Development of intellectual fuzzy logic and neural network technologies for industrial and power facilities, transport and robotics

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Moscow Power Engineering Institute (Technical University), MPEI

- founded in 1930;

- one of the largest technical universities of Russia in the field of energetic, electrical engineering, radio electronics, computer engineering;

- National research university of Russia since 2010;

- 71 departments, 550 educational laboratories and 130 research laboratories;

- more than 15,000 students from 68 countries, more than 1000 postgraduate students.

Current projects

- Development of intellectual system for forecasting emergencies at potentially dangerous industrial and power facilities

(based on neural network technologies for recognition of trends acquired by measurement of technical condition parameters of important industrial and power facilities)

- Development of intellectual system for steam demand management at CHP power stations with common main pipe

(based on fuzzy logic technologies)

- Development of intellectual automated control system for traffic management in large cities

(fuzzy logic technologies and comparison of intellectual methods)

- Development of technologies for remote reconfiguration of mobile robot intelligence on the basis of field programmable gate arrays

(fuzzy logic technologies with possibility of remote reconfiguration of the fuzzy model in the process of its operation)

Intellectual system for forecasting emergencies at potentially dangerous industrial and power facilities

- About 700 accidents occur at industrial facilities worldwide annually.

- Average losses from a single accident amount to $37 million.

- Available intellectual systems of early alert are not totally reliable on the entire scope of possible situations.

- Prospective systems based on unique and expensive equipment can not be widely implemented.

- An affordable intellectual technology for continuous automatic monitoring and early emergency alert is required.

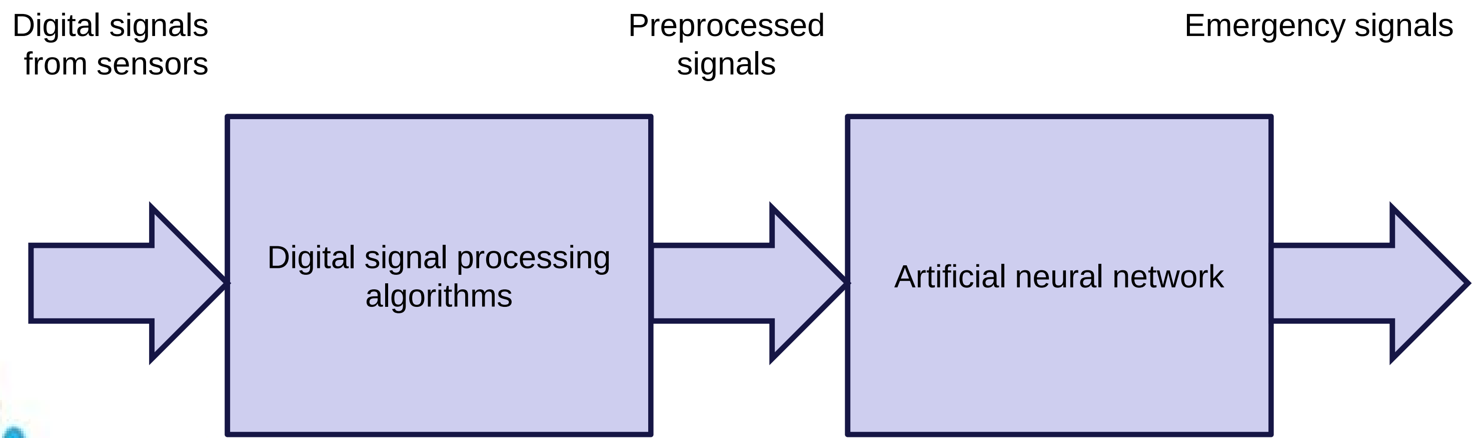
- A solution based on neural networks is proposed.

System’s operation

- System’s basis consists of intellectual classifiers of the monitored object’s technical condition, which perform continuously and automatically.

- The initial data for classifier's performance includes trends of a number of predefined parameters, acquired by continuous measuring of technical condition of the objects under monitoring (temperature, pressure, etc.)

