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APPROACHES TO ENHANCING SITUATIONAL AWARENESS IN DECISION SUPPORT SUBSYSTEMS FOR FOOD INDUSTRY

ПІДХОДИ ДО ПОКРАЩЕННЯ СИТУАЦІЙНОЇ ОБІЗНАНОСТІ В ПІДСИСТЕМАХ ПІДТРИМКИ ПРИЙНЯТТЯ РІШЕНЬ ХАРЧОВИХ ВИРОБНИЦТВ

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Abstract. *The article examines approaches to enhancing situational awareness in decision support subsystems for food industry applications. It is shown that the effectiveness of control systems largely depends on the ability to timely perceive, interpret, and predict the state of technological processes. An analysis of existing situational awareness models and their applications in decision support subsystems is carried out, highlighting their advantages and limitations. A structure of a control system for a technological complex with an integrated decision support subsystem is proposed, combining monitoring, analysis, prediction, and decision generation. Particular attention is given to the ISA-101 and High-Performance HMI concepts, which improve visualization clarity and operator interaction efficiency. The results of the study can be applied to the development of intelligent control systems with enhanced safety and reliability in the food industry.*

Keywords: *Situational awareness, decision support subsystem, ISA-101, High Performance HMI, SCADA, human-machine interface.*

Introduction

Modern food, pharmaceutical, and chemical industries require a high level of automation of technological processes to ensure product stability, safety, and efficient use of resources. Quite often, classical process control systems alone are insufficient for effective production management, creating the need to complement them with intelligent subsystems to enhance their performance.

In control systems, the operator plays a significant role, as they are capable of making the necessary decisions when provided with well-prepared information and recommendations. This can be achieved through the integration of a decision support subsystem into the control architecture, which utilizes raw data, documents, personal expertise, and models to assist operators in making decisions under abnormal situations. Such subsystems provide real-time data analysis, forecasting of potential deviations, and improved efficiency in managing production processes. However, the key factor determining their effectiveness is the level of situational awareness, which defines the ability to detect critical events in a timely manner, correctly interpret them, and predict the evolution of technological situations.

Therefore, studying approaches to enhancing situational awareness in decision support subsystems for food production is a relevant research task, aimed at integrating methods of intelligent data analysis, predictive modeling, and adaptive human-machine interfaces to improve operator interaction.

Literature Review and Problem Statement

Situational awareness is the ability of a system to perceive information about the current state of an object or process, correctly interpret it, and predict the possible development of events in order to make adequate decisions. The classical definition is provided in studies [1,2], which present a three-level model of situational awareness: perception > comprehension > projection. These works offer a theoretical basis for evaluating the information presented to the operator. However, the use of universal models under real-time conditions in production control systems remains insufficiently defined. This can be explained by the theoretical orientation of these studies and by the complexity of describing rapidly changing processes in real time - features inherent to control systems.

In decision support subsystems, situational awareness plays an important role and determines the quality and speed of generating control actions. A review of applications in the food industry [3] demonstrates potential for improving safety, traceability, process optimization, and inventory management; however, practical implementations often remain narrowly focused case studies and do not address technological process control. This is due to the high diversity of technological processes in the food sector; commercial solutions are oriented toward more universal problems and often fail to capture the specifics of particular productions.

A different line of research [4] presents a classification of decision support subsystems and approaches to their development, considering the use of knowledge bases and expert systems. Yet the issues of real-time operation and the integration of situational awareness into production systems with high rates of change remain unresolved.

In contrast to the previous study, the authors of [5] examine methods for enhancing operators' situational awareness in process control systems through visualization and intelligent interfaces. However, the study adopts a limited approach to prediction, focusing primarily on displaying the current state. A possible reason is that the employed methods rely mainly on graphical interfaces rather than predictive models.

The literature analysis shows that while the basic theories of situational awareness in decision support subsystems are fairly well developed, their use for controlling technological processes in the food industry remains insufficiently studied. Therefore, the research should focus on developing methods to enhance situational awareness within decision support subsystems for food production. The study emphasizes real-time operation, forecasting, and interaction with the operator through the visualization system.

The aim and objectives of the study

The aim of the study is to analyze methods for enhancing situational awareness in decision support subsystems for food production, taking into account real-time requirements, forecasting capabilities, and effective operator interaction with the control system.

To achieve this aim, the following objectives were set:

- to analyze existing approaches to the formation of situational awareness in decision support systems;

- to develop a structure of a control system for a technological complex with an integrated decision support subsystem;

- to analyze approaches to the design of human-machine interfaces that ensure a more comprehensive perception of the technological situation.

