In the context of the above-mentioned works, we have formulated the task of developing a concept for the construction of intelligent robotic systems based on the use of knowledge, as well as outlined the basic requirements for such systems:

- support of heterogeneous components of the robot system, i. e. support of a single open interface of interaction;
- the possibility of transferring the knowledge accumulated by the system during its operation to other robotic systems with minimal changes;
- adaptive design, i. e. the ability to change the composition of the system components without having to change the interaction logic;
- support for self-modification of the system;
- the ability of the system to expand and/or improve its set of sensors and effectors;
- the ability of the system to analyze the quality of its physical and software components.

These requirements correspond to the properties of cybernetic systems given in the OSTIS technology standard [6]. This technology is a reasonable choice for designing an intelligent robotic system, as it ensures the achievability of these properties.

In the process of building the concept of developing systems of this type, it is necessary to form a list of recommendations and general rules for designing intelligent robotic systems, and to realize an applied intelligent robotic system on the basis of the outlined theoretical provisions.

III. Proposed concept

The proposed robotic system design concept is developed using OSTIS technology.

The fundamental possibility of integrating a physical robotic system and OSTIS in the context of controlling this system is based on the developed ontology that includes a description of the basic physical components of such a system (i. e., manipulators, transporters, etc.), as well as the classes of actions that can be performed by such components.

As a formal basis for knowledge representation within the framework of OSTIS Technology, a unified semantic network with a set-theoretic interpretation is used. This representation model is called SC-code (Semantic Computer code). The elements of the semantic network are called sc-nodes and sc-connectors (sc-arc, sc-edges) [6].

Systems built on the basis of OSTIS Technology are called ostis-systems. Any ostis-system consists of a knowledge base, a problem solver and a user interface. The basis of the knowledge base is a hierarchical system of subject domains (SDs) and their corresponding ontologies. Ontologies contain descriptions of concepts necessary for formalization of knowledge within SD. Any knowledge describing some problem, its context and specification of solution methods can be represented in the form of SC-code constructs. Thus, unification of representation and consistency of different types of knowledge describing problems, their context and solution methods is ensured.

Benefits that can be achieved by using OSTIS as a design tool for intelligent robotic systems include:

- the possibility of isolating extracted knowledge, independent of the manipulator types used, and reapplying it to other robotic systems under development, eliminating the need to code single-type operations;
- convenient means of visualization, for example, with the use of SCg, which allows to determine the working conditions of the components of robotic systems;
- use of open interaction interfaces that allow adding other physical components on the fly;
- explainability of the system operation modes, which allows tracking the occurrence of emergency situations with the formation of a detailed, humanunderstandable report.

IV. Robotics system design

According to the proposed concept, we have carried out the design and development of a collaborative robotic intelligent system.

The main purpose of the developed system is to sort objects of a certain type while maintaining the ability to flexibly modify the filtering condition of objects. This type of robotic systems is popular and widely used in production conditions to select objects with certain properties (for example, to reject manufactured products or to organize them for subsequent packaging of only the same type of goods). Such an operation, if automated, significantly simplifies manual labor in production, reducing the amount of monotonous work performed.

The physical part of the system consists of the following components:

- manipulators (2 units);
- transporter;
- single-board computer;
- storage devices (general and for target objects);
- tube;
- camera;
- ultrasonic sensor;
- power supply;
- indicator lamp;
- auxiliary components such as conductors, relays, voltage converters, and so on.

The scheme of the main physical components of the system is shown in Fig. 1.

The main components of the software part of the proposed robotic system, as well as of any ostis-system, are

knowledge base and **problem solvers**. The user interface is the standard OSTIS technology tools for viewing and editing knowledge bases. The computer vision module, including a neural network model for object detection, is also a program component.

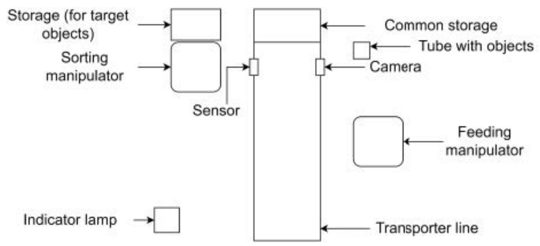

Figure 1. The scheme of the main physical components of the system

The functioning scenario of the developed system is reduced to the following main actions:

1) picking up the object from the tube by the feeding manipulator and moving it to the beginning of the conveyor;

2) switching on the conveyor and moving the object until the sensor is triggered;

3) disconnection of the conveyor at the moment of sensor actuation;

4) recognition of the object (type and color) by means of the installed camera;

5) moving the object from the conveyor belt to the target object storage by means of the sorting arm, if the recognized type and color match the set type and color;

6) switching on the conveyor belt and moving the object to the general storage;

7) switching off the transporter after the fulfillment of item 6.