- Signals about pre-emergency and emergency states of the monitored facility are generated by an artificial neural network automatically on the basis of acquired trends.

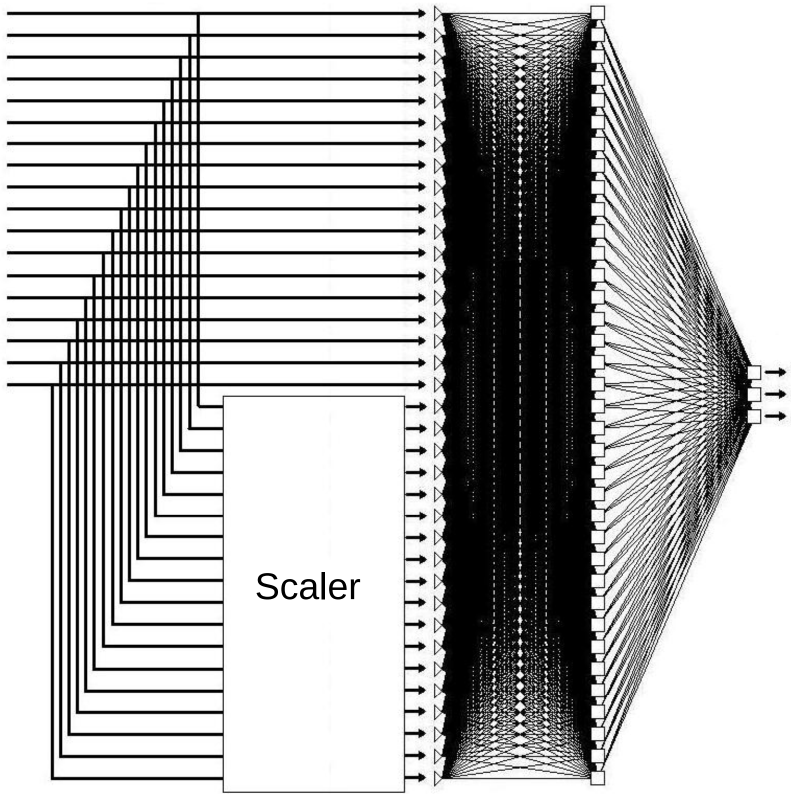


Intellectual classifier

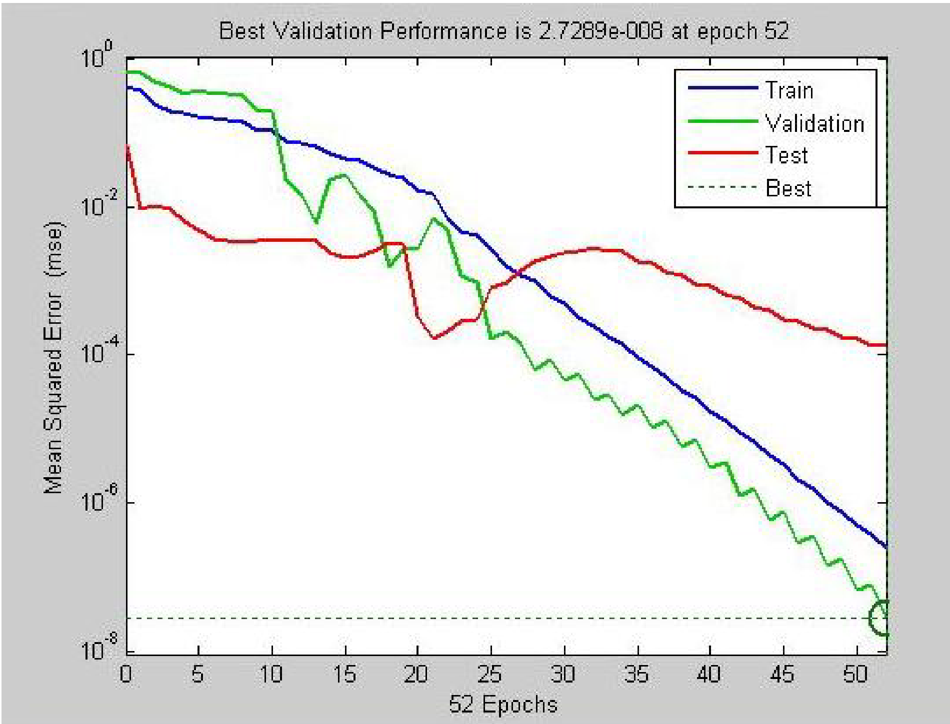
- Interpretation of observed parameters' trends is carried out by an artificial neural network

