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Multiagent modeling of emotions influence on physiological systems: new concept

Modelowanie wieloagentowe wpływu emocji na układy fizjologiczne: nowa koncepcja

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Abstract

Background: Human physiological system belongs to the most complex systems which elements has been described in detail using different mathematical models. Due to high complexity of elements, the design of whole physiological system depends on the goal of investigations. We would like to concentrate our efforts on emotions influence to physiological systems. That allows to create the model with specific properties that are important to such investigations.
Objectives: Primary aim of the study was to assess correlations – statistical relationships between emotional states and physiological parameters. Secondary aim of this work was an attempt to describe the physiological processes of subsystems - cardiac, respiratory, glucose-insulin system and their integration into a single information environment for the purpose of analysis, modeling, prediction and real-time control for a variety of diagnostic and analysis of emotional states.
Material and methods: The investigated group consisted of 30 healthy people aged 21 years. In this study multilevel multiagent system is involved in investigation of emotion states modeling.
Results: The findings show how relatively simple breathing sensor can be useful both in recording of breath in patients with disorders of consciousness, and also to record the breath in anticipation of certain stimuli in psychological experiments.
Conclusions: Proposed concept can constitute another breakthrough in reliable modeling of human physiologic processes. It introduces multi-agent approach into computational analysis of cardiovascular, respiratory, glucose-insulin system, and provides their integration into a single information environment with coherent information flow and behavior.

Key words: cardiocascular system, respiratory system, insulin, emotions, computer simulation.

Streszczenie

Wprowadzenie: Układ fizjologiczny człowieka należy do najbardziej złożonych systemów, a jego poszczególne elementy zostały szczegółowo opisane za pomocą modeli matematycznych. Z powodu ich dużej złożoności projektowanie większych systemów jest uzależnione od celu badania. Nasze wysiłki chcemy skoncentrować na wpływie emocji na systemy fizjologiczne.
Cel: Celem podstawowym badania była ocena korelacji – powiązań statystycznych – między stanami emocjonalnymi a parametrami fizjologicznymi. Celem wtórnym badania była próba opisu procesów fizjologicznych za pomocą podsystemów: krążenia, oddechowego i wydzielania insuliny, jak również ich integracji w jedno środowisko informacyjne przydatne do analizy, modelowania, predykcji oraz kontroli w czasie rzeczywistym stanów emocjonalnych w celach diagnostycznych i naukowo-badawczych.
Materiał i metody: Badaną grupę stanowiło 30 zdrowych osób w wieku 21 lat. W badaniu wielopoziomowy system wieloagentowy wykorzystano do śledzenia stanów emocjonalnych człowieka.

Wyniki: Wyniki badania pokazują, jak stosunkowo prosty czujnik oddechu może być użyteczny zarówno do rejestrowania oddechu u pacjentów z zaburzeniami świadomości, jak również rejestracji oddechu w celu predykcji konkretnego bodźca w eksperymentach psychologicznych.
Wnioski: Proponowana koncepcja może stanowić kolejny postęp w wiarygodnym modelowaniu procesów fizjologicznych człowieka. Wprowadza ona modelowanie wieloagentowe do obliczeniowej analizy układów: sercowo-naczyniowego, oddechowego oraz ‘glukoza-insulina’ oraz zapewnia ich integrację w jednolite środowisko informacyjne ze spójnym przepływam informacji oraz zachowaniem.

Słowa kluczowe: układ sercowo-naczyniowy, układ oddechowy, insulina, emocje, symulacja komputerowa.

Modern information technologies allow us to study complex interconnected systems. Human physiological system belongs to such complex systems and has been described in detail using different mathematical models [1].

There are several information systems like Hummod [2]), Pneuma [3], etc., that are widely used to simulate the autoregulation of physiological system, namely the cardiovascular and respiratory systems under conditions a variety of physiological and pharmacological interventions.

The advantage of such systems is the use of detailed mathematical models implemented in the internal algorithms. The disadvantage is the inability or significant difficulty to expansion, additions and modifications of such models, as well as their use for other studies, for instance, studies of emotional reactions and the corresponding changes in the physiological system. Application of agent-based approach [4] allow us to solve aforementioned problems to create open systems with possibility of further modifications and development of such systems. The investigations on creating multiagent systems in physiology are known [5], but their use is also limited.

