FIRE AND CIVIL SAFETY

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Vladyslav Yevsieiev
Doctor of Engineering Science, Professor, Professor
Irina Sezonova
Candidate of technical sciences, associate professor, Professor
Artem Bronnikov
Candidate of technical sciences, associate professor, associate professor
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine

SYNERGY OF HUMANS AND ARTIFICIAL INTELLIGENCE IN THE MANAGEMENT OF CIVIL PROTECTION FORCES IN ACCORDANCE WITH THE INDUSTRY 5.0 CONCEPT

Abstract. This paper investigates the principles of developing a human-centric civil protection force management system based on the Industry 5.0 concept, in which collaboration between humans and artificial intelligence is achieved through continuous information exchange, intelligent data analysis, and decision support. A structural model is proposed that integrates data sources, expert knowledge, artificial intelligence algorithms, collaborative decision-making mechanisms, continuous feedback, and ethical principles for the application of intelligent technologies within a unified information environment. The study demonstrates that combining human expertise with the capabilities of artificial intelligence in forecasting, risk assessment, resource optimization, and emergency scenario simulation enhances the efficiency of emergency response, improves the coordination of civil protection forces, and strengthens the resilience of critical infrastructure. The proposed approach establishes a scientific and practical foundation for the digital transformation of civil protection systems and the implementation of intelligent human-centric management technologies to address complex contemporary threats.

Keywords: industry 5.0, civil protection, artificial intelligence, human-centric management, cyber-physical systems, decision support, emergency management, critical infrastructure, digital transformation.

The rapid increase in natural, technological, military, and cyber threats necessitates the implementation of new approaches to civil protection force management that can ensure timely emergency response under conditions of high uncertainty and large volumes of heterogeneous information. The Industry 5.0 concept promotes a human-centric approach in which artificial intelligence does not replace human experts but rather enhances their capabilities by providing rapid data analysis, forecasting the development of hazardous events, and generating well-founded recommendations for decision support [1,2]. The synergy between humans and artificial intelligence combines professional expertise, intuition, and managerial responsibility with the high-speed processing capabilities, predictive accuracy, and advanced analytical potential of intelligent algorithms for evaluating complex emergency scenarios. Such an approach improves the coordination of civil protection forces and resources, optimizes resource utilization, and reduces response time to emerging threats [3,4]. Therefore, research aimed at developing a human–artificial intelligence interaction framework for civil protection management systems in accordance with the Industry 5.0 concept is highly relevant, scientifically justified, and of significant practical importance for enhancing public safety and strengthening the resilience of critical infrastructure [5,6].

An example of the proposed human–artificial intelligence interaction framework for civil protection management systems based on the Industry 5.0 concept is presented in Figure 1. The proposed framework is designed as an integrated cyber-physical decision support system in which all functional modules interact through continuous information exchange [7–10]. The operation begins with the Data Sources module, which forms the system's information environment by collecting data from satellite monitoring, unmanned aerial vehicles (UAVs), IoT sensors, video surveillance systems, meteorological services, operational databases, social media feeds, and geographic information systems (GIS), thereby providing up-to-date information on the condition of the territory, critical infrastructure, and the development of potential hazards [11]. The acquired information streams are simultaneously transmitted to the Human (Expert) and Artificial Intelligence modules, where the human expert applies professional knowledge, situational awareness, ethical reasoning, intuition, and managerial expertise to define strategic objectives and supervise the decision-making process, while the artificial intelligence module performs data integration, automated pattern recognition, emergency forecasting, risk assessment, resource optimization, and anomaly detection [12]. Information exchange between humans and artificial intelligence is implemented through the central Human–AI Collaborative Loop, in which Human Input provides objectives, operational constraints, priorities, and expert adjustments to the intelligent system, whereas AI Support returns analytical results, forecasts, recommendations, and alerts. These inputs are subsequently integrated within the Synergy module to generate collaborative decisions that combine human expertise with the analytical capabilities of artificial intelligence [13]. The Continuous Feedback subsystem provides permanent bidirectional information exchange among human operators, artificial intelligence algorithms, and the outcomes of implemented decisions, enabling continuous system adaptation to environmental changes, accumulation of new knowledge, and improvement of prediction accuracy. The coordinated decisions are then transferred to the Joint Decision-Making & Action module, which performs situation assessment, emergency scenario simulation, operational planning, allocation of personnel and resources, management of emergency response units, coordination of public information exchange, and monitoring of mission execution, thereby ensuring effective response to emergency situations [14]. The operation of the entire framework is governed by the Industry 5.0 Principles, which establish a human-centric management paradigm, promote effective collaboration between humans and artificial intelligence, emphasize resilience and sustainable development, and focus on creating societal value. In parallel, the Governance & Ethics module defines the regulatory framework for the ethical use of artificial intelligence, including data privacy, cybersecurity, algorithm transparency, preservation of meaningful human control over final decisions, and compliance with applicable legal requirements [15]. The overall outcome of the proposed framework is represented by the Outcomes module, which is characterized by improved public safety, reduced emergency response time, optimized resource utilization, enhanced resilience of critical infrastructure, support for sustainable development, and increased public trust in civil protection management. The achieved outcomes are continuously fed back to the human operators, artificial intelligence modules, and data sources, forming a closed-loop process of continuous learning and improvement in accordance with the Industry 5.0 concept.

