

# **ЗБІРНИК НАУКОВИХ ПРАЦЬ**

З МАТЕРІАЛАМИ V МІЖНАРОДНОЇ НАУКОВОЇ КОНФЕРЕНЦІЇ

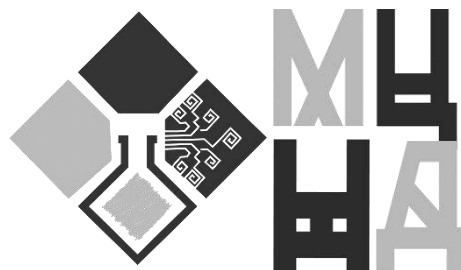
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М. ЧЕРНІВЦІ, УКРАЇНА

**«ІНТЕЛЕКТУАЛЬНИЙ РЕСУРС СЬОГОДЕННЯ:  
НАУКОВІ ЗАДАЧІ, РОЗВИТОК ТА ЗАПИТАННЯ»**



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НАУКОВОЇ КОНФЕРЕНЦІЇ



# ІНТЕЛЕКТУАЛЬНИЙ РЕСУРС СЬОГОДЕННЯ: НАУКОВІ ЗАДАЧІ, РОЗВИТОК ТА ЗАПИТАННЯ

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## **СЕКЦІЯ XI. АТОМАТИЗАЦІЯ ТА ПРИЛАДОБУДУВАННЯ**

### **FEATURES OF USING DATA FUSION WITH EXTENDED KALMAN FILTER IN INDUSTRY 5.0 CONCEPTS**

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The relevance of studying the features of using Data Fusion technologies in combination with Extended Kalman Filter (EKF) in the Industry 5.0 concept is determined by the need to ensure high accuracy, reliability, and adaptability of collaborative robotic systems that interact with humans and operate in a dynamic environment. Industry 5.0 involves the deep integration of artificial intelligence, sensor networks, and cognitive control algorithms, enabling the creation of robotic complexes with increased autonomy and safety. In conditions of multi-source data acquisition from machine vision cameras, inertial measurement units, ultrasonic and tactile sensors, there is a need for methods capable of effectively combining information, minimizing measurement errors and compensating for noise. Data fusion in the context of a collaborative manipulation robot is the process of integrating data from heterogeneous sensors to obtain a single, more accurate, and informative assessment of the system state than is possible using separate information sources. The Extended

Kalman Filter (EKF) is an extended version of the classic Kalman filter, adapted to work with nonlinear mathematical models characteristic of manipulator motion dynamics and sensor data processing. EKF allows predicting the state of the system based on a motion model and correcting this prediction with new measurements, taking into account the statistical characteristics of process and measurement noise. In combination with Data Fusion, EKF provides not only data fusion but also optimal filtering, which is particularly important for collaborative robots that must operate in real time and respond to changes in the environment with minimal delay. The use of this technology in Industry 5.0 improves the stability and smoothness of manipulator movements, ensures more accurate positioning, and better adaptation to unpredictable factors such as the movement of objects or people in the work area. Thus, the study of this area is of great importance for the development of new generations of robotic systems that combine a high level of autonomy with safe and efficient performance of production and service tasks.

Let us present key mathematical models for Data Fusion with EKF, with a description of the main parameters. The state model is based on kinematics or simplified dynamics of the manipulator and describes the evolution of the state vector  $\mathbf{x}$  over time:

$$\mathbf{x}_k = f_d(\mathbf{x}_{k-1}, \mathbf{u}_{k-1}) + \mathbf{w}_{k-1} \quad (1)$$

Where:  $\mathbf{x}_k$  – state vector (joint angles  $\mathbf{q}$ , speeds  $\dot{\mathbf{q}}$ , end-effector position and orientation  $\mathbf{p}, \mathbf{q}_0$ , sensor displacement  $\mathbf{b}_a, \mathbf{b}_w$ );  $\mathbf{u}_{k-1}$  – control action vector (torques or drive commands);  $\mathbf{w}_{k-1}$  – process noise ( $\mathbf{Q}$  – its covariance).

A measurement model defines how sensor data relates to the state:

$$\mathbf{z}_k^{(i)} = \mathbf{h}^{(i)}(\mathbf{x}_k) + \mathbf{v}_k^{(i)} \quad (2)$$

Where:  $\mathbf{z}_k^{(i)}$  – measurement vector from the sensor  $i$  (camera, IMU, encoders, rangefinders);  $\mathbf{h}^{(i)}(\cdot)$  – nonlinear function of state transformation into a measurement;  $\mathbf{v}_k^{(i)}$  – measurement noise ( $\mathbf{R}^{(i)}$  – its covariance).

Recurrent EKF equations (Prediction & Update):

- Prediction

$$\begin{aligned} \hat{\mathbf{x}}_{k|k-1} &= f_d(\hat{\mathbf{x}}_{k-1|k-1}, \mathbf{u}_{k-1}) \\ \mathbf{P}_{k|k-1} &= \mathbf{F}_{k-1} \mathbf{P}_{k-1|k-1} \mathbf{F}_{k-1}^\top + \mathbf{Q}_{k-1} \end{aligned} \quad (3)$$

- Update

$$\begin{aligned} \mathbf{K}_k &= \mathbf{P}_{k|k-1} \mathbf{H}_k^\top (\mathbf{H}_k \mathbf{P}_{k|k-1} \mathbf{H}_k^\top + \mathbf{R}_k)^{-1} \\ \hat{\mathbf{x}}_{k|k} &= \hat{\mathbf{x}}_{k|k-1} + \mathbf{K}_k (\mathbf{z}_k - \mathbf{h}(\hat{\mathbf{x}}_{k|k-1})) \\ \mathbf{P}_{k|k} &= (\mathbf{I} - \mathbf{K}_k \mathbf{H}_k) \mathbf{P}_{k|k-1} \end{aligned} \quad (4)$$

Where:  $\mathbf{F}_k$  – Jacobian  $f_d$  by state;  $\mathbf{H}_k$  - Jacobian  $\mathbf{h}$  by state;  $\mathbf{K}_k$  - Kalman matrix.