Another problem constitutes the integration of well-known models with a diagnostic equipment in real-time environment, allowing to obtain diagnostic parameters from various sensors that observe the components of the physiological system and on-line evaluation of the human condition. There is lack of standarization and integration of data flow into one information environment with coherent information flow and stimuli/behavior imaging and synchronization.

The relationship between psychology (emotional feelings, for instance) and physiology is surveyed and well known [6]. It is important to describe a relationship of components of physiological systems in emotions investigations. Several techniques have been developed for emotional state assessment so far. There is evidence for connection between emotions and body reactions. EEG results showed that during perception of emotional stimuli the LPP ("late positive potential") amplitudes were higher for the unpleasant and pleasant pictures in comparison to neutral pictures. Additionally, responses for negative stimuli were higher [7]. Skin conductance measurement is often used in biofeedback systems for better control of emotions, especially in stressful situations [8]. We can observe changes in eye movements as well, but diagnosis and control are not easy, because body reactions are not specific enough [9]. Influence of emotions on respiratory response has been proven [10]. Diagnose and control of emotional state through respiratory feedback can be useful for therapy, biofeedback trening and human-computer communication. Combination of few sensor can lead to better results [11].

Thus primary aim of the study was to assess correlations – statistical relationships between emotional states and physiological parameters. Secondary aim of this work was an attempt to describe the physiological processes of subsystems - cardiac, respiratory, glucose-insulin system and their integration into a single information environment for the purpose of analysis, modeling, prediction and real-time control for a variety of diagnostic and analysis of emotional states. In this paper we would like to show our new concept of aforementioned system, describe early results, and discuss directions of its further development.

Multi-agent approach is relatively rarely applied within systems modeling distributed control of the human body function. They are regarded as useful to reflect natural mechanism too complicated for direct modeling, influenced by too many parameters, or in situations, where parameters are difficult to assess experimentally, including cancer therapy influencing immune system [12], drug release optimization [13], or simulations of microbiological systems: cells, molecules [14]. Such solutions may be useful in many predictive systems, providing deeper understanding of the complex mechanisms inside human body. We are aware, that context adaptive behaviour of the body systems emerges from many, both local (many levels form cell-cell and cell-molecule) and global (within all body, its environment, drugs, etc.) interactions. Different compartments of the human body have their built-in behaviour (rules of operation, own knowledge) and they may be perceived as elementary agents or groups of agents. Such approach can provide useful information for external diagnostic or therapeutic devices, including assessment of the impact of selected parameters and their combinations, reasons of failures of previous or current therapeutic interventions and improper responses of the organism. Thus research on aforementioned topics may significantly contribute to development of artificial organs, micro- and nanomedical technologies. There is clear need for a new type (or even whole family) of such system that can be used in relative simple systems.

One of the main advantages of agent approach is using knowledge base as an element of agent. Knowledge bases have been widely used in medicine as separate information technologies. The multi-agent systems allow to solve difficult and complex problems using expert knowledge, which can be modified by a self-learning. One of the areas of such applications is medicine. This branch of science concerned with the resolution of diagnostic problems and the nature of healing, using a large knowledge base and a wide spectrum of cause-effect relationships between different states of health of the patient and the interaction between treatments [15, 16, 17, 18] to be taken together for treating a patient. This rather specific branch of science, based on expert knowledge - here the doctor is a good candidate for the application of artificial intelligence. These systems may in addition to proper diagnosis disease, proper diagnosis, carry out the treatment process in order to overcome the disease, or decrease the complications of the disease. As examples of medical problems is also worth mentioning: patient databases, search medical knowledge, specific support medical decisions, evaluate the effectiveness of treatment, etc. At the same time recent work on the use of multi-agent systems focuses on eliminating the drawbacks of previous medical systems, which showed a limited degree of autonomy, limited interaction with the environment and resource less knowledge in order to solve the problem. New research directions are concentrated, e.g. on the treatment of the disease in an advanced stage by many doctors at the same time. Works [17, 19, 20, 21]. In many works can be found examples these systems in order to improve the quality of patient treatment. Use in / on systems can be found in every element of the health system from dispatching ambulances, which provides advice to the hospital, the patient should fail to treatment has been chosen for the disease, and ending on the analysis of the effects of the treatment given therapy or medication data.