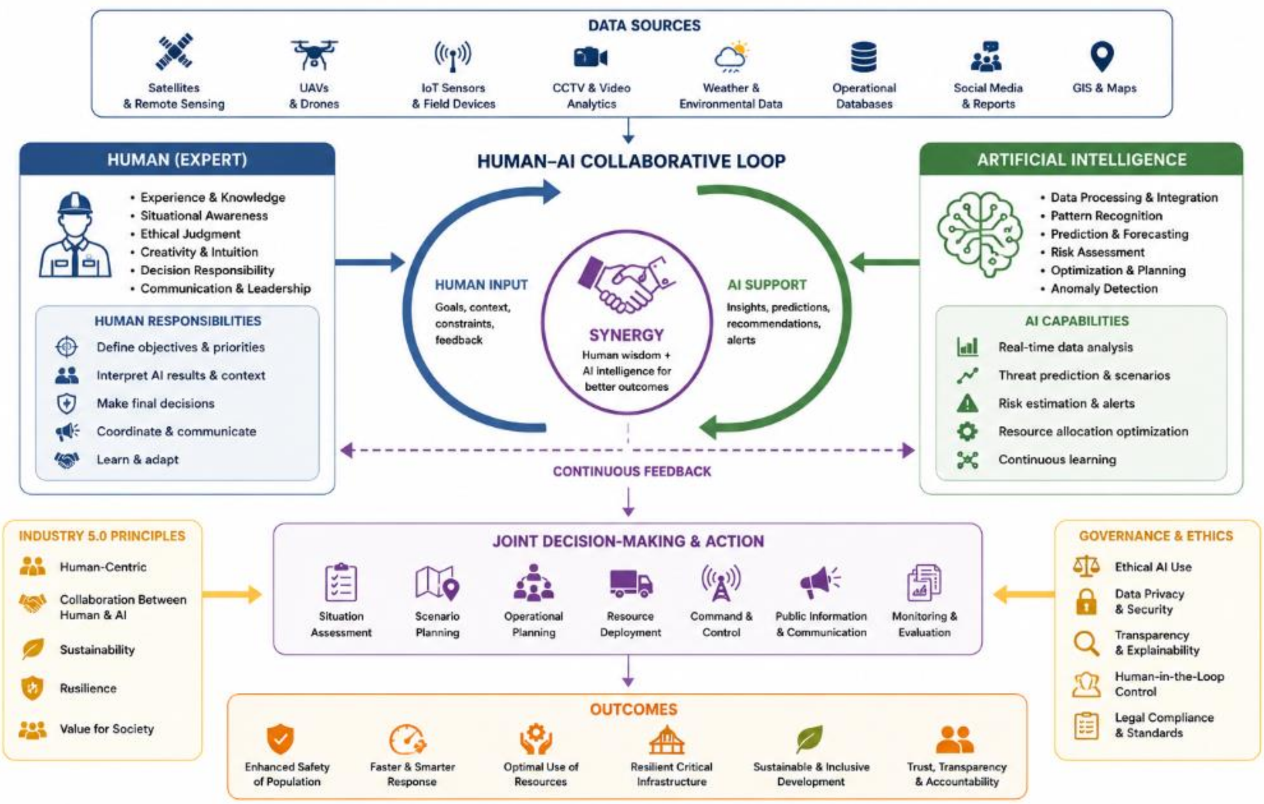

Figure 1. Human–Artificial Intelligence Interaction Framework for Civil Protection Management Systems Based on the Industry 5.0 Concept

The human–artificial intelligence interaction framework for civil protection management systems based on the Industry 5.0 concept (Fig. 1) is designed as an integrated cyber-physical decision support system in which all functional modules interact through continuous information exchange. The operation begins with the Data Sources module, which establishes the system's information environment by collecting data from satellite monitoring, unmanned aerial vehicles (UAVs), IoT sensors, video surveillance systems, meteorological services, operational databases, social media, and geographic information systems (GIS), thereby providing up-to-date information on the status of territories, critical infrastructure, and the evolution of potential hazards. The acquired information is simultaneously transmitted to the Human (Expert) and Artificial Intelligence modules, where the human expert applies professional expertise, situational awareness, ethical reasoning, intuition, and managerial competence to define strategic objectives and supervise decision-making, while the artificial intelligence module performs data integration, automated pattern recognition, emergency forecasting, risk assessment, resource optimization, and anomaly detection. Information exchange between humans and artificial intelligence is implemented through the central Human–AI Collaborative Loop, where Human Input provides operational objectives, constraints, priorities, and expert adjustments to the intelligent system, whereas AI Support delivers analytical results, forecasts, recommendations, and alerts. These contributions are integrated within the Synergy module to generate collaborative decisions that combine human expertise with the analytical capabilities of artificial intelligence. The Continuous Feedback subsystem ensures permanent bidirectional information exchange among human operators, artificial intelligence algorithms, and the outcomes of implemented decisions, enabling continuous adaptation to environmental changes, accumulation of new knowledge, and improvement of prediction accuracy. The coordinated decisions are then transferred to the Joint Decision-Making & Action module, which performs situation assessment, emergency scenario simulation, operational