Robotics and the quality of life: the case of robotics assisted surgery

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Abstract: Robotics is one of the most developing technological field that combines many scientific disciplines and has important social, ethical and economical effects. The philosophical debate on Artificial Intelligence is part of the classical branch of the philosophy of mind and developed interesting results crossing several disciplines (such as psychology, cognitive science, neuroscience, neurobiology etc.). Many interesting views moved mostly from Turing challenges about human and machine intelligence. After a general presentation of new trends in the ambit of AI, which try to intend computing as natural and embodied, we present the case of robotics assisted surgery as a very important example of a practice which requires also practical considerations.

Keywords: Turing machine; natural computing; robotics; roboethics, robotic assisted surgery.

1. *Introduction*

We are a peculiar kind of animal indeed, that kind which tries to replicate its own intelligent and autonomous being. In this context, the problem of computing namely how human and artificial intelligence compute is central (Dodig-Crnkovic, Giovagnoli 2013). Alan Turing provided the foundation for the theory of computing; after many decades of development computers are quite different from the classical Turing Machine, that was designed to mechanize computation of mathematical functions. Computers are networked and largely used for world-wide communication and variety of information processing and knowledge management. They are cognitive tools of extended mind (Clark, Chalmers) used in social interaction and they provide ever growing repositories of information. Moreover, computers play an important role in the control of physical processes and thus connect directly to the physical world in automation, traffic control, robotics and more.

After relevant criticisms to the GOFAI program (the program of the classical strong AI), that, from a philosophical point of view, are exemplified by the famous thought experiment of the "Chinese Room" invented by John Searle, new forms of computing are rapidly evolving. Computational processes running in networks of networks (such as the internet) can be modeled as distributed, reactive, agent-based and concurrent computation. This new form of computation is successful not in virtue of its termination but of its behavior: responses to changes, its speed, generality and flexibility, adaptability, and tolerance to noise, errors, faults and damage. Natural/unconventional computation can be seen as generalization and enrichment of the repertoire of classical computation models. As a generalization of the traditional algorithmic Turing Machine model of computation, in which the computer was an isolated box provided with a suitable algorithm and an input, left alone to compute until the algorithm terminated, natural computation models interaction i.e. communication of computing processes with each other and with the environment. In natural systems, computation is information processes that can proceed on both symbolic and sub-symbolic (signal-processing) level. For human cognitive processes it means that not only the execution of an algorithm can be seen as computation, but also learning, reasoning, processing of information from sense organs.

2. *Human Animals, Non-human Animals and Machines*

The human tendency to replicate its being compels scientific communities to investigate the very concept of intelligence in humans, animals and machines (Dodig-Crnkovic, Giovagnoli 2017). We can refer to both historical attempts of making connections, with machines and mechanistic models in focus, in (Wiener 1961), and (Putnam 1988). Popper (1972) made connection to the ideas of man-machine "Yet the doctrine that man is a machine was argued most forcefully in 1751, long before the theory of evolution became generally accepted, by de La Mettrie; and the theory of evolution gave the problem an even sharper edge, by suggesting there may be no clear distinction between living matter and dead matter. And, in spite of the victory of the new quantum theory, and the conversion of so many physicists to indeterminism de La Mettrie's doctrine that man is a machine has perhaps more defenders than before among physicists, biologists and philosophers; especially in the form of the thesis that man is a computer." Unlike Wiener, La Mettrie and Decartes (with his animal machine or Bête machine), who compare mechanical machinery with biological organisms, Putnam in his functionalism offers another type of machinery – computing machinery as a model of human mind.

Functionalism as theory of mind is based on the idea that mental states (states and processes that correspond to thinking and feeling) are best understood by their functional role in causal relations to sensory inputs, other mental states and behavior (Block 1996). In Marr's three-level analysis of information processing systems, it focuses on the intermediate level connecting physical level with the behavioral output (Marr 1982, 2010).

Since 1980-ies huge amount of new knowledge has been generated that changed both our understanding of mind (cognition) and our ideas of computation – what it is and what it could be.

Putnam (1988) argues that there cannot be one theory of the human mind that would be able of capturing all of its aspects at the same time, within the same conceptual framework. We agree empathically with Putnam here and move from the deep conviction that complexity of the world, including complexity of phenomena of cognition/mind cannot be exhausted by any single conceptual framework or approach, for several reasons.