One of the first expert systems for medical applications was MYCIN system, which was developed in the 70's of last century. This system has been designed to become a medical diagnostic tool. It was based on uncertain or incomplete knowledge, so that he is considered an expert system model. The structure consisted of elements such as knowledge base, knowledge base patient (containing a description of the case), the module consultation (allowing for questions, drawing conclusions and generating advice), explaining the module (which allows to show justification generated advice), the module accumulation of knowledge (allowed the accumulation of knowledge and thus modifying or expanding the knowledge base). Another example is the use of multi-agent system such as described in the work [22].

The authors of this publication presents the application of multi-agent environment to monitor the health of people unable to move on their own. In a suitable health monitoring uses a range of physical quantities that can be quite easily monitored without the need for expensive and cumbersome equipment. Monitoring subjected to such size as body temperature, skin conductivity, heart rate, electrocardiogram, respiration, and others. Additionally, it is possible to attach a GPS navigation module in the case where a patient requires a wheelchair. The system enables real-time monitoring of the patient and, if appropriate, shall take appropriate actions to protect the health of the patient. Possible actions are dependent on the state of the monitored person - suggestions may be the case, if the patient indicates fatigue or malaise, and, in the case of extremely bad readings, remote medical emergencies, and / or predefined alert on the state of the patient. As can be seen, multi-agent systems, expert systems have found a wide field of applications in the field of knowledge that is medicine from the patient-hospital contact after the functionality related to saving lives and all kinds of convalescence.

There are also systems that globally are designed to provide medical information for the sick and the healthy. They will be listed here two projects. The first system, called PALLIASYS, is used to collect information about patients palliative care, facilitate access to the data of both patients and physicians, to assist in preparing calendars visits and monitor the status of these patients. The system will send a report on the state of the patients via SMS, Web browser or an e-mail message, in the case of patients at home or, generally speaking, outside the hospital. This system will allow you to receive On-demand by the patient or physician, or in situations threatening the health of the patient, the system automatically notify your doctor or caring for the patient. The second system is a system AgentCities - a project to provide any medical information, in a flexible, easy and secure, every resident of the city or tourist. The intention of this system is also giving the possibility to determine the best route from the point of becoming a man to the nearest hospital, taking into account what kind of doctor is needed. The system is also possible the reservation visits to the doctor, who will be able to accept a person who will remain in the city during its residence in the city - not to extend such leave or before the scheduled departure.

We offer position [23] which is a review of the literature which deals with the application of multi-agent systems in medicine. The authors of this publication describe interesting references associated with the use of multi-agent platforms for the protection of health and life.

Material and Methods

The investigated group consisted of 30 healthy people aged 21 years. In this study multilevel multiagent system is involved in investigation of emotion states modeling. Each agent on appropriate level answers on properties, behavior and communication with other agents on this level (Fig. 1.).

Figures

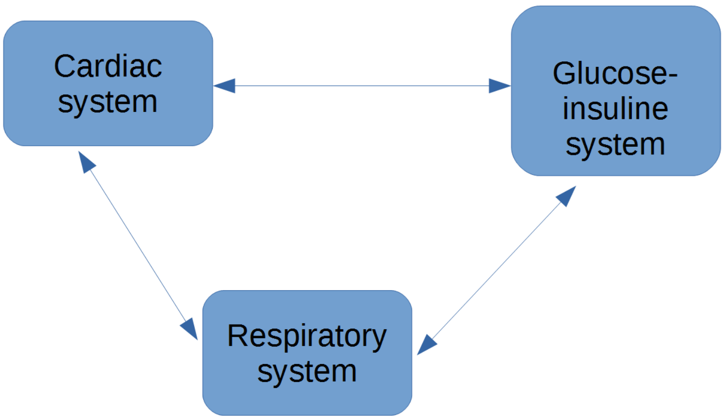

Fig. 1. Highest level of multiagent system.

To refine the definition of agents we use detail agents. For instance, respiratory system can be represents as in Fig. 2.