- Artificial neural network type is a multilayer perceptron with finite number of layers and single-type neurons with non-linear sigmoid activation functions

- Learning paradigm is a backpropagation algorithm on the basis of a given set of learning samples and Levenberg-Marquardt optimization criterion



Neural network performance



Relation between number of iterations and mean squared error of artificial neural network training, validation and test runs

Advantages and market applications

Main advantages:

- Availability
- Reliability
- Adaptability
- Continuous control
- Automatic performance

Fields of usage:

Any potentially dangerous objects, including oil and gas production and transportation facilities, power plants, power lines etc.

The system may be implemented as an addition to existing measuring-calculating systems for monitoring of technical condition of industrial equipment, which are currently not automated and use heuristic methods for evaluation of overall condition of the monitored object.

Intellectual system for steam demand management at CHP power stations with common main pipe

Main purpose – effective and reliable functioning of power supply systems for group consumers with multiple power sources connected into a network.

Type of fuzzy logic algorithm – Takagi-Sugeno fuzzy model.

Advantages:

- lower gas consumption at thermal power stations with cross-linkage, advantage in comparison to conventional control systems up to 6-8%

- lower mean normal consumption of nominal energy resource for CHP power stations, advantage in comparison to conventional control systems up to 3-4 g per 1 kWh

- accounting for persistence of processes and equipment

Implementation and market applications

Possible implementation of the technology – development of automated technological process control systems for thermal power stations with common main pipe.

The technology may be used for upgrade of existing power stations as well as by construction of new facilities.

Intellectual automated control system for traffic management in large cities

Main purpose – improvement of traffic management in large cities, minimization of traffic jams, development of algorithms and software for multifunctional devices for fuzzy traffic management systems.

Negative social and economic consequences of traffic jams:

