The 2017 World Congress on
Advances in Nano, Bio, Robotics and Energy (ANBRE17)
28 August - 1 September, 2017, Ilsan(Seoul), Korea

Required technical and intellectual abilities for autonomous mobile medical service robots

*Dmitry A. Rogatkin[1), 2)]

[1)]*Laboratory of Medical and Physics Research, MONIKI named after M.F. Vladimirskiy, Shepkina str. 61/2, Moscow, Russia;*
[2)]*LLC "R&D Center EOS-Medica", Nauchny proezd, 1, Moscow, Russia*
[1)]*rogatkin@medphyslab.com*

ABSTRACT

Autonomous mobile service medical robots (AMSMR) is one of the promising sections of the contemporary medical robotics. In this study, required technical and intellectual abilities for AMSMR were under consideration. Expert analysis of the basic scenarios of AMSMR's behavior in clinics enabled classification of such a robot as the intellectual dynamic system acting according to a situation in a multi-object and a multi-agent environment. Therefore, AMSMR should identify different objects that define the given territory (rooms, passes), different objects between and inside rooms (doors, tables, beds, etc.), other robots, means for interaction with them, people, their speech, different information for a communication and small objects for a transportation. These is the minimum set required to form the internal World model in AMSMRs. One of the most difficult problem is a recognition of door handles and door opening. Other required ability is the ability to recognize the meaning of human speech and human actions to assist them in a full manner. All these define that AMSMRs will need to pass through several learning and training programs before starting their real work in hospitals.

1. INTRODUCTION

There is a great need in medicine in performing a large number of different routine transport, information, and other auxiliary service procedures. Therefore, autonomous mobile service medical robots (AMSMR) is one of the promising sections of the contemporary medical robotics (Wang *et al*., 2006; Butter *et al*., 2008; Rogatkin *et al.,* 2013; Ciupe *et al.*, 2014). The first AMSMR named «AMS-car» appeared in the mid-1970s in the Fairfax hospital (USA) to move containers with food trays to patients. At present, there are hundreds of articles in journals, as well as in Internet devoted to different AMSMR in clinics including «HelpMate» – the project of the transport service robot for delivery of different drugs, analyses, materials, and documents inside a hospital (Evans, 1994). Also, Russian robot «R-Bot» for telepresence and remote-presence robots "RP-7", "RP-8", etc. – information robot-manipulators allowing oral and visual communication of physician with a patient (Wang *et al.*, 2006), and a number of other similar projects are known. The last generation of the "RP" robot family – robots of the "RP-VITA" series – was approved in 2013 by FDA, and its invasion into hospitals was really started (see http://www.intouchhealth.com/products-and-services/products). Robots "RP-VITA" can move themselves round the clinic territory, find up the room of

interest and a patient's bed without human participation. A doctor must only point out the aim for the robot by pressing the corresponding button. However, until now there are not general methodical manuals and rules for engineers how to create such clever machines. Due to the complex problem of creation of intelligent robots, real smart AMSMRs do not exist in hospitals yet. Today, all known medical robots including "RP-VITA" robots are rather manipulators, programmed automatons, than autonomous intellectual and smart machines.

The main objective of our theoretical study is the investigation and elaboration of the problem of formulation of scientifically justified requirements to the hardware and software for AMSMR. First, after a short Introduction in the Section 1, the basic concept (scenario) of AMSMR functioning in clinics is considered in the Section 2. Then, based on it, in Sections 3 and 4 the required technical and intellectual abilities to fulfill the concept is described.

2. FUNCTIONAL DUTY OF AMSMRs IN HOSPITALS

At the initial stage of our study, we interviewed physicians and patients of different departments of the multi-clinical and multi-functional medical research center "MONIKI" in order to receive the verbal description of the most prospective AMSMR applications in the health care system (from the point of view of both physicians and patients). Then, all interviews were generalized and analyzed by the method of the expert assessment (Rogatkin *et al.*, 2015a). In addition, we imitated and simulated different situations by means of a mental experiment to substantiate various options for the robot's duties and actions. Several simulated examples of AMSMR functioning in hospital were as follows:

Example 1. Doctor orders AMSMR to find the patient N on the hospital's premises and to inform him about the beginning of a new stage of treatment since tomorrow morning. The robot knows where the bed of the patient is; it goes into this room, but does not find him there. The patient is temporarily out. The robot makes a short detour round the territory and finds the patient in a lounge. Then AMSMR starts a verbal contact with him and informs the patient about the new treatment procedure and its sense for him.