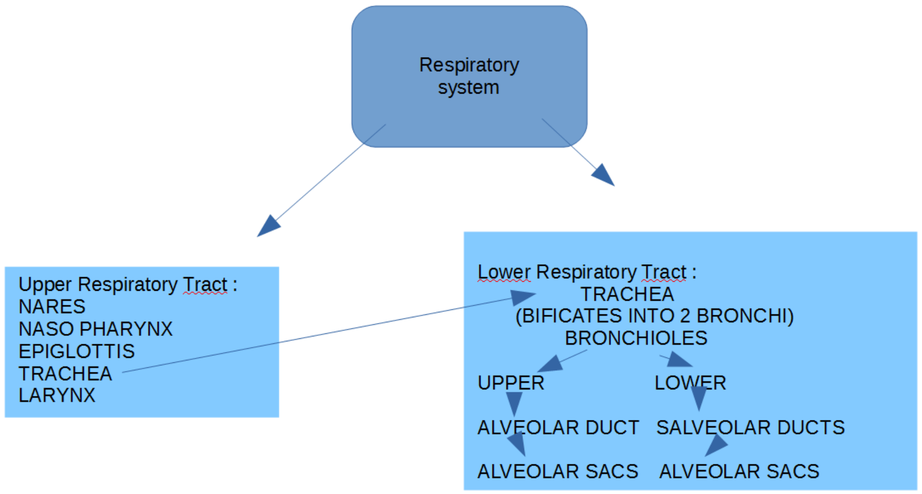

Fig. 2. Basic structure of respiratory system.

Figure 3 illustrates the properties and interaction within glucose-insuline system.

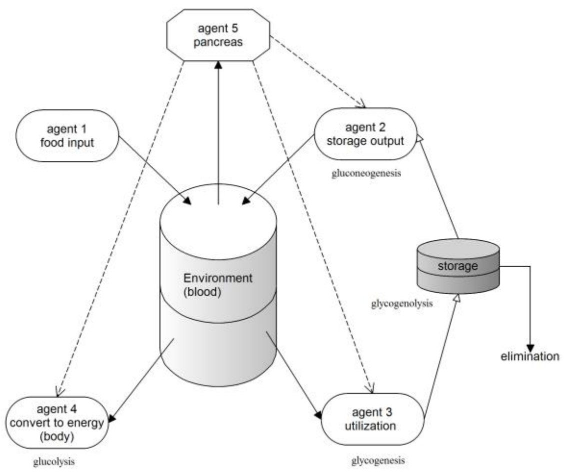

Fig. 3. Basic structure of glucose-insuline system.

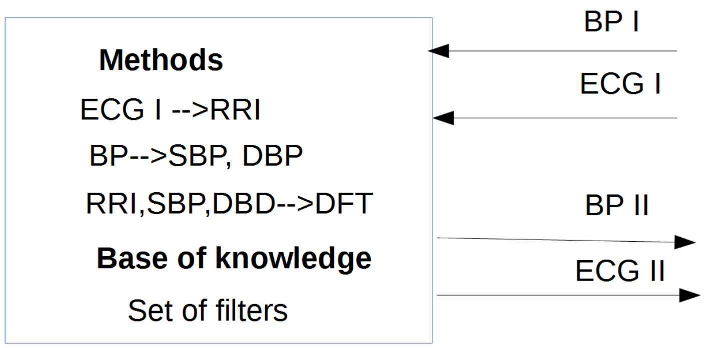

Fig. 4. Agent "Cardiovascular System". Symbols: BP- blood pressure, SBP – systolic blood pressure, DBP – diastolic blood pressure, ECG – electrocardiogram, RRI – distance between R crincle in ECG and DFT – discrete Fourere transorm.

The cardiovascular system with its control system can also be describe in term of agend approach. We known that this system is subject to precise reflexes regulation acting on many structural levels of organizm and time scale.

In terms of short-term regulation of cardiovascular system in physiological condition, the most important are those receptors that are sensitive on pressure, called baroreceptors. There are also chemical receptors, called chemoreceptors. They collect another kind of signal - level of oxygen and carbon dioxide in the blood. The chemoreceptors also have influence on control of cardiovascular system, but this is a less important than influences coming from the baroreceptors.

