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CONCEPT OF DECISION SUPPORT SYSTEM FOR INR RAS LINAC BEAM TUNING

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Abstract

During the last decade instruments of machine learning are gaining popularity in accelerator control systems. One of these instruments is decision support system (DSS) that is already successfully used in other fields of science. In this article a motivation for implementation of such system for INR RAS linac tuning is discussed. Concept of developed DSS is presented. Changes in INR RAS linac data acquisition system essential for future DSS operation are proposed.

INTRODUCTION

Machine learning (ML) techniques are widespread in modern science, industry and everyday life. ML popularity is explained in its ability to surpass human in such tasks as forecasting based on analysis of huge amount of data, online recommendation based on personal preferences or object recognition, like faces or voices.

Majority of these tasks can be applicated to accelerator physics. For example, now ML algorithms are used to detect faulty BPMs and make orbit correction of the beam at LHC [1] or to determine critical situation at the neutrino beam facility at J-PARC [2].

One of the ML instruments is a decision support system (DSS). These are systems that support decision making activities. DSSs are already successfully used in medicine and help doctors make a diagnosis considering patient's medical history and many other factors.

In theory DSS could be used to help beam operators during accelerator run. However, this system is not used for accelerators. The reason is that new accelerator complexes have precise computer models of the beamline and other ML instruments are used like already mentioned orbit correction system at LHC.

At INR RAS linac the issue of personnel is acute. For the last decade amount of beam operators reduced by half and training of new operators can take years. Moreover, INR linac was constructed almost 30 years ago and does not have a precise model.

In that case DSS, which can help beam operator to analyze the current situation and make decisions to solve problems that arise during accelerator run, is a suitable system that would be extremely helpful for routine operation. Such system would decrease problem solving time and prevent personnel from making wrong decisions during accelerator tuning.

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INR LINAC DSS CONCEPT

INR linac DSS is designed as a Bayesian network. It is based on the Bayes' theorem and can be presented as a directed acyclic graph. Its advantage is ability to insert knowledge in it by designing its structure and to determine probabilistic transition values based on the knowledge base. This type of networks is already used for accelerator tuning at LCLS [3].

Input to the DSS will be problems that arise during accelerator operation and output will be ranged list of the most probable solutions for the problems. System has 6 layers. With the increase of a layer number operator need to provide more information about the problem. To work with outer layers information to the inner layer should also be provided. Layered structure of the DSS allows its step-by-step realization. Connection between layers is shown in Fig. 1. Concept scheme of the DSS is shown in Fig. 2.

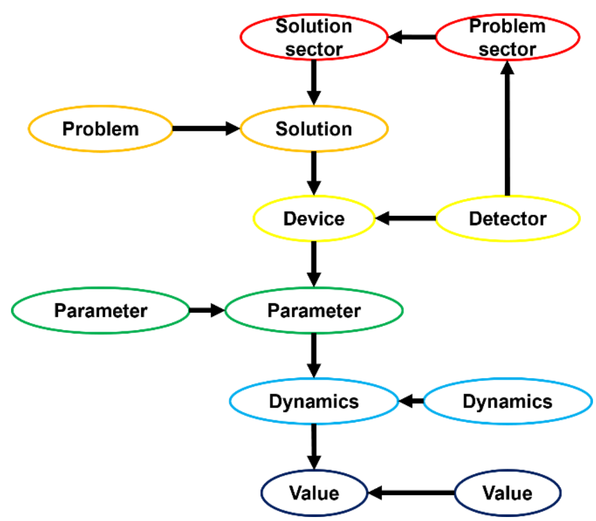

Figure 1: INR linac DSS connections scheme.

Layer 1 is a sector-sector layer. INR linac is divided into 5 sectors and multipurpose research complex (MPC), which is counted as sixth sector. and problem can be attributed to the sector where it occurred. Output of this layer is a sector number where problem solution is located. If problem occurs simultaneously at several sectors DSS should at first provide solution to the sector with the least number.

Layer 2 is a parameter-system layer. Input of this layer is a beam parameter which value is unsatisfactory. As an output DSS should provide type of the linac system, which parameters should be changed to solve the problem. If there are several problems at once, system should solve them in a prescribed way.