Example 2. Doctor before going on summer holiday must transfer to another doctor some information and documents. However, this another doctor is absent today and will be at work only in the next morning. The first doctor tells the robot to do it instead of him, and puts the documents in one of the drawers inside AMSMR like in a safe box. The next morning the robot finds the desired recipient, gives him verbal information and opens the drawer.

Example 3. On the duty-post in front of the entrance/exit of a certain department of a hospital a team of robots meets and observes incoming/outgoing people. A new visitor comes and wants to visit his friend N. Master-robot orders the slave-robot to accompany the visitor to his friend, to find his friend and to make sure that they really familiar with each other.

As a result, in addition to the telepresence (remote-presence) function, which is often mentioned in publications as the main useful function for AMSMR, the following prospective tasks were determined, which are very interesting to solve and which can be solved with the help of AMSMR:

- Interactive lecture-excursion (10-15 minutes) for patients at the moment of their admission to the hospital about daily routine in it, about building plan, etc.;
- Information of patients about the time of diagnostic and (or) treatment procedures, repeated reminding about it within 15-20 minutes before the time in the concrete day;

- Searching within the clinics for a given patient, physician, or (and) a nurse to inform them about concrete instructions, problems, including the urgent ones;
- Delivery of drugs, small things, documents, etc. to patients or medical staff in their wards (rooms) and back, save it for the given recipient;
- Listening (recording) to requirements and complaints of patients and passing these information to medical personnel;
- Monitoring of the presence of unknown objects/people on the clinic premises.

It becomes clear from the list above mentioned, that the vast majority of prospective scenarios for AMSMR is associated with a transport as well as with information-searching tasks within the limits of the room-type territory. Shortly speaking, AMSMRs are needed in hospitals to implement quite compact and rather unified set of simple instructions, such as: to implement different errands associated with seeking an object of interest, interaction with different objects, delivery of objects, receiving and storage information from people, information processing and transmission to other people. All these functional duties of AMSMR (service and assistant functions) appeared to be common for the majority of departments of a typical hospital. Consequently, they might be general for a typical and universal AMSMR. It makes the generalized task of AMSMR functioning a finite one, limited (restricted) both in physical building space and in the space of possible decisions and actions, as well as of the closed type, i.e. all possible situations and methods of their resolution can be described exhaustively in the closed form. It allows us to illustrate all main functional duties as follows (Figure 1):

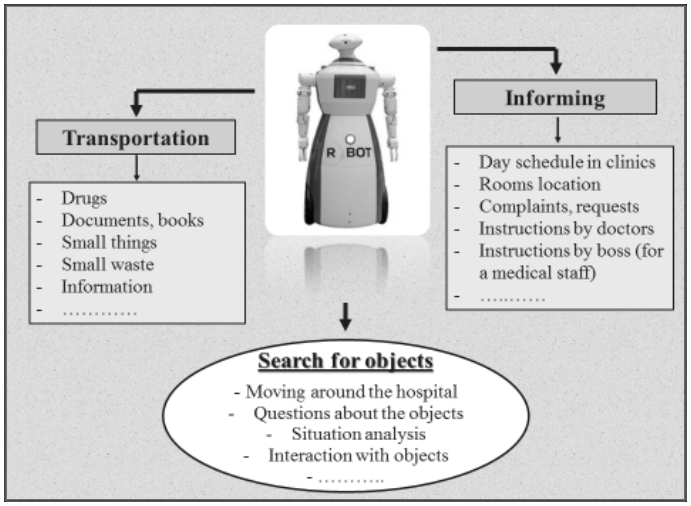

Fig. 1 Functional duties of AMSMR in hospitals.

3. REQUIRED TECHNICAL ABILITIES

As one can see, in order to perform all such duties, AMSMR needs corresponding hardware. Simple detailed analysis shows that AMSMR should consist of a mobile platform, which has attached sensors, at least one arm (a mechanical unit) to operate with doors, and audio/visual interface for interaction with people/robots. It also should have several drawers - boxlike storage compartments, made to slide horizontally in and

out of a robot's chest, which are intendent for small things for a transportation. All these determines the generalized structure of AMSMR as it is shown in Figure 2.