- Time loss

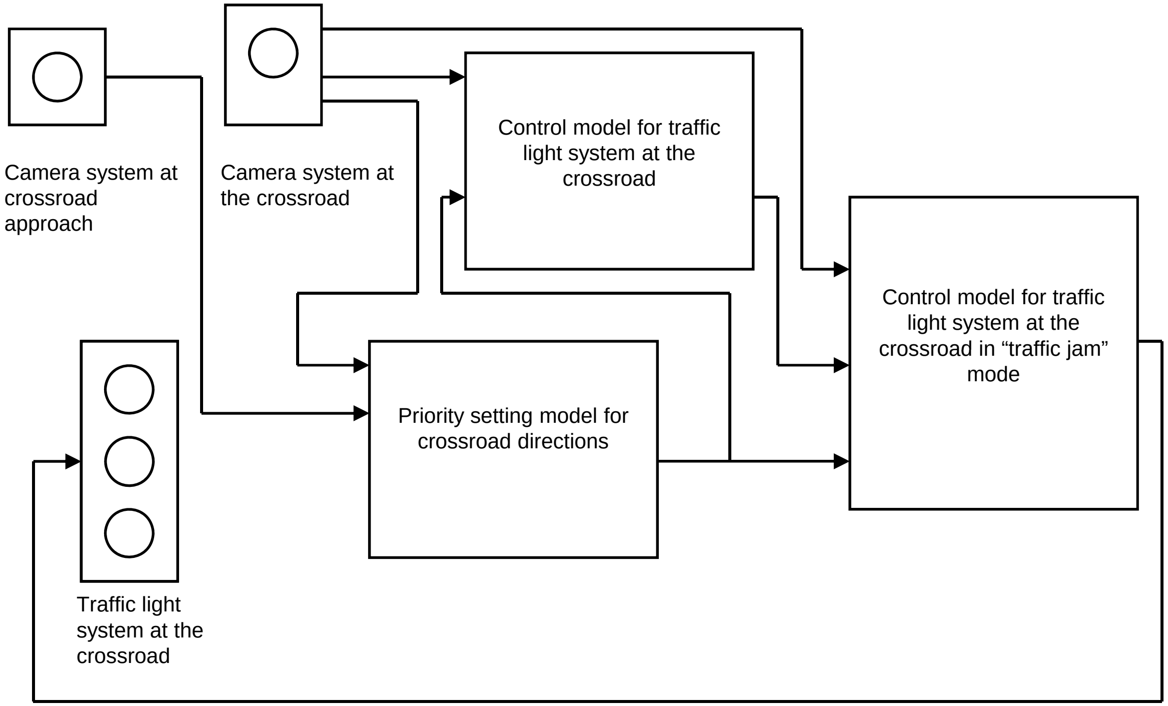
- Larger transportation costs

- Additional tear and wear of vehicles

- Stress and irritation of drivers and passengers

- Environment pollution

Architecture of multifunctional devices for traffic management in large cities

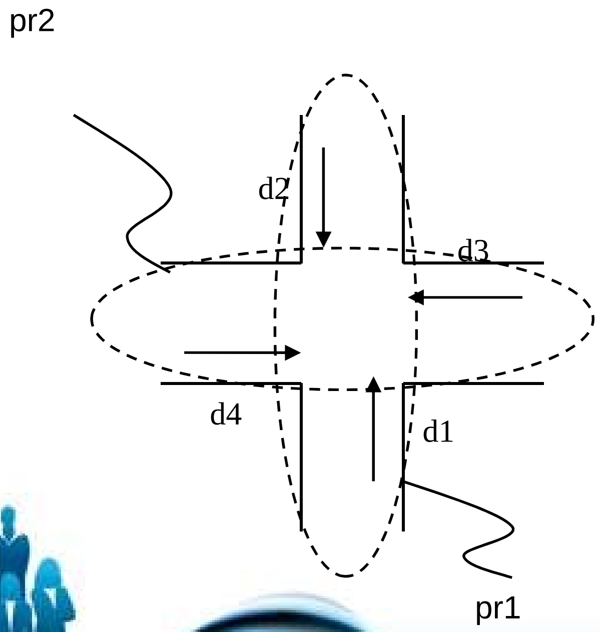


Defining feature – interaction of 3 models based on fuzzy logic algorithms

Parameters of fuzzy control model for traffic light system at the crossroad

Input parameters: number of vehicles moving in each direction (d1–d4) and priorities of directions (pr1–pr2).

Output parameters: duration of green traffic lights (time1 and time2).

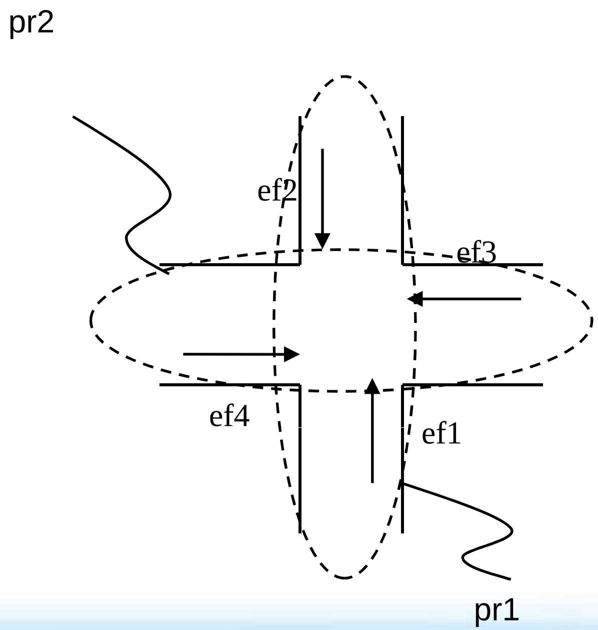


Criterion of traffic light efficiency (ef1–ef4):

