Partial soft body robots - a literature review

Yousef Amer¹, Simranjeet singh¹ and Linh Thi Truc Doan¹,²,*

¹School of Engineering, University of South Australia, Adelaide, Australia
²Department of Industrial Management, College of Engineering, Can Tho University, Viet Nam

*E-mail: linh.doan@mymail.unisa.edu.au

Abstract. One of the biggest concerns for every country is to look after their ageing population and provides them a safe life with safe medical equipment and technology. It is estimated that there will increase the ageing of the population in Japan, Western Europe, USA and India with 40%, 30%, 20% and 15%, respectively by the end of the year 2050. Hence, it will create a burden on aged care centres to hire more nursing staff members, which leads to increase the medication cost. One of the feasible solutions to solve this issue is to design the soft robots which will give care to patients at aged care centres. These robots can support patients by providing medicine to them without the assistance of the nursing staff during injury or illness. Therefore, this paper aims to investigate the need of the partial soft robotic arm which can look after patients like robots for interactive body assistance.

1. Introduction

With the advancement of technology, robots are used almost everywhere from the last century. Robots are a very powerful tool of present industry which can perform common functions without human interaction. They are used to increase safety by reducing the risk of injury during operations. According to Gupta and Arora [1], a robot is a computer-controlled device which moves objects and performs tasks while interacting with surrounding according to the program stored in it.

Robots can be classified based on different basis such as power source, control unit, use, mobility, coordinate system, a method of control, type of material etc. The structure of the robot consists of the mechanical unit, power source, tooling, drive system as seen in figure 1.

According to Hockstein et.al [2], Czech novelist Karel Capek introduced a word robot in a play named Rossum’s Universal Robots (also called R.U.R) in 1920. Robot word derives from Czech word robota which is used for servant or labour. In 1954, a primitive arm was developed by American inventor George Devol Jr. This arm could perform tasks according to the programs stored in it. A first flexible multitask robot also known as Programmable Universal Manipulator Arm (PUMA) was introduced by American Mechanical engineer named Victor Scheinman in 1975. PUMA had a great capability of shifting and lifting the objects in any orientation. There were total 700,000 robots operating in the globe in 1995 [1]. Robots are currently used in every industry such as automobile, manufacturing, medical centres and etc.

Hirose and Ogawa [2] revealed that based on the previous results, Honda built the first humanoid robot with two legs which could walk easily in 1986. Honda’s first aim was to create a bipedal robot which could walk easily in a straight line. Then the next challenge was to develop the new robot which can adapt itself in real surrounding conditions. ASIMO model was then developed by Honda which
can walk and run on the even surface. It can climb stairs and remember face pour and other so many things.

![Industrial robot with key components](image)

Figure 1. Industrial robot with key components [3].

When designing soft robotics arm, several issues need to be considered. First, current robots can lift only 60kg weight in one turn. Hence, this research aims to design the soft robotic arm which can lift more load. Second, the fabrication process is another key challenge while designing the soft robotic arm. Lastly, selecting an appropriate actuator, sensor, power source with great efficiency is also important. The main objective of the study is to develop or create partial soft robotic arm which can take care of patients without the support of nursing staff. Moreover, it can lift e patients like RIBA on its soft arms.

2. Soft robots

Soft robots are those kinds of robots which have a soft body and made up from soft materials. These are inspired by the soft body animals and so far, and several soft robots have been established. Different researchers define soft robots in different words. For instance, Rus and Tolley [4] stated soft robots as a system which has a capability of autonomous behavior, and they are primarily made up of soft materials with moduli in the range of soft biological materials. Kim, Laschi and Trimmer [5] defined soft robotics according to their original erection such as worm-like manipulators. Some of the characteristics of a soft robot are shown in table 1.

| Degree of freedom       | Infinite                                      |
|-------------------------|----------------------------------------------|
| Actuators               | Continuous                                   |
| Materials strain        | Large                                        |
| Materials               | Rubber, electroactive, polymer, silicon, elastomers |
| Accuracy                | Low                                          |
| Load capacity           | Lowest                                       |
| Safety                  | Safe                                         |
| Working environment     | Structured and unstructured                  |
| Controllability         | Difficult                                    |
| Path planning           | Difficult                                    |
| Inspiration             | Muscular hydrostats                          |

Table 1. Characteristics of soft robots [6].
ASIMO and Nao robots (as seen in figure 2) are examples of soft robots.

Figure 2. ASIMO and Nao robots [7].