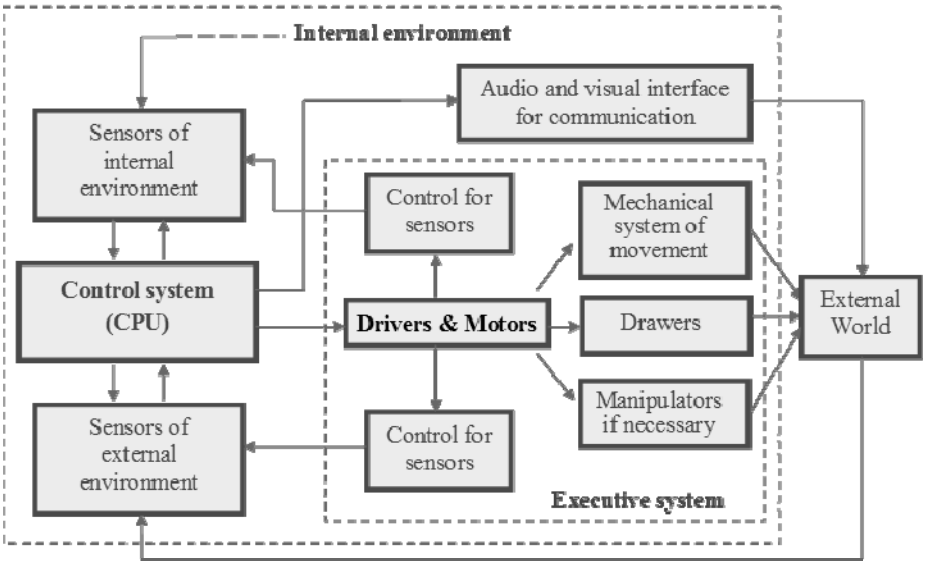

Fig. 2 Generalized structure of AMSMR.

One of the most difficult problem can be a manipulator (unit) to open doors. It is possible to adapt the environment, doors for automatic opening by external commands, but there will be not an autonomous robot acting independently in this case. Therefore, the most universal and cheap solution of this problem is a one manipulator on a mobile platform for all doors. Along with it, other hardware is typical for all mobile robots – motors, odometry sensors, distance meters, rechargeable battery, etc., so there is no need to describe them in detail here. Maybe a few words only it makes sense to tell about the speed of movement of the robot, as well as about the capabilities of the battery. The movement of the robot inside a hospital should be not faster than 1 km per hour in the general case to avoid an accidence. At urgent situation or at dangerous one, the speed can be risen up to 2-3 km per hour, but not more. The useful period of a robot action between the battery recharges should be not less than 8 hours. However, in the case of the extreme danger even after 8 hours of hard work each robot should be able to act 1-2 hours more without the battery recharging.

4. REQUIRED INTELLECTUAL ABILITIES

Expert analysis of the basic scenarios of AMSMR's behavior in clinics enabled classification of such a robot as the intellectual dynamic system acting according to a situation in a multi-agent environment. To follow the scenario in a full-scale, AMSMR must have well developed model of our World – the internal World Model (WM). AMSMR should identify different objects of a given territory (rooms, doors, door handles, etc.), people, their speech, other robots, and small things for a transportation. One of the most difficult problem is a recognition of door handles and both hardware and software resources to open the doors effectively. Other required ability is the ability

to recognize the meaning of human speech and human actions to assist them in a full manner. It proves that such AMSMRs will need to pass through several learning and training programs before starting their real work in hospitals. Since it is impossible to construct artificial intelligence without learning (Russel *et al.*, 2003; Rogatkin *et al.*, 2015b), the learning abilities should be included in AMSMR software, first of all.

Simulation of both typical situations and scenarios of AMSMR behavior in clinics allows one to formulate the required intellectual abilities for their implementation by AMSMR in different situations, as well. It is important, that any intellectual abilities are used and are necessary only if the interaction with external environment and (or) external objects (subjects) is expected or exists. Therefore, all generally required abilities can be classified according to different types of interactions (Table 1). They can differ if known or unknown object (subject, item) is coming up to interact, so, one of the base AMSMR intellectual abilities should be the determination of known/unknown object (subject, item), which follows from the checking procedure, is this object (subject, item) included in the robot's internal WM or not. Memory of AMSMR should store a history of interactions with these object, for example, the history about distributed things and (or) information between people. To interact with objects it is also necessary to recognize their functional state, for example: is the patient asleep or not; is the door opened or closed, is the object is moving or stays motionless, etc.

Shortly, WM of AMSMR, in the general case, should involve not only a structuralized set of categories (objects) of the environment and their physical characteristics for a recognition, but also should involve the means of description of the possible semantic associations between all objects, description of their possible functional state, history of their movements, their possible interrelations, and rules of such interrelations. All these determines the needed structure of WM. It must include, in addition to physical models of external objects (rooms, furniture, etc.), some general non-object and procedural (functional, semantic) terms: way, distance, trajectory, direction, motion, belonging to a man, etc. The AMSMR model itself, also, should be the important element of WM. It allows a robot to determine itself as the key element (object) of the World, which is able to move, communicate with other objects, and simultaneously (in a certain way) as a special "subject" of the World, which means impossibility to ordinary communicate with itself (with the object "I am") like with other objects. For example, it is impossible to search for itself. All these requires the presence in WM several models of the robot's "physical" and "analytical" opportunities.