1. Contemporary science is divided in multiplicity of specialist fields that use specialist (domain-specific to borrow the term from software engineering) languages. What we really are working on is learning from each other and connecting domains into a network that could be traversed when investigating different facets of a phenomenon.
2. The philosophy of science is built on unreflected metaphysical grounds inherited by the "language turn", logical empiricism and critical realism. It presupposes finite and definite axiomatic system from which all truths as utterances are derived, as an ideal of exact science and reasoning. There are no mechanisms. Science and knowledge in general are about "statements not about behaviours, processes, dynamics. In the computational formulation, this ideal of science leads to static, definite algorithms as represented by Turing Machine model of computation, with string-to string mapping". (Yuri Gurevich)
3. What we need at this stage of the development, what is being researched and constructed is a new, dynamical model in which frameworks (former formal systems) have also possibility to evolve, change rules and adapt. Instead of perfect result of computing mathematical function (that is a problem solved in the previous era of computing machinery) we want to have adaptive, learning, commonsensical cognitive computing models and devices which will make it possible to implement internet of everything with big data, intelligent cities and homes, intelligent cars, traffic, industrial process control. It will also enable much more powerful knowledge generation environments, with intelligent research tools including experimental apparatuses, visualization and perhaps articles writing software (unlike today's syntactic mockup machine-generated articles) that we will have to control and direct on the level of contents, concepts, and ideas, but not on the level of words and sentences). As Leibnitz famously explained in 1685, the value to scientists of the calculating machine he had invented: "It is unworthy of excellent men to lose hours like slaves in the labor of

calculation which could safely be relegated to anyone else if machines were used." We actually live Leibniz dream, and thanks to the development of computing machinery, scientists saved enormous amounts of time in calculating results, searching and systematizing information, and very importantly - communicating. This new level of cognitive computing will open a whole new world of possibilities for a new kind of relationships between humans, machines and the rest of the natural world.

4. Pragmatic turn: connected to the above change of focus to dynamics and resource finiteness is the change of focus from syntactic and later on "fixed-semantics" to pragmatic aspects of the relationship between the agent and its environment/Umwelt/world. Tomasello's research (2014) on the differences between great ape and human cognition (including reasoning, use of signs and behaviour) confirms the pragmatic developed by Wittgenstein (1953), Austin (1962), Searle (1969), and Habermas (1994). It shows "that communicative action predates the emergence of languages; adapted to a broader biocommunicative approach, that languages are rule-governed sign-mediated interactions in contrast to physical interactions not involving sign-generating organisms; and that sign use follows syntactic, pragmatic and semantic rules, whereas pragmatic rules designate the context of real-life worlds of the sign user" (Witzany 2006, 2007). This pragmatic view is further developed in Brandom's Analytic Pragmatism (1994, 2002), where human linguistic practices are inferentially characterized. Material inferences embedding concepts are typical of human being and underscore the difference between human and nonhuman intelligence. The pragmatic context is related to the "performative aspect" of language use. Performatives imply the possibility of acting in the world, and robotics is a field in which we can select actions useful for precise practices.

3. *The "Moral" Challenge to Robotics*

While trying to focus on complex concepts like consciousness, autonomy, decision making, free will , emotions etc., robotics requires a trans-disciplinary discussions and involves other disciplines like Logic, Linguistics, Neuroscience, Psychology, Biology, Physiology, Philosophy, Sociology, Literature, Natural History, Anthropology, Art, Design (Veruggio, Operto 2006, Giovagnoli 2013). Maybe, the most popular ethical question concerns the relationship between human kind and automata that inspired a wide number of fiction narrations but more recently became a scientific and moral topic. So, some common questions are:

- the embodiment of ethics in a robot
- which ethics is suitable for a robot

- the possibility of autonomy for a robot
- the implementing of Asimov's Three Laws in the Ethics of Robot
- the possibility to scribe "consciousness", "emotions", "personality" etc. to robots.
- sex with robots

There are some main streams in roboethics (Veruggio, Operto 2006):

1. Robots are nothing but machines. Even if they can be very sophisticated and helpful machines, they are only and always mere machines. So, we cannot apply them concepts like consciousness, free will, emotions and the level of autonomy superior to that embodied by the designer;
2. Robots have ethical dimensions. This view emerge from the observation that technology is characteristic of humans and therefore a way to distinguish them from non human animals. Humanoid robots would be symbolic devices designed by humanity to improve their capacity of reproducing itself, and to act with charity and good (Galvan).
3. Robots as moral agents. Artificial agents extend the class of agents that can be included in moral situations. They can be considered as moral patients (as entities that can be acted upon for good or evil) and also as moral agents (as entities that can perform actions for good or evil). We can focus on a kind of "mind-less morality" for AI (Floridi).
4. Robots, evolution of a new specie. On this view, not only our robots will have autonomy and consciousness, but humanity will create machines that exceed us in the moral as well in the intellectual dimensions. Our machines will be better that us and we will be better for having create them (Storrs Hall).