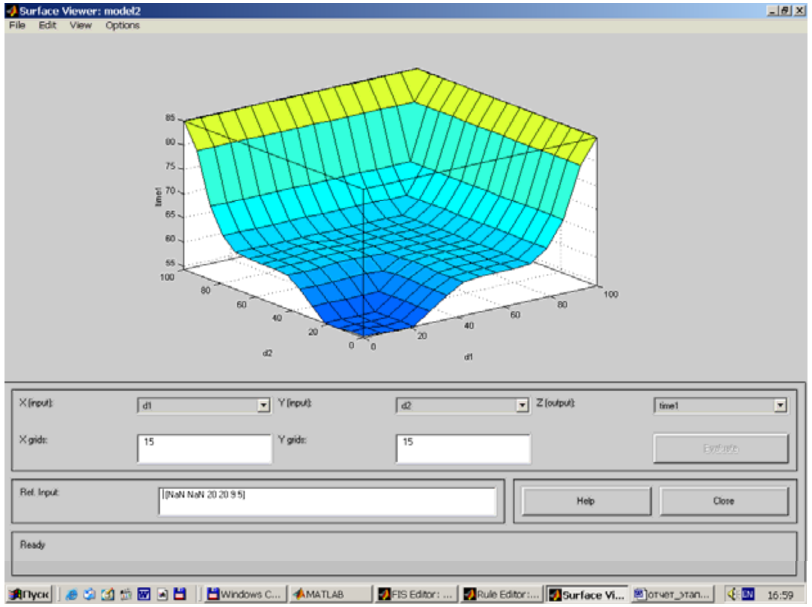
ef = K/N,

K – number of vehicles passing the crossroad during green traffic light;

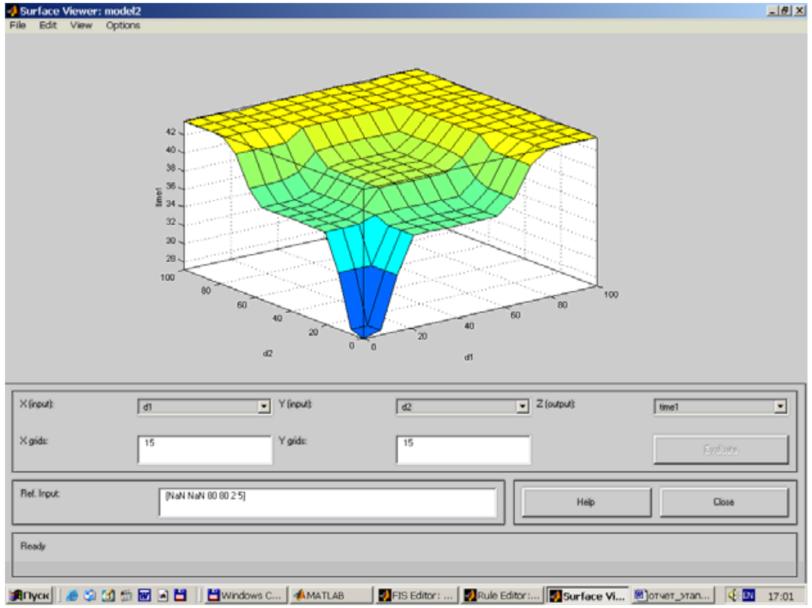
N – overall number of vehicles in a given direction.



Modeling results



Modeling results for green traffic light duration
for high priority direction and light cross traffic



Modeling results for green traffic light duration
for low priority direction and heavy cross traffic

Technologies for remote reconfiguration of mobile robot intelligence on the basis of field programmable gate arrays

Today autonomous control systems (ACS) implemented with the usage of artificial intelligence and fuzzy logic are becoming ever more common in various fields of industry.