3. Literature review
Polygelines et al. [8] developed a soft robotic glove (as seen in figure 3) which utilizes a hydraulic soft actuator for assistance and at-home rehabilitation. These actuators were composed of elastomeric materials and it is mechanically programmed to perform twisting, bending and other functions. Combined fluidic pressure sensors are utilized to measure soft actuator’s internal pressure and thus by mean of it controls the finger movement. In the end, they conclude that soft robotic glove gives more freedom to the user compared to existing equipment because of its open palm design.

Figure 3. Soft robotic glove [8].

Ferris et al. [9] built a powered ankle-foot orthosis (as shown in figure 4) for people, which consists of carbon fiber and polypropylene shell, two artificial muscles. Dorsiflexion and plantarflexion torque are provided by these two artificial muscles about the ankle. The drawbacks of the previous prototype were covered by this new design as it provides more ease to don and doffs. This prototype can support patients during rehabilitation to recover after the neurological injury [10].

Mukai et al. [11] explained that there is a very high demand for soft robotics in medical and aged care centers to face the glitches which are caused due to an aging population. One of the most challenging parts of nursing care is to lift and transfer the patient from wheelchair to bed or vice-versa. To overcome this problem, they have developed a soft robot namely robot for interactive body assistance (RIBA). This robot can be used for heavy tasks needing human interaction. This robot is successful in transferring a patient from beds or wheelchairs (as seen in figure 5). RIBA can perform tasks according to the instructions given to it by the instructor or caregiver. The whole body of RIBA robot is made up of soft materials such as polyurethane foam and silicon elastomers for safety purposes. There are different types of sensors such as tactile or vision sensors are used in RIBA. Specifications of RIBA are shown in table 2.
Figure 4. Pneumatically powered ankle-foot orthosis adopted from [9].

Figure 5. RIBA lifting the patient adopted from [11].

Specifications of RIBA:

| Specifications of RIBA [11] |
|-----------------------------|
| Dimensions:                 |
| Width: 750 mm (when arms are folded) |
| Depth: 840 mm               |
| Height: 1,400 mm            |
| Weight inc. batteries: 180 kg |
| D.O.F. Head: 3 (only 1 in current use) |
| Arm: 7 each                 |
| Waist: 2                    |
| Cart: 3 (with 4 motored wheels) |
| Base movement: Omnidirectional with omnidirectional wheels |
| Actuator type: DC motor     |
| Payload: 63 kg (tested value) |
| Operation time: 1 hour in standard use |
| Power: NiMH batteries       |
| Sensors: Vision: 2 cameras |
| Audio: 2 microphones        |
| Tactile: Upper arm (128 pts. each) |
| Forearm (94 pts. each)      |
| Hand (4 pts. each)          |
| Shoulder pad (8 pts. each)   |
Dahl and Bulous [12] presented the various uses and applications of soft robotics in hospitals, medical care centers and social care sectors. They described that the traditional robot has a very low level of autonomy and mainly concentrates on the specialized platform for surgery or rehabilitation. These kinds of robots need qualified staff for ensuring the appropriate usage. Neuromata robot and da Vinci robot are the examples of these traditional robots. In hospitals, robots are using for transporting of equipment to supporting nursing staff and to help nurses for caring the patients. They further give examples of RI-MAN and cody robots which are very useful to helps nurses in lifting patients from bed with more safety (as seen in figure 6). Authors concluded that these kinds of soft robots play crucial roles in the medical centers and hospitals in upcoming years.

![Image](https://via.placeholder.com/150)

**Figure 6.** RI-MAN robot [13].

Causo et.al [7] explained that robots are used as a tutor for children. In their research, they review a different type of robots used in education. In the present world, robots are the source of attraction for smaller children and they like to play with these robots. Robots in the educational field can be classified according to the target users, robot role and venue of learning. The target users can be primary school students or secondary students. Likewise, robot role can be different depending upon the situation. They can be used as a companion or learning instructor. Robots can be categorized into three different form such as humanoid robot, semi-humanoid and pet-like robots. A humanoid robot is a robot with a body shape designed as a human body. Nao and Asimo robots are two examples of humanoid robots which look like a small child and attract the attention of other children to play with them. Nao robot is a humanoid robot which was launched in 2004 by Aldebaran robotics. It has 25 degree of freedom which helps Nao robot in smooth dancing and walking like a human being. It can be used to provide educational training for children. It has attached a camera, microphone and speaker. ASIMO (as seen in figure 7), a humanoid robot, was launched by Honda. It is used as a companion to small children. Asimo has specifications of 130 cm height, 50 kg weight and has 57 degrees of freedom.

