

**INTERNET OF ROBOTIC THINGS (IoRT) - AN INTERDISCIPLINARY  
BRANCH OF ENGINEERING AND SCIENCE**

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Today a more complicated structure of the system of intellectualization is being developed. The main subsystems of this structure are: the subsystem of high-speed computer devices; the subsystem of information high-precision sensors; the subsystem of mathematical models of optimizing the parameters and working modes of machines. Each of these subsystems is characterized by a set of hardware and software with its requirements for operation and maintenance [1].

System design is based on understanding the interaction between physical parameters, physical process and state (fig.1).

Types of physical quantities	Measuring quantity	states
<b>mechanical</b>	Displacement (length, width, height, thickness, level), position, velocity, acceleration, time, volume, quantity, flow, pressure, work, power, moment, etc.	Density, specific gravity, permeability, accuracy, strength, elasticity etc.
<b>acoustic</b>	Pressure and speed of sound, frequency, phase, wavelength, resistance, energy, work of sound	Specific resistance, sound absorption, reflection, speed of sound in matter
<b>thermal</b>	Temperature, heat flow, thermal conductivity, the amount of heat, etc.	Thermal conductivity, specific heat capacity, thermal expansion, boiling, fusion, shrinkage
<b>optical</b>	Brightness, illumination, luminous flux, light wave frequency, energy, etc.	Absorption, reflection, polarization, etc.
<b>electric</b>	Current, voltage, field strength, current frequency, current spectrum, power	Electrical conductivity, dielectric constant, electrical strength, etc.
<b>magnetic</b>	Magnetic force, magnetic field strength, magnetic flux, magnetic resistance, magnetic inductance, mutual inductance, etc.	Magnetic susceptibility and permeability, magnetic induction and etc.
<b>radioactive</b>	Radiation flow, radiation intensity, radiation energy, etc.	Penetration, radiation transformation, etc.

Figure 1 – The interaction between physical parameters, physical process and state

In the most classic form the structure of control system consists of several control loops. Each control loop is responsible for controlling external and internal factors. The controller generates a control signal depending on the value of the control error (fig. 2).

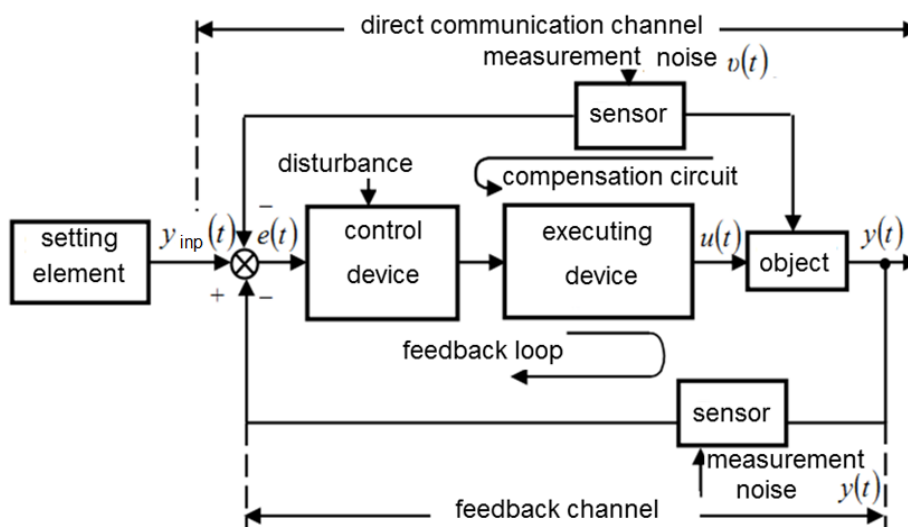


Figure 2 – The structure of combined control system

In the most classic form the structure of intelligent system consists of three levels [2]. The lower level of input/output includes sensors, actuators. The intermediate level consists of controllers. Their task is to process the obtained data, to give the control action, to transfer data to the upper level. At the top level there are the database servers and operator stations, whose task is to give the operator a man-machine interface and to carry out the exchange with the server and programmable logic controllers (PLC). The current tasks of managing complex objects are accompanied by analysis of many factors, processing large arrays of information obtained from diverse, distributed in space, information sources. The decisions on the workflow are taken in terms of the dynamic changes in the external environment.

