ESMERA HEALTHCARE CHALLENGES

Robots are becoming increasingly useful in healthcare environments and have the potential to be a game-changer in healthcare. *As shown in the following graph from the IFR World Robotic report of 2018, the medical sector is the second largest sector for service robots after logistics. Within 2018 20% more service robots were installed than in 2017. Until 2021, 5 times more robots will be installed than in 2017.*

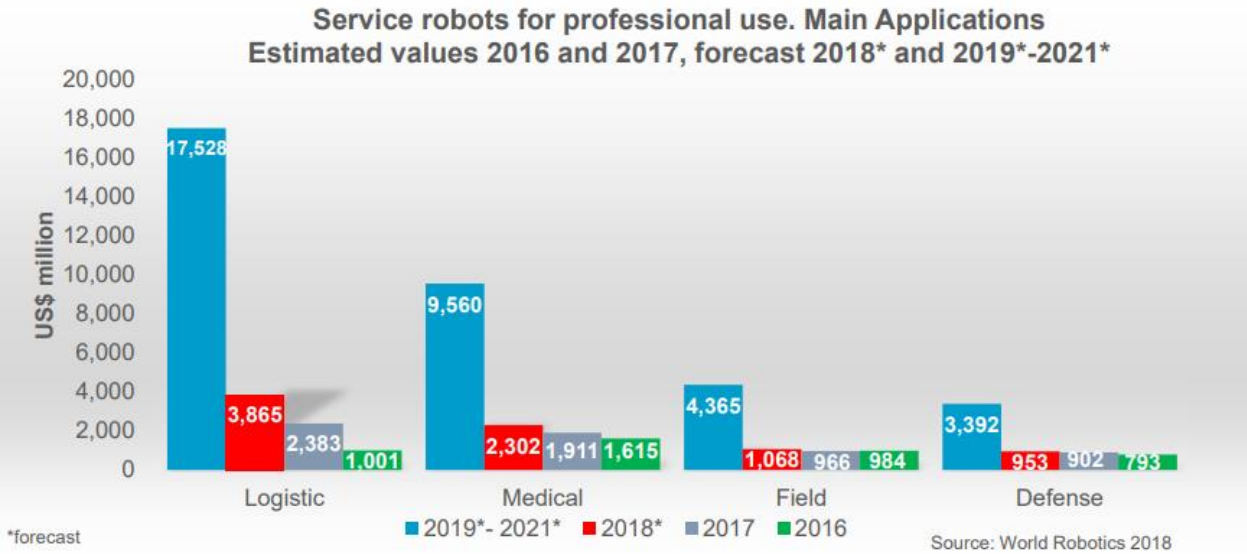

Figure 1. Service robots for professional use[1]

Today they also appear in many areas that directly affect patient care, where they can improve health and well-being, filling care gaps, supporting caregivers, and aiding health care workers. Types of robots in healthcare range from logistic robots that transport food, trash, linen, etc. over exoskeletons, surgery robots or assistive robots to Nano-robots that can operate inside the human body. Additionally, robots are used in the healthcare industry and laboratories. Frontrunners have deployed robots in hospitals, elderly homes, clinical laboratory, however, a great deal of applications in healthcare remain untouched by robots yet.

This domain offers the following technical topics of interest:

- Autonomous vehicles: autonomous navigation (incl. unmapped environments), map building and localisation, operation in dynamic environments such as hospitals; operation in close proximity with humans; and adaptability to environments with changing layouts.
- Human-machine interaction: robots in the healthcare sector encounter increasingly situations where they need to interact with humans or at least react towards human behaviour e.g. by following an order. The user interface has to be easily understandable.

By answering to this challenge, it would be possible to contribute to overcome some of the key barriers to market of robotic systems in healthcare, i.e., (1) lack of flexibility and adaptation of systems to changing facilities, (2) high cost of ownership and long term return on investment, (3) usability and acceptance (4) easiness to operate.