8) switching on the green signal of the indicator when there are objects in the tube; 9) switching on the red indicator signal when there are no objects in the tube.

Let's describe the physical components of the system in more detail.

A. Physical components

Manipulators are used for gripping and moving objects. In this project, we used manipulators with different types of grippers that are widely available on the market — mechanical (pincer) grippers (Fig. 2) and vacuum grippers (Fig. 3).

Transporter is intended for moving objects to the specified point of technological operation (Fig. 4).

Single Board Computer — a specialized computer on which the OSTIS platform is deployed and the logic for controlling the system operation is implemented. In our implementation, the SBC Raspberry PI 5 (Fig.) [7] was used for this purpose.

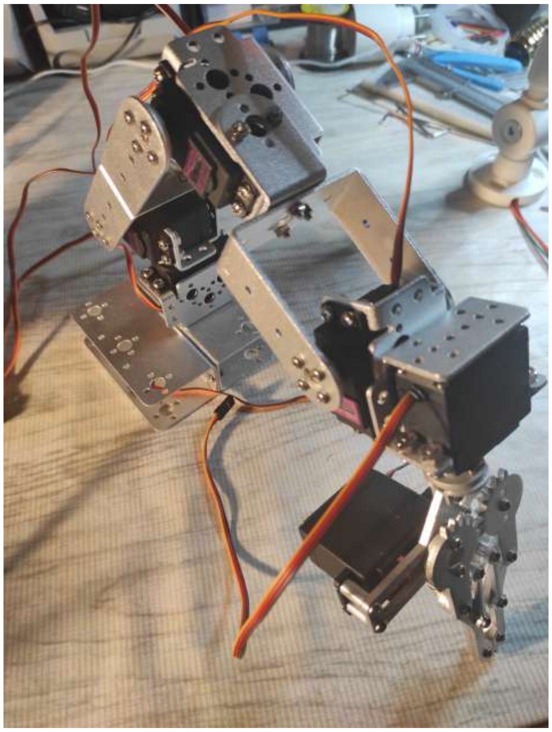

Figure 2. Manipulator with mechanical gripper

Figure 3. Manipulator with vacuum gripper

Storages — special containers used to store objects of a certain type (Fig. 6).

Tube – a container for storing objects that is shaped to be gripped by a manipulator (Fig. 7).

Camera is used to detect objects in the field of view and determine their characteristics. We used a 2 megapixel FullHD backlit camera ZONE 51 LENS.

Ultrasonic sensor is used to identify situations in which the object is in a given point of the conveyor. For our project we used the HC-SR04 sensor (Fig. 8) [8]. Power supply is required to power all physical devices in the system. We used a 360-watt, 24-volt, 15-amp power supply.

Indicator lamp is intended for light indication of the

Figure 4. Transporter part

Figure 5. SBC Raspberry PI 5 with heat sink installed

system status. In our project we used a TD-50 lamp with two color options (red and green) (Fig. 9).

B. Program components: knowledge base

The ontological approach is used for knowledge structuring, the essence of which is to represent the knowledge base as a hierarchy of subject domains and their corresponding ontologies. OSTIS technology provides a basic set of ontologies on the basis of which ontologies of applied ostis-systems are built.

The following subject domains are identified for the considered intelligent robotic system:

Figure 6. Storage for objects with placed objects

Figure 7. Fragment of the tube with placed objects

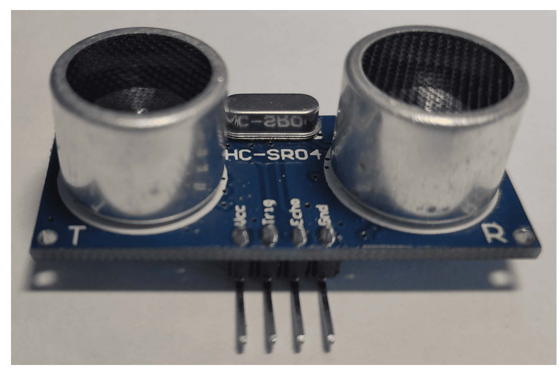

Figure 8. Ultrasonic sensor

Figure 9. TD-50 indicator lamp

- Subject domain and its corresponding robotic device ontology;