithms for controlling a control object under conditions of unpredictable disturbances. A specific approach to the implementation of a separate stage of fuzzy inference describes a certain algorithm of actions. Criteria for choosing a certain algorithm for the implementation of fuzzy inference technology are the formulated technical problems.

Generalized algorithm for generating the rule base and the methodology for the implementation of the fuzzy inference procedure is shown in Fig. 6.

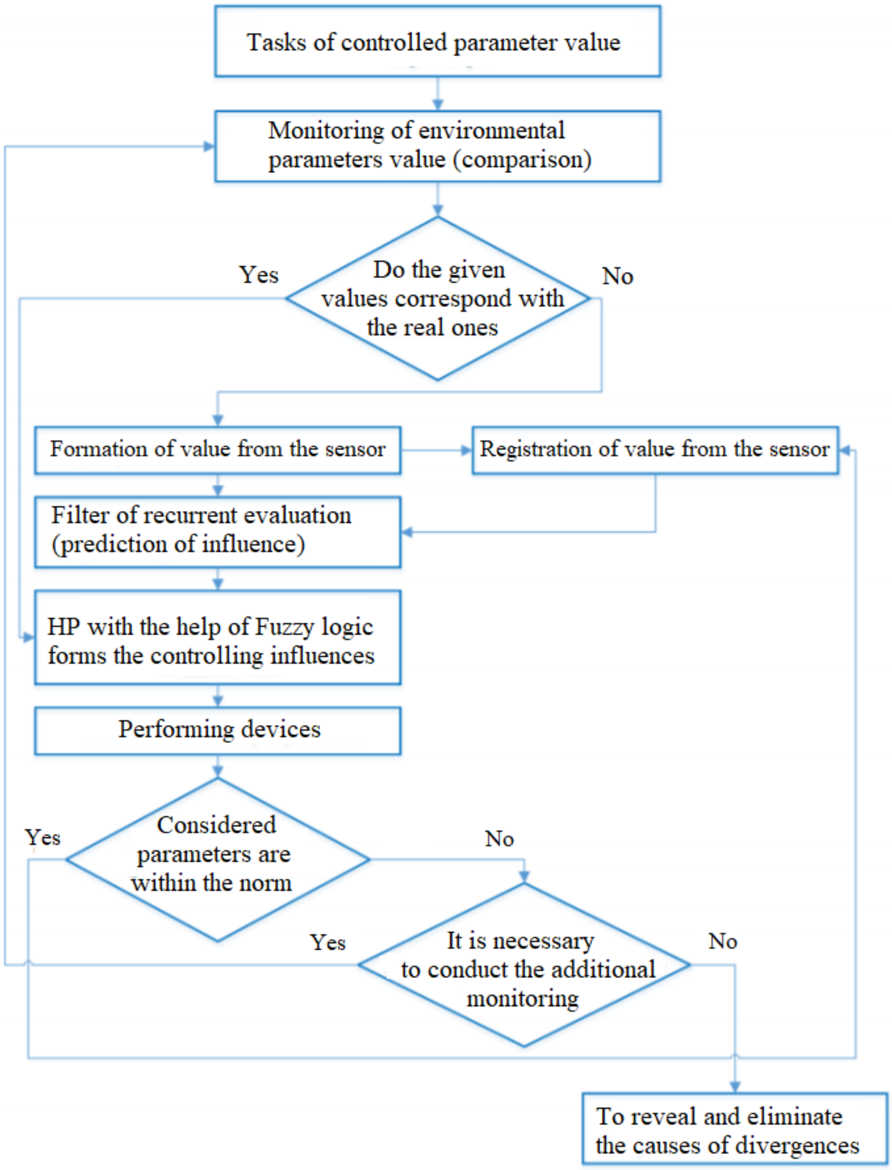

Fig. 6. ***Generalized algorithm for forming the base of rules and methodology for implementing the procedure of fuzzy inference.***

When designing a fuzzy control system, the following problems were solved [9; 10, 14, 15]:

- transition from the numerical value of the input data mismatch estimate to its verbal representation in terms of fuzzy logic (fuzzification);
- formation of a base of rules for a fuzzy regulator based on expert opinions, data from monitoring and procedures for determining control actions, "processing" of a set of linguistic rules, taking into account the adopted preferences and assumptions (through the mechanism of the membership function);

 converting the weighted result back to numerical form (defuzzification).

When solving fuzzification problems in relation to the regulation of the climatic parameters of the management/control object (MO), it is necessary:

 determination of linguistic variables and the composition of their terms in order to determine the current state of the control object, its characteristics, necessary control actions, taking into account internal and external disturbances and specific features of the control object;

 determination of the FP of physical quantities and terms corresponding to linguistic variables, based on the opinions of experts and the conclusions of the forecasting system from the data of observation processing.

Consider a system for automatic temperature control in archive storage with a fuzzy logic controller (FLC) (Fig. 7).

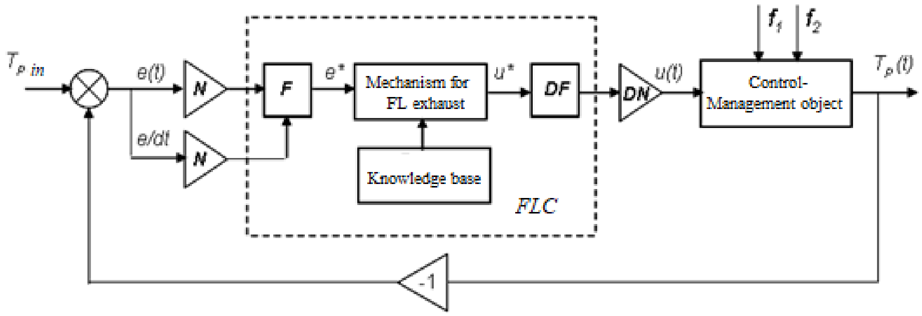

Fig. 7. ***A system for controlling the temperature regime in archival storages with a fuzzy logic controller.***

Fuzzy controller is assigned the task of developing a control action in the range of changes in the dynamic control error and its derivative with respect to its threshold values.

According to this scheme, the input vector of the FLC is fuzzed form $E^* = (e_1^*, e_2^*)$ using a fuzzification block F, then the fuzzy inference is performed in the rule base, resulting in a fuzzy output variable u^*. The translation of the values of the control vector u^* from the fuzzy region to the crisp one u is carried out by the defuzzification unit DF.

Block N is intended for preprocessing the input signal of the regulation error and its derivative:

$$e_i^N = \begin{cases} e_i \ , & |e_i| < e_i^{max}; \\ e_i^{max} sign(e_i), & |e_i| \geq e_i^{max}. \end{cases} \quad (1)$$

Post-processing of the output control signal u is carried out by the DN block, where the denormalization tasks u are solved:

$$u = u_N DN = u_N |u_{max}|, \quad (2)$$

where u_{max} - is maximum value of the control supplied to the object.

As a rule, the NLR knowledge base contains a description of the terms of linguistic variables (LV), which must be defined in advance for each input and output variable.

Conclusion. As a result of the analysis of external factors affecting the high-quality storage of information on paper, as well as the study of microclimate control models in storages, a fuzzy system for controlling the microclimate of archival document storages was proposed.

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