The Internet of Things (IoT) and Industrial IoT (IIoT) have developed rapidly in the past few years, as both the Internet and “things” have evolved significantly (Fig.3) [3].

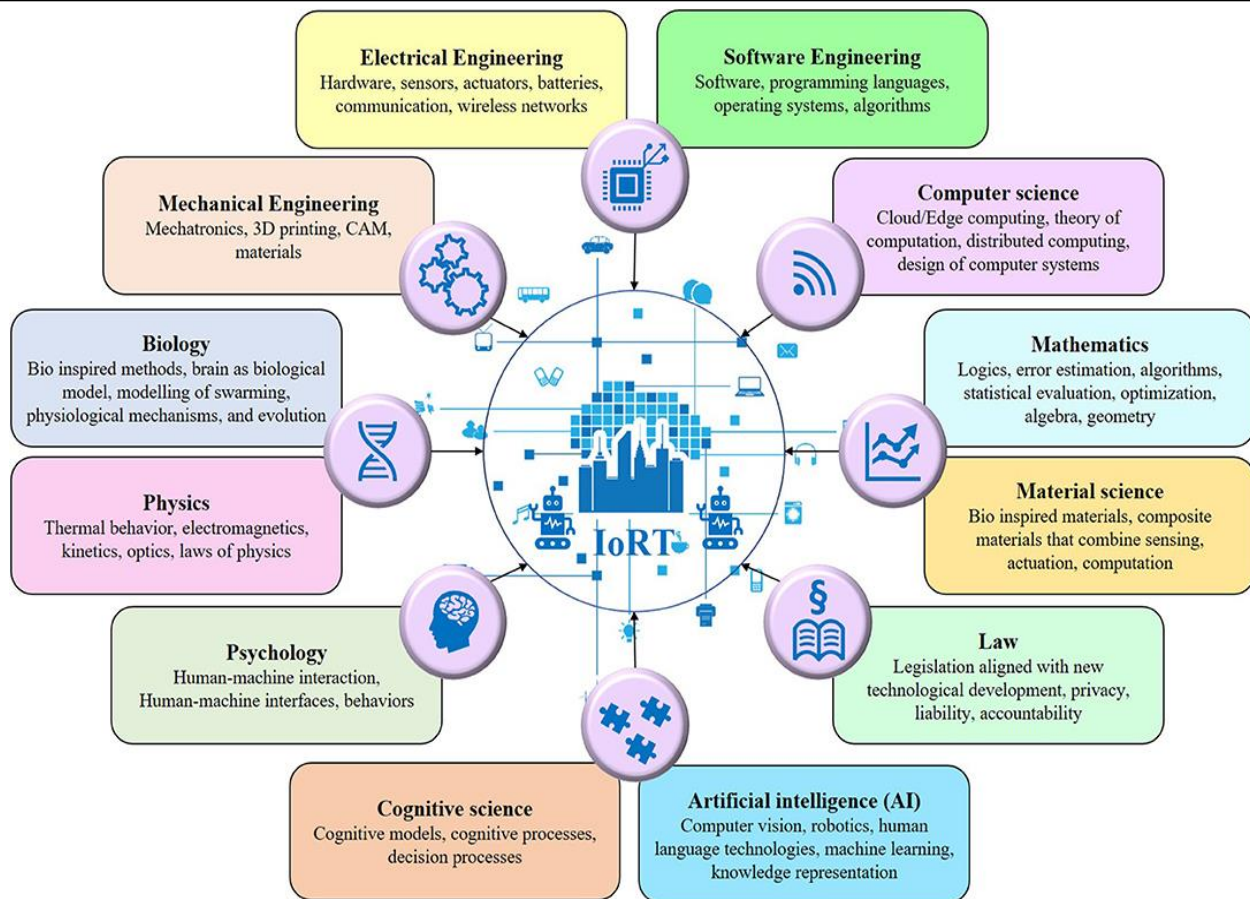


Figure 3 – IoRT An interdisciplinary branch of engineering and science

"Things" now range from simple Radio Frequency Identification (RFID) devices to smart wireless sensors, intelligent wireless sensors and actuators, robotic things, and autonomous vehicles operating in consumer, business, and industrial environments. The emergence of "intelligent things" (static or mobile) in collaborative autonomous fleets requires new architectures, connectivity paradigms, trustworthiness frameworks, and platforms for the integration of applications across different business and industrial domains. These new applications accelerate the development of autonomous system design paradigms and the proliferation of the Internet of Robotic Things (IoRT). In IoRT, collaborative robotic things can communicate with other things, learn autonomously, interact safely with the environment, humans and other things, and gain qualities like self-maintenance, self-awareness, self-healing, and fail-operational behavior [3]. IoRT applications can make use of the individual, collaborative, and collective intelligence of robotic things, as well as information from the infrastructure and operating context to plan, implement and accomplish tasks under different environmental conditions and uncertainties. The continuous, real-time

interaction with the environment makes perception, location, communication, cognition, computation, connectivity, propulsion, and integration of federated IoRT and digital platforms important components of new-generation IoRT applications. This paper reviews the taxonomy of the IoRT, emphasizing the IoRT intelligent connectivity, architectures, interoperability, and trustworthiness framework, and surveys the technologies that enable the application of the IoRT across different domains to perform missions more efficiently, productively, and completely. The aim is to provide a novel perspective on the IoRT that involves communication among robotic things and humans and highlights the convergence of several technologies and interactions between different taxonomies used in the literature.

Developments in heterogeneous IoRT processing and dynamic autonomous systems build on decentralized architectures, parallelism and concurrency require new concepts for integrating intelligent, cooperative, and collaborative robotic things with other IoT/IIoT applications (fig. 4).