As Veruggio and Operto maintain, the design of Roboethics requires the combined commitment of experts of several disciplines, who working in transnational projects, committees, commissions, have to adjust laws and regulations to the problems emerging from the scientific and technological achievements in robotics. Roboethics requires the involvement of disciplines like Robotics, Computer Science, AI, Philosophy, Sociology, Ethics, Theology, Biology, Physiology, Cognitive Sciences, Neuroscience, Psychology, Industrial Design. The development of Robotics and Roboethics, favors the birth of new curricula studiorum and specialities, necessary to manage a subject so complex (Forensic Medicine can be considered a good example of this new trend).

Let's now present a concrete case where Robotics is successfully applied in our scientific practice, namely, the case of Robotics Assisted Surgery (RAS). Successful surgical innovations focus on increasing patient safety and quality of life but, at the same time, require deep discussions on social, moral and economic questions.

4. *History of robotic surgery*

Surgery has traditionally been an arena with a strong surge for improvements to the benefit of the patients. After discovery of asepsis, modern anesthesia and laparoscopy, robotic technology could be considered an ultra-innovation in this field, commenced to be adopted in early 90's (Santoro 2013, Watanabe 2014).

Robot is a "mechatronic" device combining mechanics, electronic and informatics. Robotics were applied to surgery in the early 1970s endorsed by the NASA and the Defence Advanced Research project Administration (DARPA) with the aim of replacing the surgeon's physical presence and providing care to astronauts in spacecraft or to soldiers in battlefields. In event of natural catastrophes remote controlled robots could work in protected surgical pods.

At the same timer VPL Inc. developed a wired glove that allowed physical interaction with virtual scenes.

The combination between this two innovation combined with the robotic expertise of the Stanford Research Institute gave birth to the first robotic system suitable for minimally invasive surgery PUMA 200 (1985).

The first application to surgery of robot was archieved in 1985 by Kwoh that used the Puma 560 to perform in a more precise way neurosurgical biopsies using CT guidance.

In 1988 Davies *et al.* performed a transurethral resection of the prostate using the same robot. This system led to the development of PROBOT (1988), a robot specifically built for transurethral resection of the prostate. Meanwhile, Integrated Surgical Supplies Ltd. of Sacramento, CA, was developing ROBODOC (1992), a robotical system designed to help surgeons to be more precise in hip replacement surgery. ROBODOC was the first FDA-approved surgical robot.

In 2001, with the launch of ZEUS system, Computer Motion Inc. laid the groundwork of the modern concept of robotically-assisted surgery. This robot was designed to allow the surgeon to control robotic arms device that was docked to the patient remotely from a console. Still in 2001, Marescaux utilized the ZEUS system to perform a robot-assisted cholecystectomy on a patient in France, who was 4000 km away from the surgeon in New York, the so-called "Operation Lindbergh".

In parallel and independently, another group of Californian researchers founded in 1995 Intuitive Surgical International and set about to develop a surgical robotic system for medical use, the Da Vinci Surgical System. The first clinical application of Da Vinci Surgical System was in 1998 with the prototype "Mona" and in 2000 the Da Vinci became the first FDA-approved fully robotic system for application in laparoscopic surgery and the first operative surgical robot in the US. Afterwards, with Da Vinci type S and type Si (released in 2009) and type Xi (released in 2014) were provided less bulky and more ergonomic devices. Da Vinci System is substantially constituted of two parts: the first is docked to the patient and therefore necessarily put in the operating room; the second is the surgeon workplace and therefore placed in another environment, even far away.

Nowadays more than 3000 Da Vinci Surgical Systems of different generations are worldwide; the number of robot-assisted procedures that are performed all over the world has tripled from 80.000 in 2007 to 205.000 in 2009.

5. *Advantages and disadvantages of robotic surgery*

The Da Vinci Robot increases the surgeon's skill and provides more accurate hand-eye coordination, promotes a more ergonomic position at the console, and improves the vision that becomes HD and 3D and also long operations can be performed without effort. Often the robot technology enables surgery than with traditional technologies would be extremely difficult or impossible. Furthermore, it allows to eliminate even the slightest tremor of the hands and increases the so-called "degree of freedom" of operating instruments that pass from four to seven. All these advantages lead to a shortening of the learning curve particularly for surgeons who already have experience with video-assisted minimally invasive surgery.