In practice quite frequent are the cases when due to changes of working conditions it becomes necessary to modify intellectual algorithms of ACS. In some cases when ACS is used in remote or hard-to-reach terrain (ocean depth, in space, etc.) immediate access to it can take a lot of time, be very costly or at all impossible.

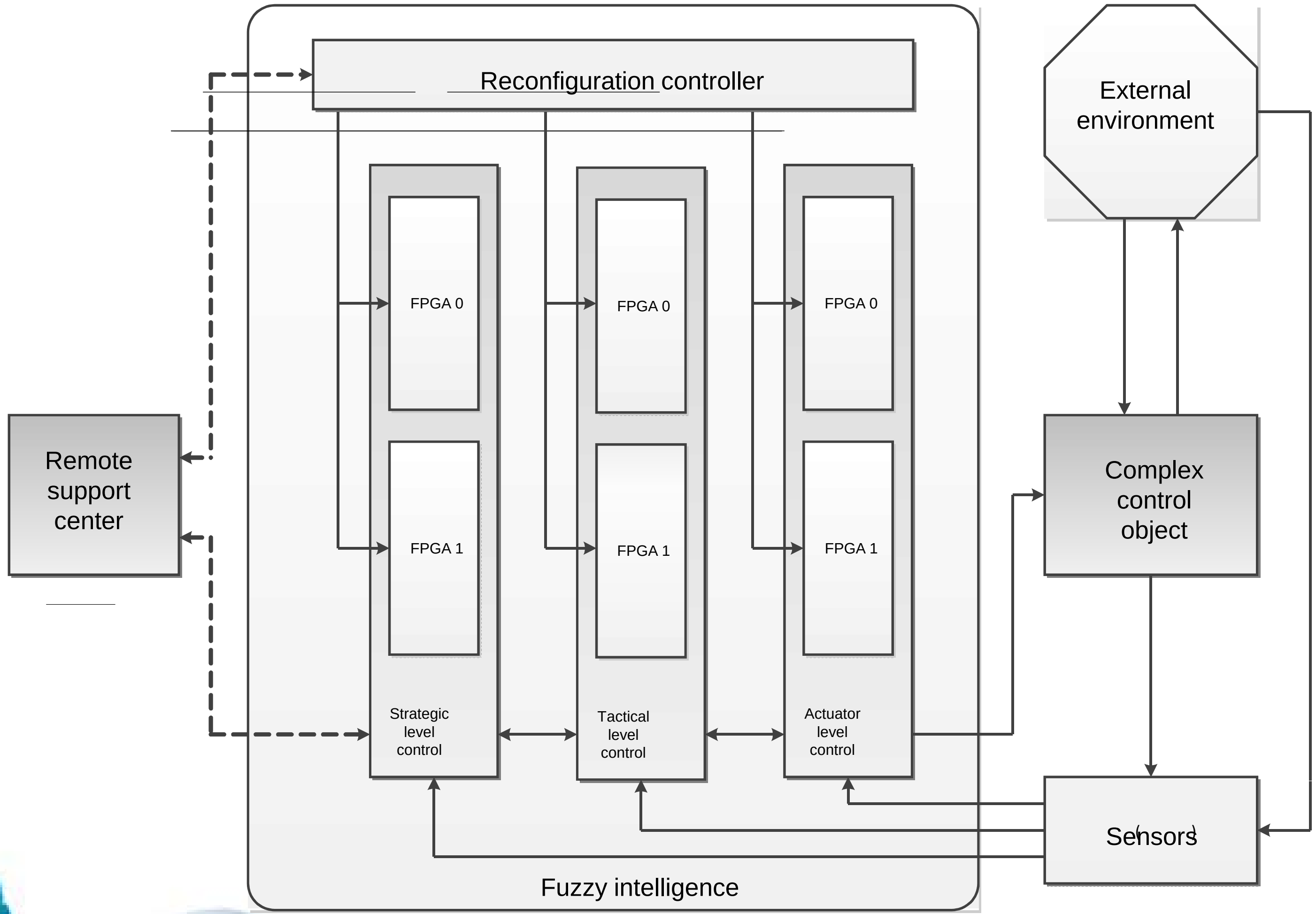
Remote modification of intelligence will allow to solve this problem and to raise efficiency of usage of ACS.

