LIQUID ROBOTICS

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Soft robots are a subfield of robotics where instead of the rigid features of a typical robot we have a robot made of soft materials like liquid, gel, and soft materials. Although this field is advancing rapidly the recent trends have to be improved further as they could be harmful to use and the way to use it rightly and make it better is the main thing here. Through this paper, we would like to suggest methods and ways which could lead to breakthroughs in this field. We have learned about the discovery and what suggestions we can give like, if the robot can pass through the jail bars of a particular spacing length then what about if it could be shortened to such a space that it could go to an atomic level, which is something intriguing. The conclusion is that the trends in this field have been great but discovery is at a primitive stage as it needs much attention, we have given our suggestions on what we think could be more possible here.

Keywords: soft robot, neodymium, actuator

Introduction

Liquid robotics is a new field in robotics that has never been explored before. This field might seem really irrelevant at first sight because we are talking about a soft thing that could just travel in many pieces of equipment or transform into different bodies. It is super imaginative. Well, this field is going to be the revolutionized fields of nanotechnology, biomedicine, and robotics.

This is going to be a revolution in drug delivery targets, making efficient sensors, and actuators giving further rise to nanotechnology. The liquid robot which is in the form of a droplet or a shape-shifting body is very flexible and deforms easily compared to the original rigid robot. They can be in different shapes like droplets or shape-shifting items, even if you break them, they will attach and form themselves back again. It can capture any germ or disease-causing parasite because of its immense flexibility of spreading itself out and traveling in the minimum amount of space like 1.5 mm. This is being improved especially in the field of cancer-fighting, and this could help in fighting and wiping out the cancer cells. The robots made of soft material can deform easily break through jails and reform itself back again. This would not be used for criminal purposes but this shows the ability of how if we make a machine out of the liquid metal, it can regain itself and make it better and stronger, and this is the need of the hour. We need less labor and more work output in a short time, so this is going to revolutionize in the coming future. Soft robots will change our lives.

The recent trends in soft robotics have made headlines and it's the most interesting field right now as it has never been explored and the papers published in this field are too recent. In this paper, we will be reviewing the trends in this field what improvements could be made and how is this going to impact in the future. This paper aims to provide suggestions on the different trends and how we can go about them safely and further enhance them.

Description

1. **The jailbreaking robot**

This discovery was made on 25th January 2023 a shape-shifting robot was made which could seep through the jail bars and turn back to its original form, that is when it's inside the jail it's in its solid form, and as it soon seeps it turns into a liquid for seeping and then when it comes out it turns out to be an original robot (Fig 1)(Fig 2). This was done by researchers from the Chinese University of Hong Kong and Carnegie Mellon University who created the shape-shifting or the "phase-shifting" material by embedding magnetic particles within gallium, a metal featuring an extremely low melting point of just 29.8C, or roughly 85F. To achieve this, the magnetically infused gallium is exposed to an alternating magnetic field to generate much heat through induction. In addition to gallium, the robot contains an alloy of three
other elements (neodymium, iron, and boron) to amplify its response to magnetic fields. In the future, it will be used in construction repair and medical science. But its dangers still lie, the jailbreaking robot could be made and this would be tough to capture it if it escapes, though it is at a very less developed stage as the scientists have just tested it by letting it go through jail bars to know its flexibility of the soft robots and that is at the present state it's impossible to imagine but in future, if misused it can be dangerous. It could lead to a rise in criminals. Moreover, neodymium magnets cannot be used in high-temperature areas, as it is not very resistant to corrosion. Moreover, it is brittle by nature and it can lead to deformation or breakdown of the item in between. This technology would be used in space exploration as work for replacing items would be needed every time and the liquid robot can help in this case, but given the conditions in space are too high it might not be the right time to use it as a construction material. Moreover, these materials are harmful to the human body. We need to create the material for the robot in such a way that it aligns with every different task. Construction materials on Earth and space should have different materials for each respectively. The flexibility and ductility should also be arranged in that way. If this is further experimented through much thinner jail bars can make it feasible to seep through at the atomic level, which makes the liquid in the robot go to a very atomic level. This could solve many things at the atomic level this way- but this is something that I propose through this discussion. [10]