[1] https://ifr.org/downloads/press2018/WR_Presentation_Industry_and_Service_Robots_rev_5_12_18.pdf

Also, by solving these challenges, healthcare personnel, whether in care facilities or laboratories, will be supported in their daily work by automating tasks. It will be possible to automate tasks where no human is needed in order to relieve the personnel so that they can focus their work on more qualitative tasks e.g. spending more time with the patient.

The solution will have to fulfil the tasks of an assistive and/or clinical robot as described in the Robotics 2020 Multi-Annual Roadmap:

- **Assistive robotics:** The primary function of the robotic system is to provide assistive help either to carers or directly to patients either in a hospital or in a specialist care facility.
- **Clinical Robotics:** defined as robotic systems that support "care" and "cure" processes. Primarily in diagnosis, treatment, surgical intervention and medication, but also emergency healthcare. These robots are operated by clinical staff or other trained care personnel.

The solutions to be accepted by the market have to take into account usability, acceptability, cleanliness and autonomy with the tasks in order to relieve the healthcare sector.

As defined under healthcare and civil domains in the Robotics 2020 Multi-Annual Roadmap, the key abilities that are relevant for this challenge are:

- **Perception ability:**
    - Detection of a specific object
        - Situation / activity monitoring allowing to "propose" assistive activities to the user
        - Learning and detection of objects and / or environment to be manipulated
        - Recognition of more than 10000 objects indoor
        - Reliable grouping of objects with small differences
        - Sensing of volume and other parameters
    - Detection in a challenging environment
        - High-resolution multimodal perception and interpretation of objects, environments, persons and scenes
        - Reliable application in changing lighting conditions, indoor environment and for changing objects
- **Dependability:**
    - A safe system, a robust system against failure
        - Reliable about service
        - Reliable in a changing environment
    - Easy usability
        - For the commissioning
        - For daily life use and the interaction with the human
        - For other participants who are not familiar with the technology
        - Easy usability for service
        - Easy to clean
- **Autonomy**
    - Relief of care personal
        - No human interaction needed but possible
        - Hands-free operation
        - Novel kinds of interfaces
- **Integration**
    - Standard software

        - Easy integration into existing machinery
        - Easy adaptability to changing conditions
        - Plug and Play technology
    - Modular robots
- **Interaction:** The systems have to work in close proximity to humans. Thus, the systems should be designed with inbuilt safety capabilities, as well as adequate interaction abilities.
    - Shared workspaces and human safety
        - Run around human and any other objects
        - Prioritize human safety
    - Recognition of and adaptation to human behaviour
- **Safety**
    - Safety certified OS
    - A safety certification procedure for software
    - Intrinsically safe systems (mechanical systems and actuators)
    - 3D supervision systems to ensure collision-free manipulation
    - Semantic analysis of situation allowing to avoid critical situations in advance
    - Hardware safety concept including redundant sensing, processing devices and certified safety controllers
    - Safety verification procedures to comply with ISO 13482 and medical guidelines
    - Use of materials which fulfil the hygienic standards
- **Mechatronics**
    - Lightweight and energy-optimized design
    - Modular design to adapt the robot to the environment
    - Modular design to make a customized product
    - Low-cost robots
- **Navigation**
    - Indoor 3D mapping
    - 3D mapping and remapping with changes in the environment
    - Local real-time mapping for safe manipulation close to humans
    - Collision-free navigation and manipulation in dynamic environments
    - Automatic path planning merging visual, robot sensors information and knowledge-based medical information
- **Cognitive abilities and Natural Interaction**
    - Context understanding, situation awareness
    - Accurate and secure grasping of all sort of material and objects of different shape, texture, size and weight
        - Handling fragile objects
    - Automatic set of grasping posture in daily activities, making the system disappearing.
    - Multi-system, user procedure planning and task allocation, online procedure evaluation, re-planning and instructing, multi-expert diagnosis
    - Supervised learning from experience of new behaviour, of user preferences
- **Action Planning**
    - Multi-modal emotion understanding
    - Understanding of tasks and environments
    - Workflow planning (sequence of tasks)

ESMERA has identified following challenges as potential scenarios that proposals can use to develop and test their innovative ideas. Under each Healthcare challenge, ESMERA propose two options of industrial challenges that can be solved, option a) ESMERA proposed challenge and option b) Open challenge.