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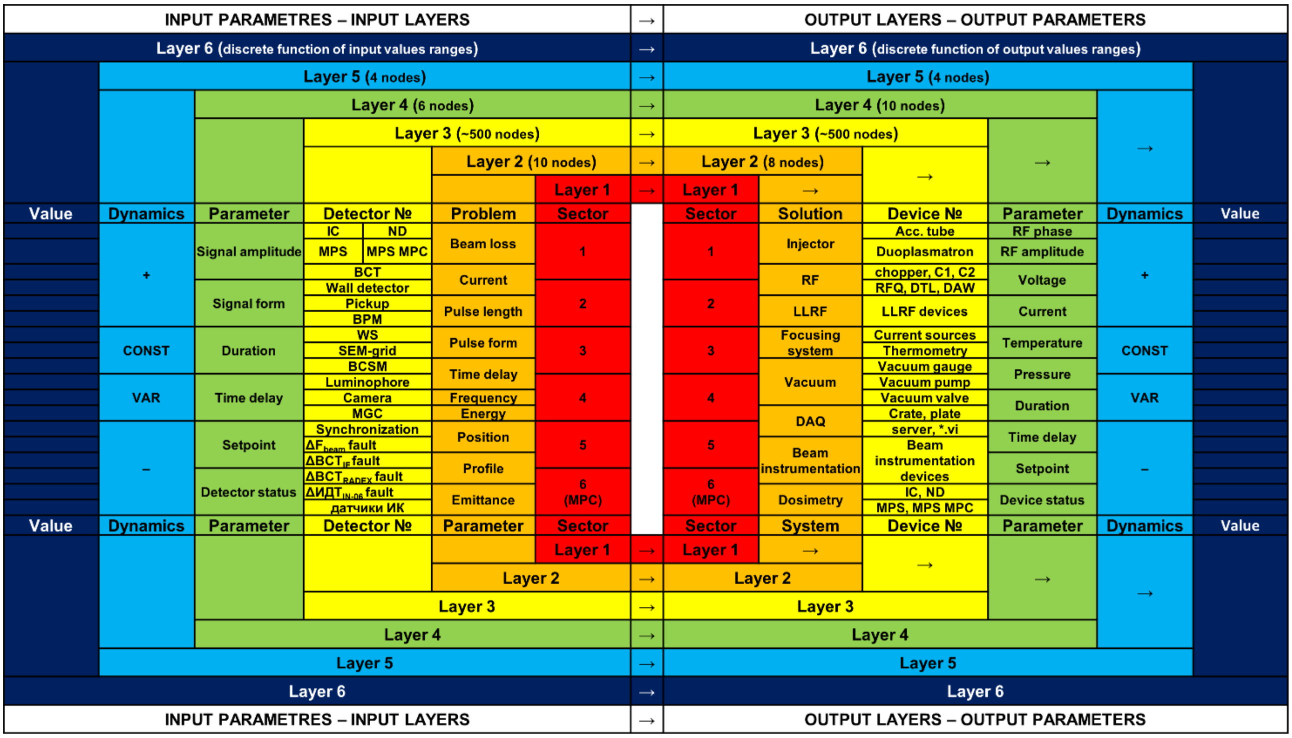

Figure 2: INR linac DSS concept scheme.

Layer 3 is a detector-device layer. Here operator should name the detector on which problem can be seen and number of that detector. To operate with layer 3, operator does not need to fill in sector information because type and number of the detector is enough to determine sector of the accelerator. Output of this layer is a device, which parameters should be changed.

Layer 4 is a parameter-parameter layer. Input is a parameter of the detector, which value is abnormal. Output is a parameter of the device which should be changed.

Layer 5 is a dynamics-dynamics layer. Input is a dynamic characteristic of a parameter which is not satisfactory to the operator. Output is a required dynamic of a device parameter, which should solve the problem.

Layer 6 is a value-value layer. At this layer DSS is planned to operate in an automatic mode. It should monitor all signals acquired by INR linac data acquisition (DAQ) system and check values of these signals. Output is range of values for the device that should be changed.

For the first two layers knowledge base of the DSS can be filled manually. A special option was added to INR linac electronic logbook to acquire data for knowledge base. From layer 3 data analysis should be done in an automatic mode. Data for the analysis should be taken from DAQ system, which should be upgraded.

Change in parameters is chosen as a criterion for a problem and a solution. When some of the beam parameters values become unsatisfactory, data analysis software will start to monitor accelerator systems parameters values. When beam parameters return to satisfactory level, system will record accelerator systems parameters that changed.

INR LINAC DAQ SYSTEM

The INR linac DAQ system is a software package based on the LabVIEW. It consists of DAQ sources running on servers, DAQ receivers running on client computers and DAQ storage server. Data is transmitted via the protocol UDP MultiCast (Fig. 3) [4].

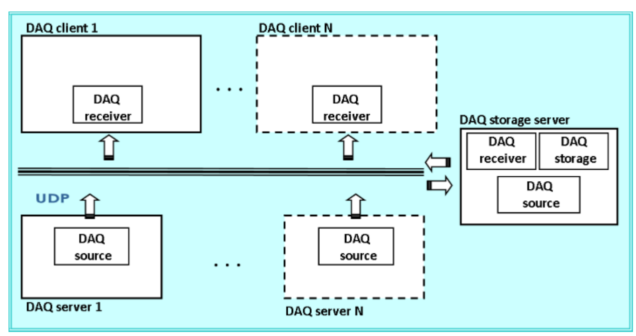

Figure 3: INR linac DAQ system scheme.

DAQ storage server performs data storage and operates as a DAQ source, because it collects data from some servers, which operates on TCP/IP protocol and is not yet implemented into UDP MultiCast system. The period of cyclic polling on the servers is 1...5 seconds. To reduce the network load, not all parameters are transmitted after each survey, but only the changed ones (delta encoding). Once a minute, the entire volume of data is transmitted from the source servers. The data is transmitted in XML format.