Prospective element basis for intellectual ACS are field-programmable gate arrays (FPGA). Inner structure of modern FPGA can be modified in real time which allows creation of devices with fast reconfiguration of executable functions on their basis.

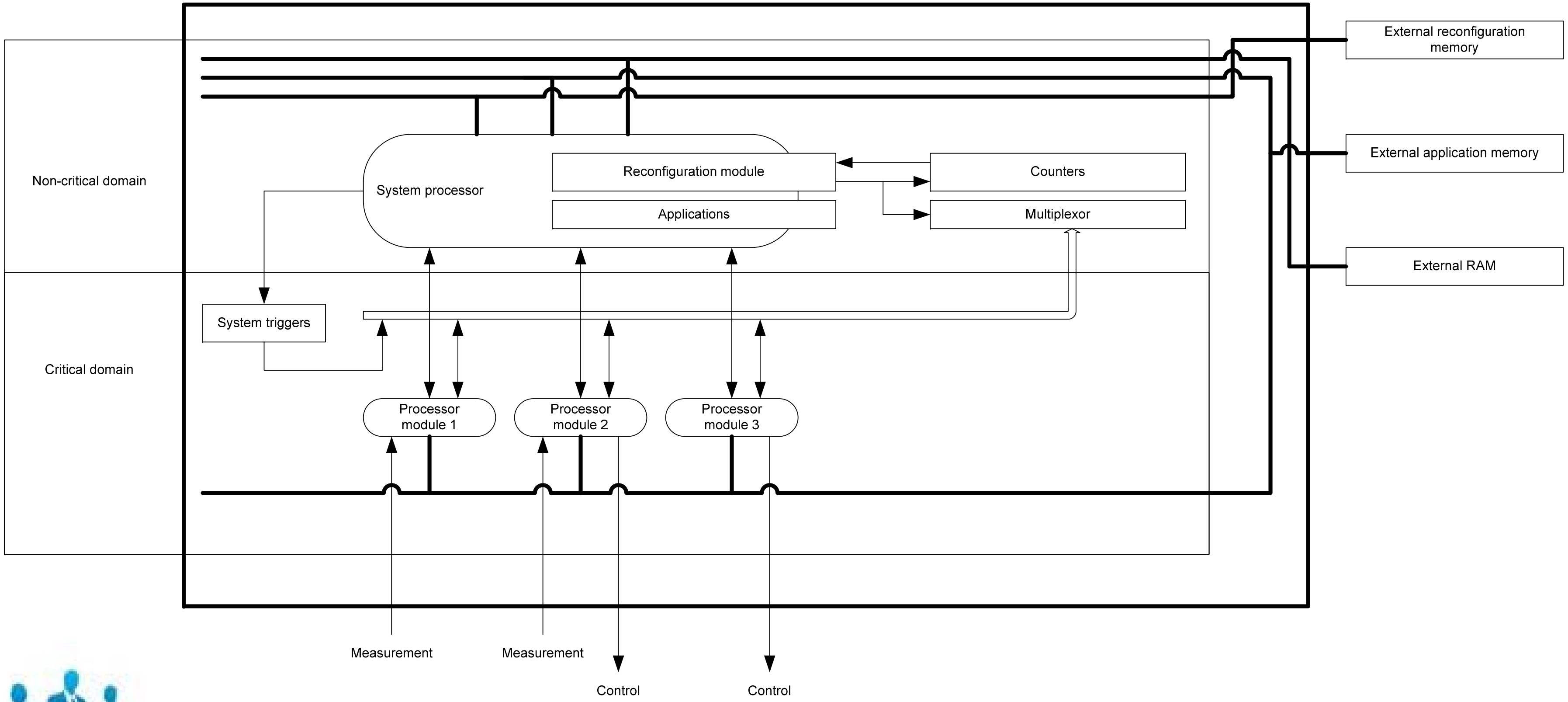
Remote modification of fuzzy intelligence of ACS implemented on the basis of reconfigurable computing technologies and FPGA is estimated to increase the life cycle of autonomous control systems in certain applications by 15-20 %.