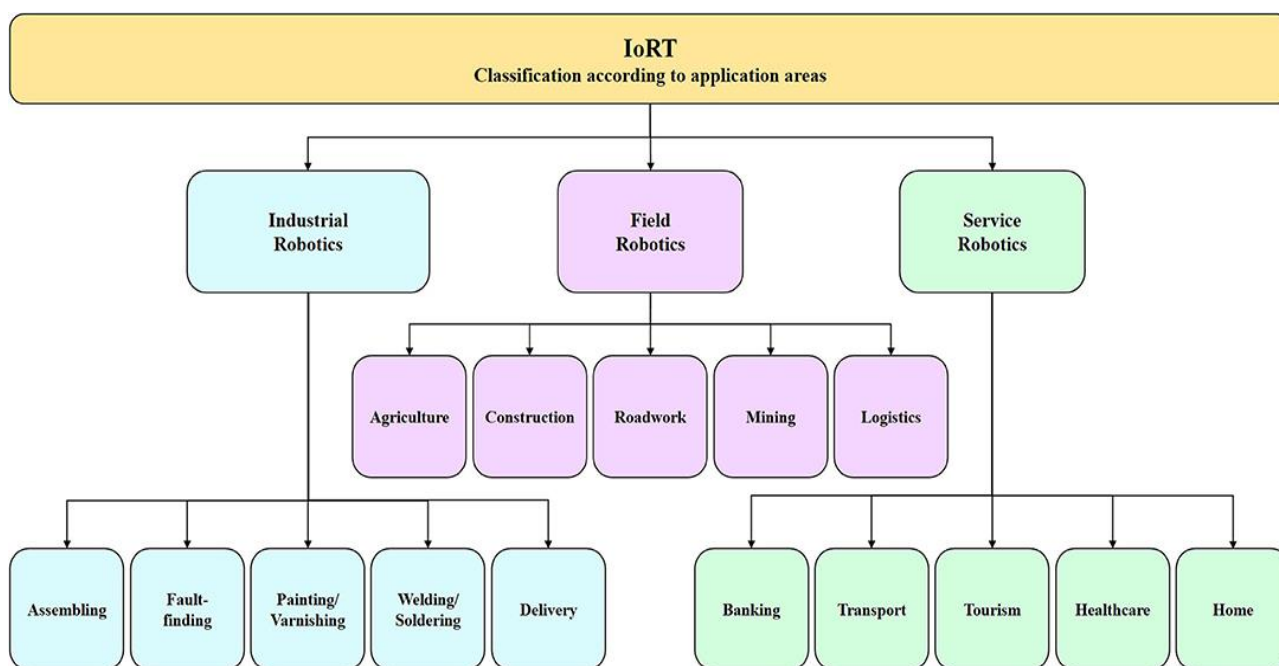


Figure 4 – IoRT classification according to application areas

A different IoRT taxonomy is based on the origin of robotics technology employed for the different applications, as presented in Figure 5.

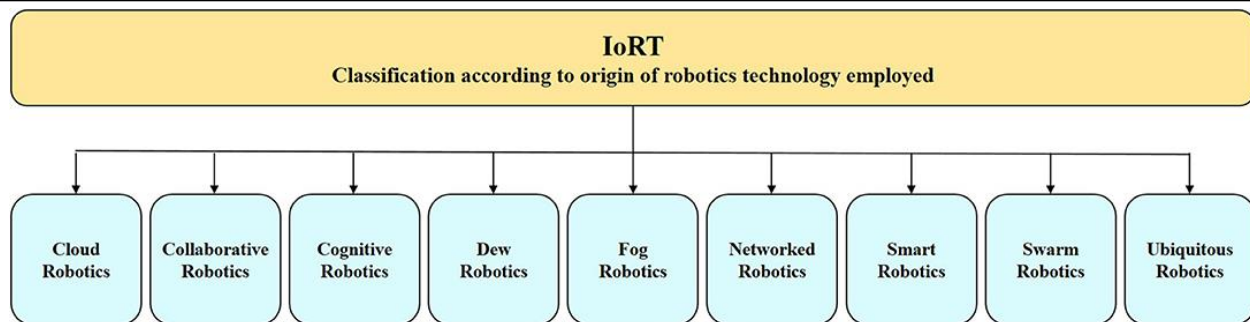


Figure 5 – IoRT classification according to origin of robotics technology employed

Cloud robotics is defined as a cloud-centric technology where the “robots are connected to cloud computing infrastructure” to get access “to distributed computing resources” with “the ability to share training and labeling data for robot learning”.

Collaborative robotics (co-bot) is defined as a technology where the robot is designed and programmed to physically interact with humans in a commonly used environment and workspace.

Cognitive robotics is considered a technology that allows enabling “a robot with intelligent behavior by providing it with a processing architecture that will allow it to learn and reason about how to behave in response to complex goals in a complex world”.

Dew robotics technology is linked to “dew computing” considering the tasks “extremely distributed” over many machines, “which are heterogeneous, ad-hoc programmable, and self-adaptive.

Fog robotics is addressing technology that is based on robot systems that use fog computing for processing data and services.

Networked robotics is addressing technology that includes “multiple robots operating together coordinating and cooperating by networked communication to accomplish a specified task”.

Smart robotics is referring to technology using “an embodied AI system that can learn from its environment and its experience and build on its capabilities based on that knowledge”.

Swarm robotics is using a technology based on “an approach to the coordination of multiple robots as a system which consists of large numbers of mostly simple physical robots”.

Ubiquitous robotics is addressing the technology for “integrating robotic technologies with technologies from the fields of ubiquitous and pervasive computing, sensor networks, and ambient intelligence”.

Robotic systems are seen as critical components for humanity's growth in the new digital era. The robotic systems were turned into industrial IoRT applications when technologies of IIoT, AI, robots, intelligent networking, and electric mobility emerged. Robotic things can now be connected to anything and everyone at robotic system is utilized to overcome the noise, congestion, and time-delay limitations of network robots.

Designing intelligent systems for operator support is iterative in nature and is based on the design of individual modules, subsystems and their integration into a single unit based on artificial intelligence and the use of modern tools of creation of intelligent applications.

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