The baroreceptors are located in the aortic arch and carotid sinuses. They are stretch receptors and respond to the pressure induced stretching of the blood vessel. From literature we can find that there are also another receptors in the the cardiovascular system that have also contribution to control this system as reflexes. They can be also add to agent model as another kind of sensors of agent. This implies that a model will reflect physiological activity more realistic way. From the point of view of process modeling is better when the model is as simple as it is possible. Taking into account that generally pressure is fundamental factor that is under regulation, we can assume, that we have a average respons of the agent on pressure. This respons is define in empirical parameters located in agent methods and memory. If blood pressure increases it stimulate these two kind baroreceptors. Signals from this receptors are transmitted via afferent nerve pathways to the nucleus solitarius in the medullary cardiovascular center. This center comprises two functional areas: pressor center and depressor center. The depressor center under signal having its origin in the activity of baroreceptor, is then activated. The sympathetic activity decrease. We observe decreases contractility, heart rate, and vascular tone. This causes that pressure of blood and finaly baroreceptors activity decrease. When this low pressure is obtain then reflex from baroreceptors is inhibited. As a consecuences of this we observe growing activity of sympathetic nerves. The response on this growing activity is increasing contractility, heart rate and vascular tone. This gives increase blood pressure [24].

From agent point of view important is reaction of control center on input signal. We can obtain this reaction measuring Heart Rate Variability of a heart. This method use discrete fourier transform of RRI signal, that is obtain from ECG as period ot time between consecutive R wave. In that convention base of knowledge is the set of filters acting on RRI signal in frequency domain. The same procedure we can use to systolic and diastolic blood presure. The stage of considered system is define as ratio between power in low frequency and high frequency. As a output of the system we obtain new set of signals in time [25, 26, 27, 28].

To describe the elements of the systems we add to the tradition definition of an agent, namely, fields, methods and knowledge base the mathematic models of appropriate elements. The structure of model-based agents [29] is shown in fig. 5.

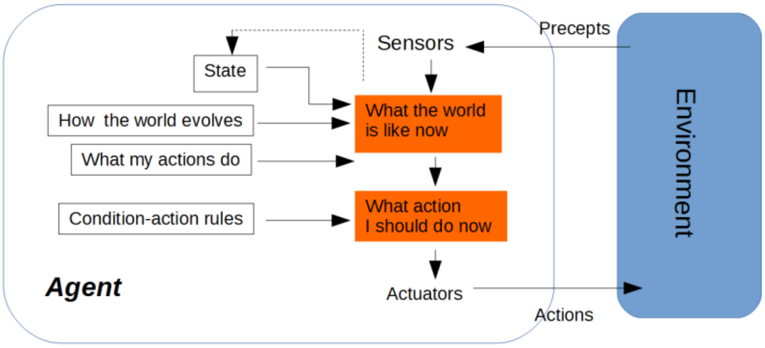

Fig. 5. Model-based agent.

Besides we consider the possibilities of agent's communication with different sensors. For instance, the agent of respiratory system uses flow-rate sensor to get information about breathing process (Fig.6.).

Fig. 6. SFM300 flow-rate sensor.

Our solution in the area of the respiratory agent is based on experiments with the own solution, based on SFM3000 breath sensor and dedicated software for computational data analysis (fractal dimension, nonlinear dynamical models, neural models, and neuronal dynamics [30, 31] and imaging. This sensor measures the flow rate of air, oxygen and other non-aggressive gases, providing about 2000 points per second with 12-bit resolution.

Study protocol encompassed sets of standarized images playing role of specified stimulation. Researchers use standardized images databases eliciting required emotional states. Each image was earlier validated, identified by the Nencki Affective Picutre System (NAPS) arousal and valence scores, as well as by a self-reported emotional label (associating a subjective positive or negative emotion). The relationship between emotional feelings and physiologic data sets was surveyed.

The study was accepted by the appropriate Bioethical Committee. The subjects gave written informed consent before entering the study, in accordance with the recommendations of the Bioethical Committee, acting on the rules of good Clinical Practice and the Helsinki Declaration.

Results

Aforementioned breathing sensor can be useful both in recording of breath in patients with disorders of consciousness, and also to record the breath in anticipation of certain stimuli in psychological experiments. There is possible to induce selected emotional states using standardized photos – The Nęcki Affective Picture System – NAPS [32], and such photos-associated change of the emotional state can be detected [10].