The study materials and methods

The object of the research is decision support subsystems with elements of situational awareness for food production.

The study employs the methodology of systems analysis to investigate the principles of situational awareness formation in decision support subsystems for food industry applications. The theoretical foundation includes:

- models of situational awareness;

- classifications of decision support subsystems, including expert systems, knowledge bases, and predictive models;

- concepts of human-machine interfaces aimed at improving visualization clarity and enhancing operator interaction efficiency.

Results of investigating the approaches to enhancing situational awareness in decision support subsystems

Analysis of Existing Approaches to the Formation of Situational Awareness in Decision Support Systems.

The development of an intelligent system requires the use of advanced algorithms within the decision support subsystem. Situational awareness is a crucial component in process control systems, particularly in food production, where the stability of conditions is of decisive importance. In such systems, situational awareness implies the ability to perceive, comprehend, and predict the state of all processes within the complex in order to make effective decisions in real time.

The main stages of situational awareness functioning in a decision support subsystem [1, 2]:

1. Perception. At this stage, the system collects and interprets data from numerous sensors that monitor the parameters of the technological process. The collected data are

processed to form a basic picture of the current state of the process.

2. Comprehension. The system analyzes the obtained data to determine whether all processes operate within permissible limits or if there are deviations or anomalies. Rules, models, and algorithms are used to evaluate the state of the controlled object and identify possible causes of disturbances. This stage often involves data processing through expert systems, logical rules, or machine learning methods.

3. Projection. Based on current data and modeling, the system predicts how the situation will evolve in the near future. Projection includes assessing how changes in one or more parameters will affect the rest of the process. This allows for corrective actions before critical deviations occur. Predictive models may rely on artificial intelligence algorithms trained on historical data or on physical and chemical models of the technological process.

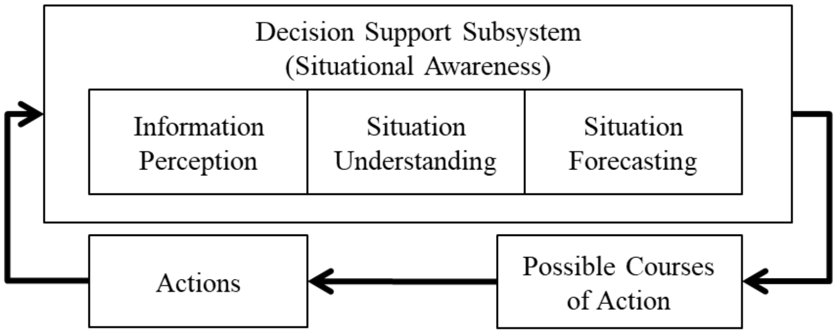

Figure 1 - Model of the functioning of a decision support subsystem with elements of situational awareness

Overall, situational awareness methods can be divided into two main directions:

1. Development of an intelligent system that uses process monitoring data, raw data, documents, personal knowledge, and/or models to help operators ensure optimal control or make decisions in abnormal situations.

2. Development of a human-machine interface in accordance with modern ergonomics standards and visualization design principles: the ISA-101 standard and the High-Performance HMI recommendations.

To develop the structure of a control system for a technological complex with an integrated decision support subsystem.

Quite often, classical automated process control systems alone are not sufficient for effective management, and it becomes necessary to complement them with intelligent subsystems to enhance their performance. In control systems, the operator plays a significant role, being able to make the required decisions when provided with well-prepared information and recommendations. This can be supported through the integration of a decision support subsystem into the control system, which utilizes raw data, documents, personal expertise, and/or models to help users make decisions in abnormal situations.