![Image](https://via.placeholder.com/150)

**Figure 7.** ASIMO and Nao robots [7].

Tiro robot is a semi-humanoid robot (as seen in figure 8) which acts as a teaching assistant robot. Tiro robot provides teaching lessons to students in a class. Tiro has 130 cm height and 70 kg weight. It has in built camera, speakers and 16 pairs of ultrasonic sensors. The Robovie R3 robot has a height of 108 cm, weight 35 kg and has 17 degrees of freedom. It has 11 tactile sensors attached to its body. Apart from these sensors, It consist of 2 USB cameras, 2 microphones, a speaker. It provides voice-
based English conversation. Further, it performs other functions such as shaking hand, greeting, welcoming, kissing, hugging, singing, playing and entertaining etc. Maggie, a semi-humanoid robot, has 6 degrees of freedom. The examples of semi-humanoid robots are shown in figure 9. It is equipped with tactile sensors and 12 sets of bumpers, camera, speaker etc. The PaPeRo was launched by NEC and has height 38.5 cm, weight 5 kg. The degree of freedom for PaPeRo is 4. It has 2 facial recognition cameras and microphone for voice recognition. It can also be connected to the Internet to gain further information.

**Figure 8.** Examples of semi-humanoid robots[7].

Pleo the dinosaur, eMuu, probo are the examples of pet-like robot (as seen in figure 9). eMuu is one eye robot which can show its feelings according to the interaction with human being. The Huggable robot, which is companion robot, was launched by MIT Media Lab for various purposes such as healthcare, aged care, education etc. It has soft body sensitive skin with more than 150 sensors. During educational activities, it is controlled by a teacher on the internet.

**Figure 9.** Examples of pet-like robots [7].

A recent study carried out by [14] showed that children feel less pain and smile more when medical treatment is given to them with these robots. The main aim of this robot is to divert the minds of children from pain to other things. These robots also give companionship to elderly people in several tasks so that they cannot feel loneliness. These robots act as a fruitful source for the aging population.

According to Harwin, Rahman and Foulds [15], a few robot assistive applications have been developed for numerous applications since the 1960s. For example, upper-limb exoskeletons, gait exoskeletons and ankle rehabilitation robots are some examples of soft robots used in medical fields.

Moving further, soft robots are also used to reduce the service cost of nursing staff which is very high in the present world. It was reported by Guild [16] that the number of aged care workers had been increased from 262000 in 2007 to almost 352,000 in 2012 which represents the 34% increase in the size of the workforce of aged care in last five-year time interval. Almost 202,000 workers were employed in the residential care segment. Hence, it is also the one main reason why we need soft robots.

Gnanamanickam et.al [17] presented that more than half of the permanent citizen of Australia residing in residential aged care have dementia. People with dementia need great support from others at any time to divert their thinking. AUD 88,000 per person is the cost associated with the health and residential care for dementia patient in residential care segment. figure 10 shows robot supports dementia patients at aged care centers. Hence, soft robots are necessary in order to reduce this cost.
Figure 10. Robot supports dementia patients at aged care centers [18].

Soft robots are used for numerous applications in the medical field such as neurosurgery, surgery, serving patients, providing physiotherapy to patients, teaching children, orthopedics etc. apart from these, they support the patient during rehabilitation and helps during fracture or dementia problems. The percent applications of service robots in medical fields are depicted in figure 11. Karabegović and Dolecek [19] listed several other merits of robots in the medical field as follows:

a. These robots promote medical processes by delivering precise control of devices.
b. These robots reduce the risk factors and provide more safety to patients during surgery.
c. It increases the quality of surgery.
d. It can give better care to patients without the assistance of the nursing staff.

Figure 11. Percent applications of service robots in medical fields [19].

4. Conclusion and Further work
From the above discussion, it is concluded that soft robots are the major need of modern science and the medical field. Soft robots can support the patients without the assistance of the nursing staff. They can provide more safety in the workplace. Hence, the design of the partial soft body robots’ part is necessary which can assist with the patients with more care and then it will lead to reducing strain on the nurses and doctors at various medical and aged care centres. In the next phase, 3D printing technique will be used to fabricate soft robots since it can provide high quality and simultaneously print several materials. This will lead to some significant advantages such as lifting the patients with more care and safety on its arms, handling heavy object without crushing it, more flexibility due to more degree of freedom.

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