The activity of agent is based on external goals of modeling. For instance, we design the multi-agent model for estimation of user's emotional states, and active control of emotions based on standardized photos. In this case the parameters of breathing signals are used to design of the model of prediction of the emotion state.

We use such parameters like frequency and amplitude of breathing signal.

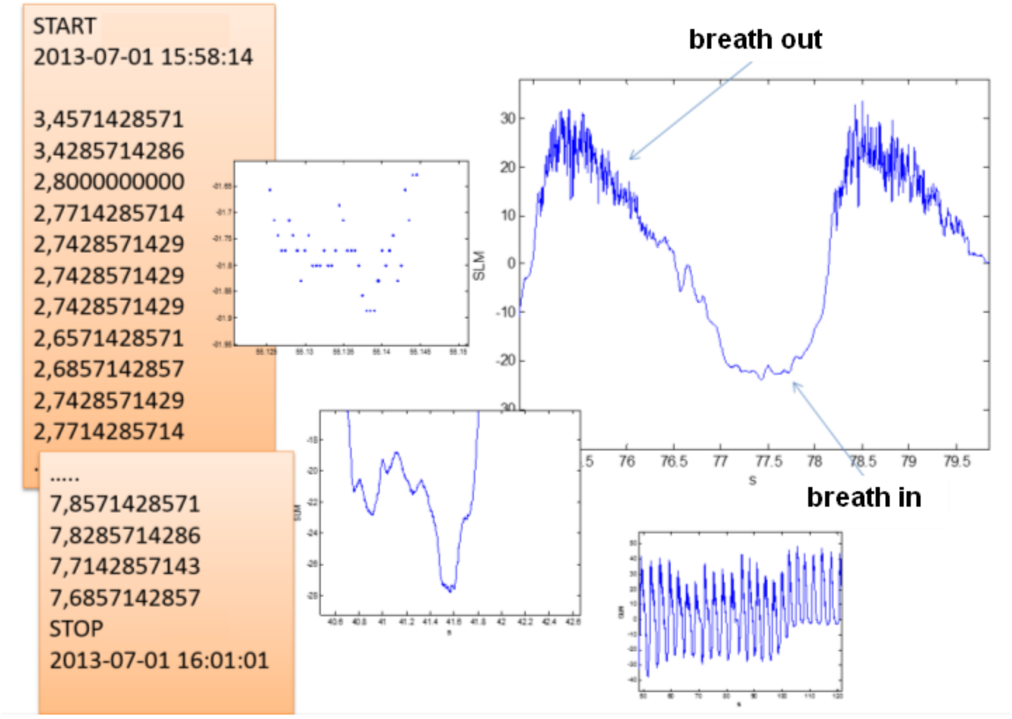

Fig. 7. Breathing signal.

For prediction of the breathing parameters we use the fuzzy recurrent dynamical model

[illegible]

[illegible]

where L_i are linguistic variables, m is a space dimension and τ is a time delay of breathing model. We could classify such rules by linguistic variable L_m (with the same antecedents).

Discussion

Preliminary results of research on our approach allows for deriving computational rules for automated classification of selected breathing patterns according to the characteristics of selected emotions. Such results may be useful in a reverse task: using breathing signals to automatic estimation of users's emotional states, and active control of emotions (e.g. in pilots, air-traffic controllers, people with depression, etc.). Such approach to affective computing can open novel possibilities, combining analysis of breathing patterns with appropriate sets of images (during further research: voice, music – where available). The simplest way to do this by agent is to find rule from destination class rules with antecedent that contains linguistic variables $L_2,\ldots,L_{m-1},L_m$ and predict next state L_{m+1}.

Limitations of the curent stage of research allow for describe our results as preliminary. Unfortunately there is lack of other research on aforementioned area allowing for compartmental study. Current further studies focus on development of our concept toward both increased biological relevance and better computational tools for analysis and visualization of such complex multi-agent systems operation. Application of fuzzy logic rules may be important directions for further research. We hope our work presented here will inspire another research teams. There is need for interdisciplinary cooperation in the aforementioned area.

Conclusions

Proposed concept can constitute another breaklthroug in reliable modeling of human physiologic precesses. It introduces multi-agent approach into computational analysis of cardiac, respiratory, glucose-insulin system, and provides their integration into a single information environment with coherent information flow and behaviour [33, 34, 35].

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