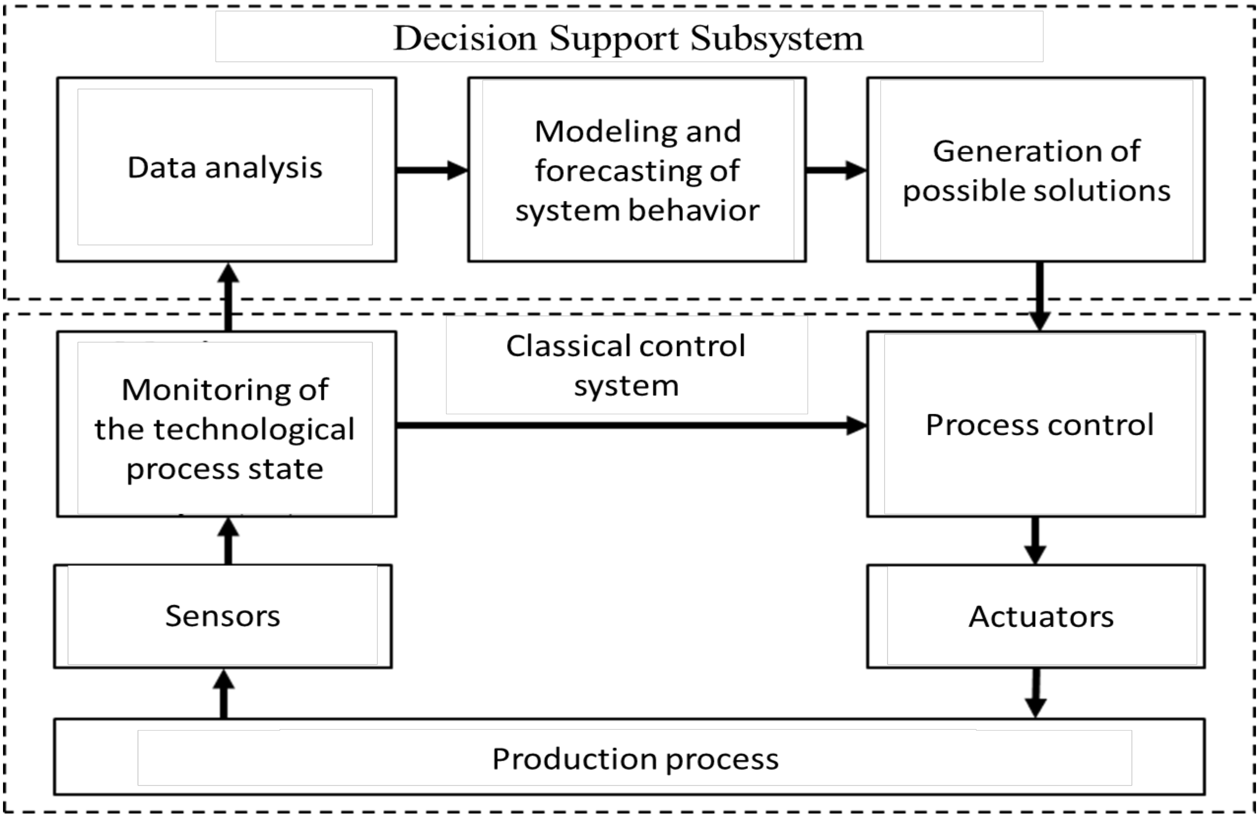

Figure 2 - Structure of a control system for a technological complex with an integrated decision support subsystem.

Figure 2 shows the structure of a control system with an integrated decision support subsystem. The system consists of the following main elements:

- Monitoring of the technological process state: collects information from all sensors and monitors parameters at all stages of drying;
- Data analysis and processing: processes information to detect deviations during the technological process;
- Modeling and forecasting of system behavior: applies algorithms to determine

optimal operating modes of the system;

- Generation of possible solutions: enables automatic or semi-automatic decision-making to ensure optimal operation of the complex, as well as the use of artificial intelligence methods (e.g., neural networks or expert systems) to identify the best actions in different situations (both during normal mode changes and in emergency conditions).

Analysis of approaches to the design of human-machine interfaces that ensure a more comprehensive perception of the technological situation.

The construction of a human-machine interface in accordance with the principles of modern ergonomics standards and visualization system organization ensures prompt response to changes in the control system. In other words, these approaches allow the operator to timely detect and react to changes in the technological process, preventing abnormal situations or inefficient management of the technological complex.

The ISA-101 standard defines the requirements for human-machine interface design aimed at supporting the operator in decision-making. In the context of situational awareness, it provides[6]:

- Structured screen organization: from an overall process overview to detailed unit-level information;
- Data prioritization: displaying only critically important information for quick perception;
- Unified color policy: bright colors are used exclusively for signaling deviations, preventing operator overload.

This directly supports all three levels of situational awareness: perception (through minimalist graphics), comprehension (through data prioritization), and projection (via trend integration and dynamic cues)[7,8].

The High-Performance HMI concept, formulated based on research in operator workstation ergonomics and later supported by ISA-101[9], includes:

- Use of gray-background graphics with minimal colors;
- Highlighting deviations instead of constant “multicolor” displays;
- Displaying trends directly on the working screen for better situation forecasting;

- System status indicators at the overview level, allowing the operator to quickly identify an “anomalous zone.”

In the context of situational awareness, High Performance HMI is aimed at reducing the operator’s cognitive load, increasing the speed of deviation detection, and enabling the prediction of emergency situations[10-13].