Today a number of approaches is known to formation of such WM for autonomous mobile robots (Roth *et al.*, 2003; Burgard *et al.*, 2008; Elfring *et al.*, 2013). However, the overwhelming majority of such WM are de-facto a simple geometrical description of the territory map and objects location in the indoor environment (Kułakowski *et al.*, 2010). They describe statistical panorama (situation) of the territory, but tell nothing of the history, logic, and the possible ways of this situation development with time. Such WM is, definitely, needed, but it is only one of the elements of the really required, full-scale, effective and workable WM for AMSMR.

Some publications (Burgard *et al.*, 2008; Elfring *et al.*, 2013)) indicate that a set of special semantic attributes of the objects describing sense (semantic) associations between all objects are needed to create WM of full workable. To our opinion, WM presented by B. Coltin *et al.* (Coltin *et al.*, 2010), is the most similar to the required WM

Table 1. Main required intellectual abilities for AMSMR.

No.	At interaction with:	if known:	if unknown:
1	Territory (rooms, passes)	Determination of the current location, way planning, obstacle avoidance, doors opening.	Mapping, incorporation new data in the internal WM database, doors opening.
2	Furniture, other objects	Recognition of the object to interact. Recognition of belonging of the object to the person (robot). Determination if the object is obstacle; if it is, than is it movable (like a door) or not (like a cupboard). Planning an effective procedures to interact (to remove, to bypass, to search for a patient inside (if bed), etc.).	Classification to one of the known type of objects. If impossible, then alarm. Determination of belonging of the object to the person (robot). Determination of friendly or dangerous objects. If friendly, incorporation new data in the internal WM. If dangerous – alarm.
3	People	Recognition of the person to interact. Recognition of doctor/nurse/patient. Exchange of information (if necessary). Recognition of orders (commands). Exchange of small things (if necessary). Performing actions by commands. Prioritization of the commands.	Determination of friendly or dangerous. If friendly, incorporation new data in the internal WM. If dangerous – alarm.
2	Other robots	Recognition of the robot to interact. Exchange of information (if necessary), of commands, and data with it. Validation of the necessity and correctness of such exchange. Determination of the situation master/slave. Teamwork.	Determination of friendly or dangerous. If friendly, incorporation new data in the internal WM. If dangerous – alarm.
3	Small things	Recognition of the thing to interact. Recognition of belonging of the thing to the person (robot). Determination of the thing dimensions, if it is possible to be located and transported in drawers.	Classification to one of the known type of things. Determination of belonging of the thing to the person (robot). If impossible, then alarm.
4	Itself	Prioritization of actions. Planning of actions. Evaluation of the possibility to act in the given situation. Evaluation of the battery charge and health of the internal “organs” (blocks, units) to act.	Not applicable

for smart AMSMR. It offers a modelling approach that differentiates among the motion models of different objects in terms of their dynamics, namely the static landmarks (e.g., goal posts, lines, corners), the passive moving ball, and the controlled moving robots, both teammates and adversaries. In their article WM is a tuple {O, X, S, M, H, U}, where: O is the set of labels of objects in the World, X is the set of possible object states, S is the set of possible sensor readings, M is the set of models of the objects, H: MxO→X is a hypothesis function that returns the current state of an object, U: MxOxS→M is the model update function. Perception of the state of the World by the robot using such WM is the most completed today, but, unfortunately, this WM is restricted by the objects of the football playing situation only. It is based on the concrete football-game data of robot's sensors (tuple S), and, therefore, it is not widely applicable for AMSMR. AMSMR needs its own, special WM. Therefore, the problem of development and formation of such WM is one of the key problem on the way of AMSMRs incorporation into hospitals.

5. CONCLUSION

We tried to develop the formal and scientifically based approach for substantiation of technical and intellectual abilities for autonomous mobile service medical robots (AMSMR), as well as technical requirements to AMSMR "from first principles". Until now, really smart, intellectual AMSMR do not exist in our hospitals due to the complex problem of creation of such intelligent machines. At present, there are not any general methodical manuals and rules for engineers how to create such AMSMR. What should be done as the first step on this way? Should we create a hardware or a software first? In fact, this unstudied situation is one of the key reasons preventing the worldwide usage of robots as daily service machines (Mastrogiovanni and Chong, 2013).