Currently, DAQ system consists of 17 source servers,13 servers that transfer data via DAQ storage server and 18 servers, which are not implemented into the system.

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DAQ UPGRADE

Currently, INR linac DAQ system stores not all acquired data. System stores information about accelerator systems, such as RF, focusing, vacuum and water-cooling systems and information about accelerator alarms. Beam parameters such as current, position, profiles and beam loss are not stored automatically. For DSS data analysis software all beam parameters should be stored. Also new signals, which are constantly added for accelerator control, should be added to DAQ system.

Examples of DAQ upgrade during last year are presented below. It concerns new diagnostics and upgrade of already existing software. Software for tomographic reconstruction of transverse phase portrait in online mode is shown in Fig. 4.

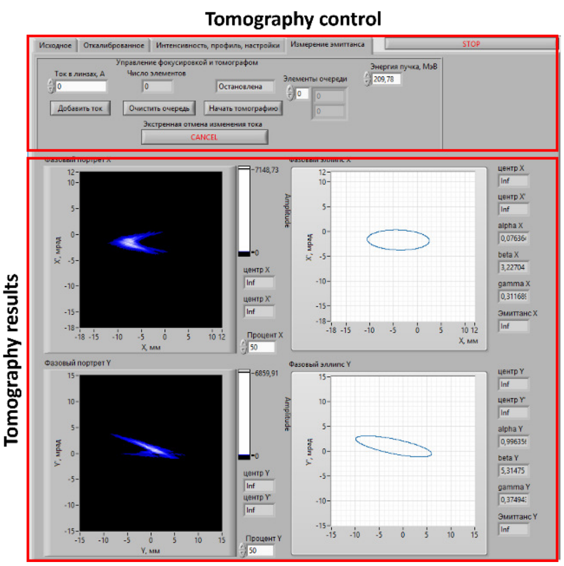

Figure 4: Online tomography software.

During beam tuning this procedure takes 10 minutes and provides Twiss parameters and transverse emittance values. Incorporation of this data into DSS knowledge base can help in future beam tuning.

Upgraded software for beam current and loss monitoring is shown in Fig. 5. Upgraded version has DAQ servers' status control panel and recomposed beam loss distribution panels. All new features were implemented to improve perception of presented information.

CONCLUSIONS

Decision support system is a promising technology that will decrease mental stress on beam operator and problem-solving time. Developed concept of the DSS allows its step-by-step implementation. With proposed INR linac DAQ upgrade this system should become a useful instrument for accelerator tuning.

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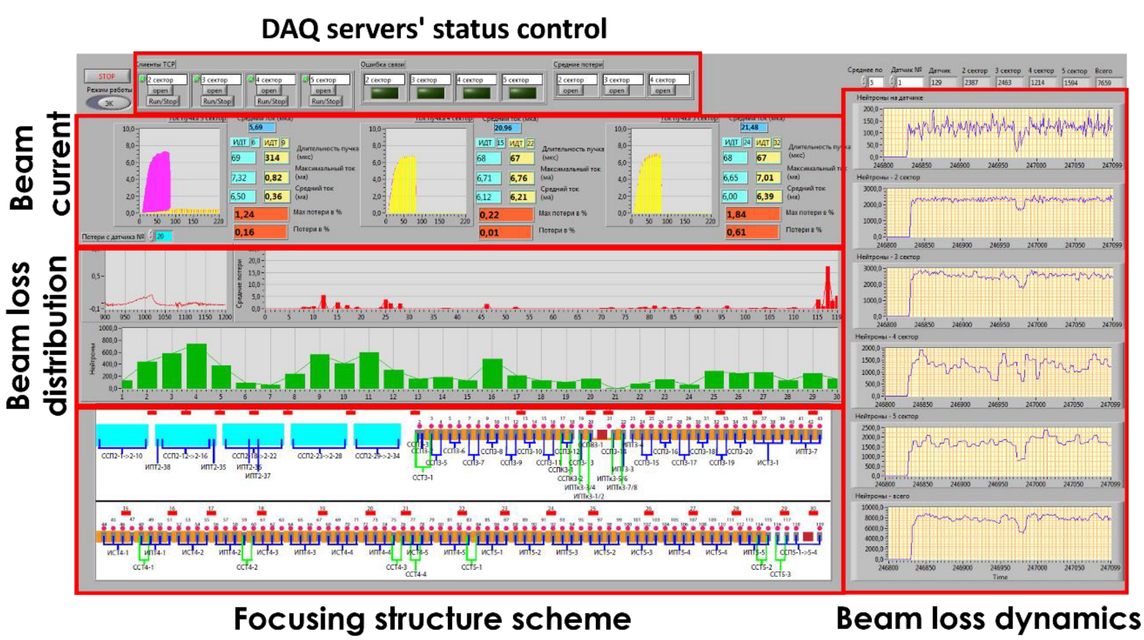

Figure 5: Beam current and loss software.

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