The developed data fusion models based on the Extended Kalman Filter provide increased accuracy in estimating the state of a collaborative manipulation robot through the comprehensive use of information from multiple sensors in real time. They allow for effective compensation of measurement errors and reduction of noise influence, which is particularly important in dynamic and unpredictable production environments. Thanks to adaptive data processing, the models ensure stable and reliable control even in the presence of incomplete or partially distorted data..

**Conclusions.** The performed study proves that the integration of Data Fusion technology with the Extended Kalman Filter algorithm is an effective tool for improving the accuracy and reliability of collaborative manipulation robots within the Industry 5.0 concept. The proposed approach allows combining data from heterogeneous sensors into a single coherent model of the system state, providing more complete and reliable information about the environment and the current position of the robot. The use of EKF ensures the correction of measurement errors and the consideration of nonlinear characteristics of the controlled object, which is especially important in dynamic production scenarios. The developed mathematical models and algorithmic solutions contribute to improving control stability, reducing the impact of noise and incomplete data, and enable timely response to changes in the working area. The proposed approach can be scaled up for multi-component robotic systems, ensuring effective coordination of actions between individual robots and humans. The results obtained confirm the feasibility of further development of Data Fusion and EKF integration methods in the direction of creating intelligent control systems for Industry 5.0.

### References:

1. Li, Y., Zheng, Y., Luo, Y., Qiu, S., & Sun, L. (2025). Seismic load identification for damper-added and base-isolated frame structures using EKF-UI algorithm and data fusion technique. *Journal of Building Engineering*, 104, 112426.

2. Ariante, G., Caso, F. L., Menichino, A., Di Vito, V., Ponte, S., & Del Core, G. (2025). Improved UAS Distance Estimation via LiDAR-Radar Data Fusion Using Extended Kalman Filter. In Proceedings of the 2025 12th International Workshop on Metrology for AeroSpace (MetroAeroSpace) (pp. 69-74). IEEE.
3. Wang, S., Yi, S., Zhao, B., Li, Y., Li, S., Tao, G., ... & Sun, W. (2024). Sowing depth monitoring system for high-speed precision planters based on multi-sensor data fusion. *Sensors*, 24(19), 6331.
4. Ariante, G., Caso, F. L., Menichino, A., Di Vito, V., Ponte, S., & Del Core, G. (2025). Improved UAS Distance Estimation via LiDAR-Radar Data Fusion Using Extended Kalman Filter. In Proceedings of the 2025 12th International Workshop on Metrology for AeroSpace (MetroAeroSpace) (pp. 69-74). IEEE.
5. Nevludov, I., Yevsieiev, V., Maksymova, S., Gopejenko, V., & Kosenko, V. (2025). DEVELOPMENT OF MATHEMATICAL SUPPORT FOR ADAPTIVE CONTROL FOR THE INTELLIGENT GRIPPER OF THE COLLABORATIVE ROBOT MANIPULATOR. *Advanced Information Systems*, 9(3), 57-65.
6. Nevludov, I., Yevsieiev, V., Maksymova, S., & Artyukh, R. (2025). Mathematical model of adaptive hierarchical high-level control of a three-link collaborative robot manipulator. *Current state of scientific research and technology in industry*, (2 (32)), 58-68.
7. Maksymova, S., Yevsieiev, V., Chala, O., & Ababneh, J. (2025). DECISION-MAKING MODEL FOR CONTROLLING A COLLABORATIVE ROBOT-MANIPULATOR BASED ON THE SENSOR FUSION METHOD AND THE RULES OF RULE-BASED SYSTEMS. *Multidisciplinary Journal of Science and Technology*, 5(6), 526-538.
8. Maksymova, S., Yevsieiev, V., Chala, O., & Ababneh, J. (2025). DECISION-MAKING MODEL FOR CONTROLLING A COLLABORATIVE ROBOT-MANIPULATOR BASED ON THE SENSOR FUSION METHOD AND THE RULES OF RULE-BASED SYSTEMS. *Multidisciplinary Journal of Science and Technology*, 5(6), 526-538.
9. Chala, O., Ababneh, J., Yevsieiev, V., & Maksymova, S. (2025). BIO-INSPIRED PRINCIPLES FOR MODELING INFORMATION COLLECTION IN COLLABORATIVE ROBOT ENVIRONMENTS. *Multidisciplinary Journal of Science and Technology*, 5(6), 9-18.
10. NEVLUDOV, I., YEVSIEIEV, V., & GURIN, D. (2025). MATHEMATICAL MODEL OF BLOCK PROCESS PLANNING IN SYSTEMS OF TASK ALLOCATION BETWEEN PEOPLE AND COLLABORATIVE ROBOTS IN INDUSTRIES 5.0. *Bulletin of Kherson National Technical University*, 1(1 (92)), 157-163.