The expert analysis of basic scenarios of AMSMR behaviour enabled classification of such robots as intellectual dynamic systems acting according to a situation in a multi-agent environment. AMSMR are expected in clinics to implement different errands associated, mainly, with seeking an object of interest, interaction with it, receiving and storage information from people, information processing and transmission to other people. In order to perform such duties, AMSMR first needs corresponding hardware. Detailed analysis showed that AMSMR should consist of a mobile platform, which has attached sensors, at least one mechanical unit (arm) to operate with doors, and audio/visual interface for interaction with people. It also should have several drawers - boxlike storage compartments, made to slide horizontally in and out of a robot's chest, which are intendent for small things for a transportation.

As it was also shown in the study, to follow the scenario in a full-scale, such a robot must have a well-developed model of our World – the World Model (WM). AMSMR should identify different objects of a given territory (rooms, doors, door handles, etc.), people, their speech, other robots, information for a communication, and small things for a transportation. One of the most difficult problem is a recognition of door handles and both hardware and software resources to open the doors effectively. Other required ability is the ability to recognize the meaning of human speech and human actions to assist them in a full manner. Since it is impossible to construct the artificial intelligence without learning, the learning ability should be included in AMSMR software

as the basic ability. Then, any intellectual abilities are necessary only if the interaction with external environment and (or) external objects is expected or exists. Therefore, all required abilities can be classified according to different types of interactions. Such a classification was formulated in this study. It allows the formal description of functional requirements to robot's software and WM, assisting to create WM in a closed form.

REFERENCES

Burgard, W., Hebert, M., 2008. World modelling. *In Springer Handbook of Robotics, B. Siciliano and O. Khatib eds. 853-869.* Springer. Berlin.

Butter, M., Rensma, A., Boxel, J., *et al.*, 2008. Robotics for Healthcare. *Final report of the study within framework of the e-Health activities of the EU Comission*. EU Comission, DG Information Society. Brussel.

Ciupe, V., Maniu I. 2014. New Trends in Service Robotics. In *New Trends in Medical and Service Robots*, *Ed. By D. Pisla et al.* Mechanisms and Machine Science. 16. 57-74. Springer Publishing. Switzerland.

Coltin, B., Liemhetcharat, S., Meriçli, Ç., Tay, J., Veloso, M., 2010. Multi-humanoid world modelling in standard platform robot soccer. *In Proceedings of 2010 IEEE-RAS International Conference on Humanoid Robots*. Nashville. TN. USA.

Elfring, J.,Van den Dries, S., Van de Molengraft, M., Steinbuch, M., 2013. Semantic world modeling using probabilistic multiple hypothesis anchoring. *Robotics and Autonomous Systems*. 61(2). 95-105.

Evans, M.,1994. Helpmate: An autonomous mobile robot courier for hospitals*. In Proceedings of International Conference on Intelligent Robots and Systems (IROS '94)*. 1695-1700. Munich. Germany.

Kułakowski,K., Wąs, J., 2010. World Model for Autonomous Mobile Robot - Formal Approach. *In Proceedings of 18th International Conference on Intelligent Information Systems (IIS'2010)*. 37-45. Poland.

Mastrogiovanni, F., Chong, N. Y., 2013. The need for a research agenda in intelligent robotics. *Inelligent Service Robotics*. 6. 1-3.

Rogatkin, D. A., Lapitan, D. G., Lapaeva, L. G., 2013. Conception of the mobile autonomous service medical robots. *Biomeditcinskaya radioelektronika [Biomedical radioelectronics]*. 5. 46-56. (in Russian).

Rogatkin, D.A., Lapaeva, L.G, Bychenkov, O.A., 2015a. Autonomous mobile medical service robot: scenarios of behavior and a world model. *In Proc. of 4-th Int. Conf. on Biomedical Engineering and Biotechnology (ICBEB2015)*. 9-10. Shanghai. China.

Rogatkin, D.A., Kulikov, D.A., Ivlieva, A.L. 2015b. Three Views on Current Data of Neuroscience for the Purposes of Intelligent Robotics. *Modeling of Artificial Intelligence*. 6(2). 98-136.

Roth, M., Vail, D., Veloso, M., 2003. A real-time world model for multi-robot teams with high-latency communication. *In Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems*. 2494–2499. Las Vegas. Nevada.

Russel, S., Norvig, P., 2003. *Artificial Intelligence. A Modern Approach*. Prentice Hall, New Jersey, 2nd edition.

Wang, Y., Butner, S., Darzi, A., 2006. The Developing market for medical robotics. *In Special issue "Medical Robotics". Ed. by T. Kanade, B. Davis and C.N. Riviere, Proc. IEEE*. 94(9). 1763-1771.