In the framework of the developed method reliability of FPGA reconfiguration process is reached with the help of multidomain architecture.

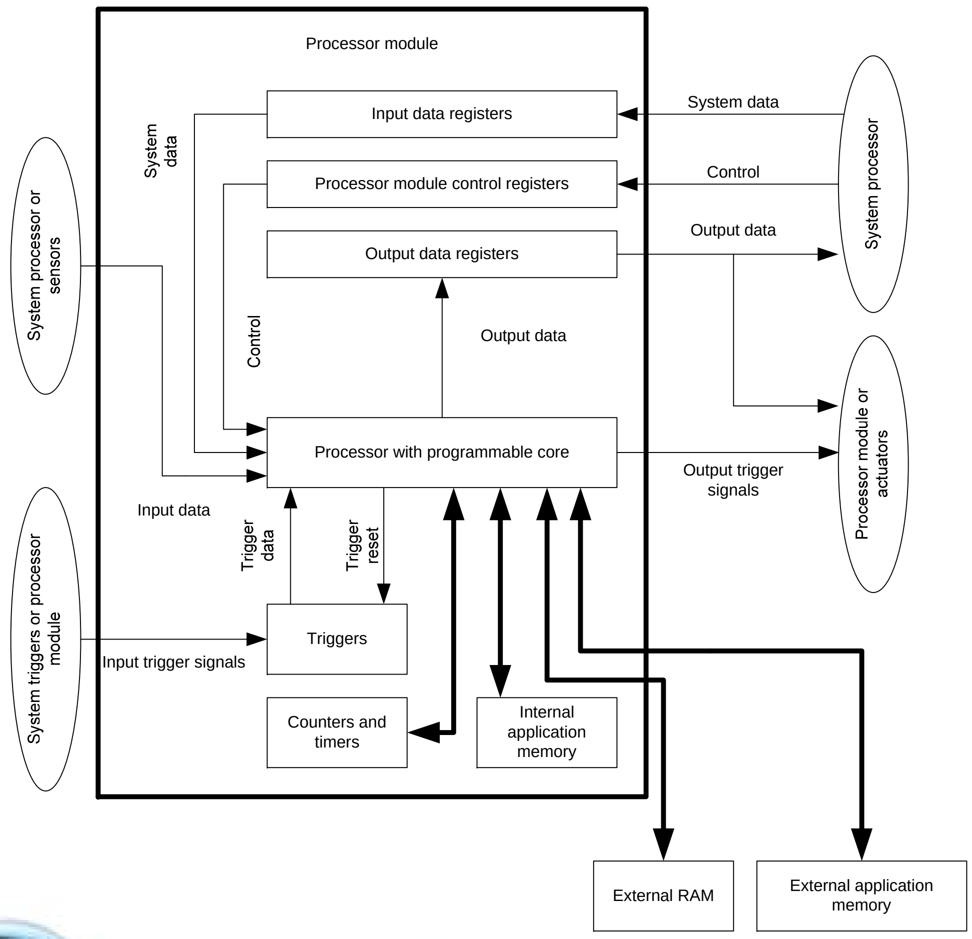
System’s operation



System's layout



Reconfigurable processor module



Advantages

- Automatic remote reconfiguration of mobile robot intelligence without the need of human operator activity.

- Reconfiguration of mobile robot intelligence without physical exchange of its hardware.

- Simplifying the process of technological upgrade of autonomous devices and equipment.

- Integration of latest intellectual technologies into mobile robot intelligence through its remote modification in real time.

- Providing an additional level of freedom in the task of optimization of costs of mobile robots, their power consumption, productivity, reliability and design time.

Moscow Power Engineering Institute invites potential partners to participate in joint R&D projects and industrial implementation of the developed technologies

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