planning, allocation of personnel and resources, management of emergency response units, coordination of public information exchange, and monitoring of mission execution, thereby ensuring an effective response to emergency situations. The operation of the entire framework is governed by the Industry 5.0 Principles, which establish a human-centric management paradigm, promote effective collaboration between humans and artificial intelligence, emphasize resilience, sustainability, and societal value creation, while the Governance & Ethics module defines the regulatory framework for the ethical use of artificial intelligence, including data privacy, cybersecurity, algorithm transparency, preservation of meaningful human control over final decisions, and compliance with applicable legal requirements. The overall outcome of the proposed framework is represented by the Outcomes module, which is characterized by enhanced public safety, reduced emergency response time, optimized resource utilization, increased resilience of critical infrastructure, support for sustainable development, and greater public trust in civil protection management. The achieved outcomes are continuously fed back to human operators, artificial intelligence modules, and data sources through the feedback loop, forming a continuous cycle of learning and improvement in accordance with the Industry 5.0 concept [16-18].

Conclusion. The conducted research confirmed that the synergy between humans and artificial intelligence, in accordance with the Industry 5.0 concept, provides the foundation for developing adaptive civil protection management systems capable of operating effectively under dynamic and multifactorial threat conditions. The proposed framework enables the integration of heterogeneous information sources, intelligent data analysis, decision support, and continuous feedback between human experts and artificial intelligence algorithms, thereby improving emergency response efficiency, enhancing the quality of managerial decisions, and optimizing resource utilization. The practical implementation of the proposed approach will facilitate the digital transformation of civil protection systems, strengthen the resilience of critical infrastructure, and support the development of a modern human-centric emergency management model aligned with the principles of Industry 5.0.

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