Healthcare Challenge 1: Precise measurement and sorting within special conditions

Perception technology provides a robot with the means to measure and interpret its environment. Especially in healthcare, this perception is required within special condition. In order to enable intelligent behaviour, perception technologies process raw sensor measurements to infer additional information and represent sensor data in a useful way. Additionally under some conditions sorting of this biomedical samples as described in Robotics 2020 Multi-Annual Roadmap is relevant as well. The developed systems have to be able to operate with(in) organic objects and soft objects. This challenge focuses on technologies and systems that allow robots to handle arbitrary objects of varying geometry and weight while requiring only a few to no user input.

It is expecting from the solution to fulfill the following metrics:

- **Precision of measurement:** This KPI can be considered in two main topics as follows:
    - Precise measurement within given boundary conditions: In healthcare precise measuring is very important. It is used in the production of medicine but also for lab tests or in other areas. The number of possible lab tests in a hospital is more than 1500[2]. For a lot of them, the patient gives a blood sample and different tests are carried out. For the tests, different liquids have to be separated into different tubes (aliquoting process). This precise measurement should be done by a robot to increase accuracy, reliability and could already give some lab results through using new testing methods while separating the liquids. For these processes, the measurement unit has to be part of the existing machinery. This means there are given boundary conditions which have to be fulfilled, e.g. size, communication system, etc.
    - Measurement of specific parameters based on optical difference: Within laboratories, specific items have to be sorted in different categories. The sorting conditions are no standard parameter where common technologies (e.g. sort by size) can be used. The objects to sort have different optical appearance how they differentiate from each other. The robot should detect different categories based on the optical difference. Additionally, the task for the robot is to separate these objects without damaging them.
- **Cautiousness of handling objects:** It is expected from the system to have accurate and secure grasping of all sort of material and handle them without damage on the material.
- **Adaptability to handle different objects:** It is expected form the system to have accurate and secure grasping of all sort of material and objects of different shape, texture, size, weight, etc.

Under the above challenge, ESMERA project proposes two options. The proposer must address at least one of these challenges although addressing more than one or highlighting where elements of the proposed system could be used for the benefit of more than one system would be beneficial.

A) ESMERA proposed challenges: this challenge is extracted from *two* industrial use case which are:

[2] https://labtestsonline.org/tests/thiopurine-methyltransferase-tpmt

HEALTHCARE CHALLENGE 1. A1 (H1.A1)

Liquid Volume Detection in Automated Pipetting Units: Automation lines introduced in clinical laboratories and hospitals are often composed by a transport system that brings the tubes from check-in robots to other many pre-analytical robots/modules; after that the tubes are presented to third parties' analysers, and then managed by other robotic modules for storage, reruns or disposal. This is done without human intervention, to avoid errors that repetitive tasks usually bring.

In these automation lines, one of the core robots is the pipetting unit, that aliquots the liquid from a primary tube to secondary others to be sent to different analysers (aliquoting process) or aliquots the liquid from different primary tubes to the same secondary one to concentrate test checks (pooling process).

Figure 1: Aliquoting module

Figure 2: Pipetting unit and tube and tip

HEALTHCARE CHALLENGE 1. A1 (H1.A2)

Detection of male and female mosquitoes: The goal is to have a technology that can separate males from females with an ability to process several million mosquitoes per day.

The length of the adult is typically between 3mm and 6mm. The smallest known mosquitoes are around 2 mm (0.1 in), and the largest around 19 mm (0.7 in) Mosquitoes typically weigh around 5 mg[4]. All mosquitoes have slender bodies with three segments: a head, a thorax and an abdomen.

The robot should be able to discriminate the mosquito males from the mosquito females when transported on a conveyor belt. Measurement of success is a false positive result below 0.1%;

The ultimate goal is to physically separate them in two containers (one of males the other of females), without damaging them.