This shortening of the learning curve is even more evident when compared with conventional laparoscopy. Despite this, even if robotic training programs have become part of many surgical school programs, an official accreditation in robotic surgery has not yet been established.

On the other hand, there are also some disadvantages of robotic-assisted surgery, including the absence of tactile feedback, instrument collisions and the need to reposition the instruments in wide surgical fields. Some authors emphasize the high costs(with a price tag of a million dollars for each device, their cost is nearly prohibitive), time consuming procedures(docking phases extends the operative time) and the lack of clinical evidence in the absence of standard requirements for robot-assisted laparoscopy training.

6. *Application of robotic surgery*

For sure the most frequent application for robotics is to treat urologic oncologic diseases (Robotic-assisted laparoscopic radical prostatectomy for prostate cancer is by far the most commonly performed robotic operation). Further common uses are for gynaecologic, thoracic, and head and neck surgeries (Strickland 2016, Lee 2014, Spinoglio 2016). In the field of general surgery, moreover oncological surgery, robotic-assisted surgery is used for resections for colo-rectal cancers, pancreatic cancer, gastric cancer adrenalectomy for adrenal lesions and hepatectomy for liver lesions. Robotics is also used for benign diseases as achalasia (Heller myotomy), gastro-esophageal reflux disease and/or hiatal hernia (Nissen fundoplication) and in bariatric surgery.

By making an analysis of surgical operations that are performed with robotic technology, it has emerged that robotics offers some positive short-term results such as lower intraoperative blood loss, shorter lengths of stay in hospital, safety profiles and oncologic short-term outcomes comparable to open or laparoscopic approaches. However, regarding long-term oncologic and functional outcomes, data from large studies are currently lacking.

7. *Robotic surgery in the Italian context*

Italy occupies the leading position in Europe, along with Germany, as spread of Da Vinci robotic surgery units, that are placed in 46 Hospitals (data updated at June 2011).

With regards to the overall volume of robotic surgery performed in Italy, the published data shows the number of interventions have tripled from 2007 to 2011.

The spread of robotics in Italy has to confront with two problems: costs and surgeons training. Average costs are around $2,000,000 for buying the machine, $200,000 each year for its maintenance and $2,000/3,000 for every operation. However, actually, in Italy are different purchasing possibilities that make the acquisition cost of the robot not far from that of any other equipment available today for diagnostic or therapeutic purposes, like MRI, CT-scan, CT-PET or linear accelerators for radiotherapy. The analysis of the type of interventions carried out in robotic surgery shows a clear prevalence for major and oncologic surgery, since the ratio between costs and DRG remuneration from the NHS make it currently inappropriate for minor operation.

The second problem is about surgeon training. Of the current users of Robots, the vast majority said they already have multi-year laparoscopic experience and that this autonomous training took place almost always without an expert tutor, but only with the help of the robot technicians.

Scientific community considers Robotic Surgery as a nowadays clinical reality, although there are no definitive data from experimental trials, well accepted by both surgeons and patients. Italian data regarding years of activity from 1999 to 2011 suggest that confidence developed by surgeons with robotic technology and the increasing interest of patients are driving Health administrations to overcome the impact of the high initial costs and to invest in this advancing technology.

8. *Conclusion*

In this article, applications of robotics as an application of new computation-controlled technology are illustrated by the contemporary developments in the robot-assisted surgery, specific for Italian context. Of course, the process of increased use of intelligent robotic technology in medicine is by no means limited to Italy, but it is global, and current reports show steady development and increase of the use of technology all over the world. Compared to our introductory philosophical analysis of the possible trends in the development of new computational modelling, that would support intelligent technology, we can conclude that projections regarding possibilities of fully autonomous robotic devices depend strongly on the area of application. Autonomous cars and other vehicles are much closer the goal that we can already now anticipate. Fully autonomous surgical robots, in spite of encouraging progress of technology will need some years to develop. Thinking in terms of an even longer time horizon, autonomous conscious machines with ability to ethically deliberate in complex and sensitive situations are still a far away goal in medical applications. Müller and Bostrom (2014) have investigated just how far in the future the experts anticipate this development of different stages of AI can be expected. Robot-assisted surgery is definitely a field with huge potential for application of sophisticated new computational technologies (Strickland 2016).

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