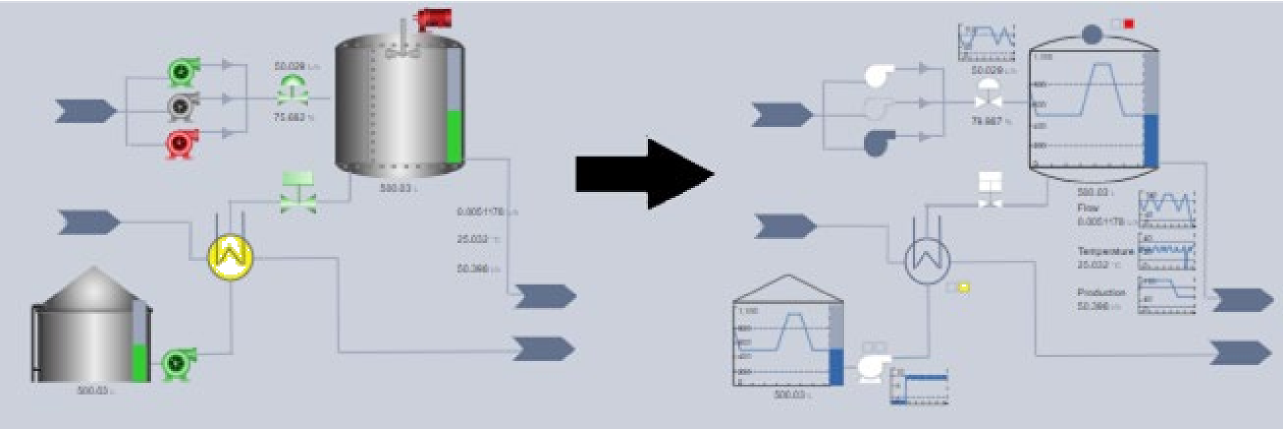

Figure 3 - Example of applying ISA-101 and High-Performance HMI approaches.

SCADA system developers integrate the ISA-101 and High-Performance HMI concepts into their templates to enhance situational awareness:

- Wonderware InTouch (AVEVA): provides Situational Awareness Library templates including standardized colors, trend widgets, and other panels[14];

- WinCC Unified (Siemens): supports Performance HMI Style, emphasizing minimalist graphics and contextual indicators[15];

- Ignition (Inductive Automation): offers Perspective modules with ready-made situational awareness components, such as alarm summaries, heatmaps, and KPI indicators[16];

- iFIX (GE): implements High Performance Graphics compliant with ISA-101 and supports multi-level display construction[17].

These templates allow the basic principles of situational awareness to be ensured without additional development: rapid problem detection, deviation localization, and understanding of its causes.

Conclusions

The conducted literature analysis has shown that the concept of situational awareness is a key factor in the effectiveness of decision support systems. However, its application in the management of technological processes in food production remains insufficiently studied.

A structure for a technological complex control system with a decision support subsystem is proposed, combining process state monitoring, data analysis and processing, modeling and forecasting, as well as generation of control decisions. This ensures improved management efficiency and reduces the risk of abnormal situations.

The ISA-101 and High-Performance HMI concepts, which focus on enhancing visualization clarity and operator efficiency, were considered. It has been shown that their implementation in SCADA systems (InTouch, WinCC Unified, Ignition, iFIX) supports all three levels of situational awareness: perception, comprehension, and projection.

The obtained results confirm that the application of situational awareness enhancement approaches in decision support subsystems for food production contributes to increased management efficiency, reduced likelihood of operator errors, and improved safety of production processes.

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Анотація. *У статті розглянуто підходи до підвищення ситуаційної обізнаності в підсистемах підтримки прийняття рішень для харчових виробництв. Показано, що ефективність систем керування значною мірою залежить від здатності своєчасно сприймати, інтерпретувати та прогнозувати стан технологічних процесів. Виконано аналіз існуючих моделей ситуаційної обізнаності та методів їх застосування у підсистемах підтримки прийняття рішень, окреслено їхні переваги й обмеження. Запропоновано структуру системи керування технологічним комплексом з підсистемою підтримки прийняття рішень, яка поєднує моніторинг, аналіз, прогнозування та генерацію рішень. Особливу увагу приділено концепціям ISA-101 та High Performance HMI, що підвищують наочність візуалізації й ефективність взаємодії оператора. Результати дослідження можуть бути використані для створення інтелектуальних систем керування з підвищеним рівнем безпеки та надійності у харчовій промисловості.*

Ключові слова: *Ситуаційна обізнаність, підсистема підтримки прийняття рішень, ISA-101, High Performance HMI, SCADA, людино-машинний інтерфейс.*