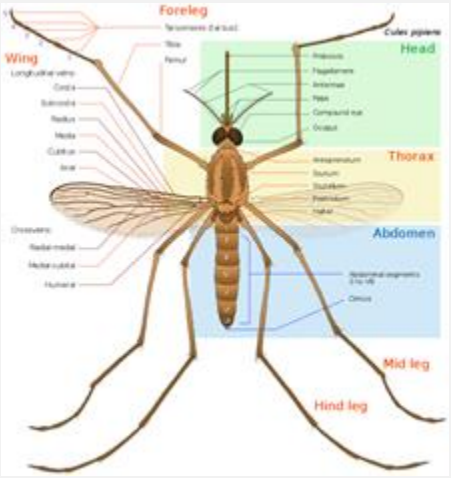

Figure 3 Anatomy of adult mosquito

B) Open challenge (HEALTHCARE CHALLENGE 1.B (H1.B))

[4] Krinsky, W. L. (2013). Medical Entomology for Students. Proceedings of the Entomological Society of Washington, 115(1), 112-115.

Any other proposal for similar technologies is eligible for funding, provided that a thorough explanation of the industrial needs is presented. The proposals will also have to clearly identify the state of the art in commercially available solutions and highlight the differences/advances over it. More specific each proposal in order to be in line with the ESMERA requirements has to provide:

- Clear indication of the company, institution or other that are in need of the proposed solution (no funding is allocated to challenge providers)
- Description of the problem that the company or companies need to be solved.
- Proof that currently there is no comparable solution (concept or approach, performance, cost…) in the market.

The healthcare sector offers exhaustive areas for potential robotic solutions. The following suggestions are examples of possible challenges that have been identified outside ESMERA. For this problem, ESMERA cannot offer a challenge provider (thus no extra points will be assigned during evaluation). Applicants interested in submitting a proposal for the below challenges will need to find a challenge provider and show that their product is relevant for the market.

Healthcare Challenge 2: Cleaning

The spread of infectious disease from hands and surfaces has a great impact on the spread of infections in the healthcare industry. Furthermore, 60% of German nursing homes experience bad hygiene, especially regarding food leftovers that in some cases are simply ignored. Additionally, patients often suffer from bad oral hygiene because employees' lack of time, prioritisation and competencies. Especially time-consuming or routine tasks are not done appropriately enough. Automatic cleaning solution exists on the market today, but they do not fulfil the demand, users request fully automated systems. Some examples in this category are:

- **Cleaning of wheelchairs, toilet chairs, beds and nightstands:** This theme was chosen because the employees experience this task as time consuming. Employees do not appreciate the task as they e.g. are forced into ergonomically incorrect positions. Furthermore, there is not enough time allocated for the tasks and it causes a lack of sufficient cleaning which raises the risk of transmitted infections.
- **Cleaning of patients' hands:** Cleaning of patients' hands is lacking in the everyday routines of the employees. This includes cleaning of hands after use of the toilet, before and after eating, etc.
- **Cleaning of dentures:** This task is mainly done quickly and not too often. The fact that the employees de-prioritize the task, can be offensive to the patient. Furthermore, the lack of cleaning of dentures can cause bacteria in the mouth cavity and pneumonia.

Please consider **HEALTHCARE CHALLENGE 2.B (H2.B))** ID for this challenge.

Healthcare Challenge 3: Transportation of equipment

Related to the Robotics 2020 Multi-Annual Roadmap assistive robots provide help to carers or patients directly. Transportation of equipment means a lot of walking for the care personal and physical stress. Some examples can be:

- **Transporting Food:** the task requires a lot of walking back and forth. All of the employees have to prepare and bring food at the same time; this creates a crowded workflow in the kitchen area. This task also includes the **perception of food intake.** To support the healing process for the patient it is important that they eat enough and the right food. For this, the hospitals have to track what food did they deliver to the patient and what was actually eaten. To do this for all patients manually takes a lot of time. Furthermore, the patients' food intake is often not registered, because the task is time consuming and because food is brought to the patient by one person and picked up by another.
- **Transportation of large equipment:** this task is physically hard and time-consuming. The employees have to call an orderly to pick up large equipment, e.g. for lifting patients, which is also time-consuming. This theme also includes transport of laundry, which is being transported by the employees.

Please consider **HEALTHCARE CHALLENGE 3.B (H3.B))** ID for this challenge.