Fig 1: the soft or the shape shifting robot when it was initially inside the jail

Fig 2: the robot comes out of the jail after converting to liquid and regains its shape

2. The magnetic slime robot

This is also recently discovered and it is going to be mainly used in solving problems in circuits and problems in the body. It can catch disease-causing germs or cancer cells in the future or anything that a kid swallows by mistake, this thing can remove it from the body instead of doing any surgery, which will save the person's life in a matter of

seconds. It can travel through any sort of maze when controlled by external magnets. The magnetic slime is made of neodymium which is dangerous to be used in a human’s body but right now they have covered it with silica which is not harmful to the body (Fig 3). However, its safety and its use have not been guaranteed, as mentioned in the previous discovery of how neodymium is dangerous. So the research is still under process. It has loads of potential. To make this black blob creative, scientists are adding color to it making it alluring. The slime is flexible as it can spread in all directions and catch many items in its surroundings (Fig 4). It can squeeze itself up to 1.5 mm and who knows if it's developed further it can squeeze much further. The research should be done more on how it can go through much smaller spaces. It should be further made easier and safer to use. It was found by Li Zhang from the Chinese University of Hong Kong and this blob can reach up to speeds of 30 mm/s. If you even cut the blob into pieces they rejoin back to form a blob because they have hydrocarbon bonds in between them. But its slimy nature can make it a little risky as it might break down in between as it cannot solidify whenever and wherever needed. It is a good thing to be flexible but maybe
it cannot be considered as a permanent solution wherever we need permanency as it’s a slime after all and many a time we need equipment to be strong and hard so this could fail those purposes. If we could achieve solidification after its use is over, it would be great. Also, there is an increasing demand for upgradation in existing properties like actuation strength, deformation capability, and durability, and most importantly, reduction in robotic tethering which refers to the dependence of the robots on the station for power and other regulations.

The mentioned materials come short on at least some of these properties. Elastomer-based soft robots are limited by the inability to reconfigure at the site and to pass through spaces narrower than their bodies. Fluid-based robots are limited by the very property that gives them great deformation power (fluidity), as the unstable shape poorly adapts to the environment. They also need demanding environments to work. E.g.: ferrofluids require hydrophilic surfaces to keep their shapes. A solution to this is thought to remote controlling and input system. Magnetism and magnetic material should be considered to modify the mechanical properties of elastomers. A few publications have shown that they can demonstrate traits like controlled deformation and remote actuation for tether-less soft robots. [8]

The robot has functionalities like:

1. Grasping solid objects
2. Swallowing and transporting harmful objects
3. Circuit repairing and motion monitoring.
4. Movement in 2-phase fluids, air even surfaces like hydrogel or plastic.
5. Ability to self-heal at room temperature
6. Conduct electricity.

Fig 3: A simulation showing how the magnetic slime can remove the germ from the organ (on left) The magnetic slime is made of neodymium and covered with silica (on right)

Fig 4: slime catching the material which shows its flexibility

3. Caterpillar soft robot

This was just yesterday as I am writing this review paper, this is how recent are the findings! This is a soft actuator, which is a robot made of soft material suited to organisms. It has been said that there has been no soft actuator made to date that could move in more than 1 direction (Fig 5). So the researchers at North California University attempted to make a soft robot that could slip through things and it undergoes the same locomotion as a caterpillar hence the name. Moreover, it is slow as a caterpillar which is the only hindrance here, which can be improved by adjusting the electrical current that is applied, but again there is a limit for controlling the electric supply. The actuator is made of layers of a liquid crystal elastomer (LCE) with a pattern of silver nanowires embedded within them. The LCE reversibly and then deforms when it is heated up, and the nanowires conduct that heat via an electrical current. The top layer contracts when heated, while the bottom layer expands, which enables actuation in multiple directions, but right now it's just in 2 directions which is not sufficient. Our greatest challenge is to allow it to move in all directions, if we could convert this into a slimmer version of this robot, like
a thin wire that could move the middle part of its body too or it could move in any way, this could lead to a breakthrough in soft robotics motion. But the mechanics behind it have to be resolved. [9]

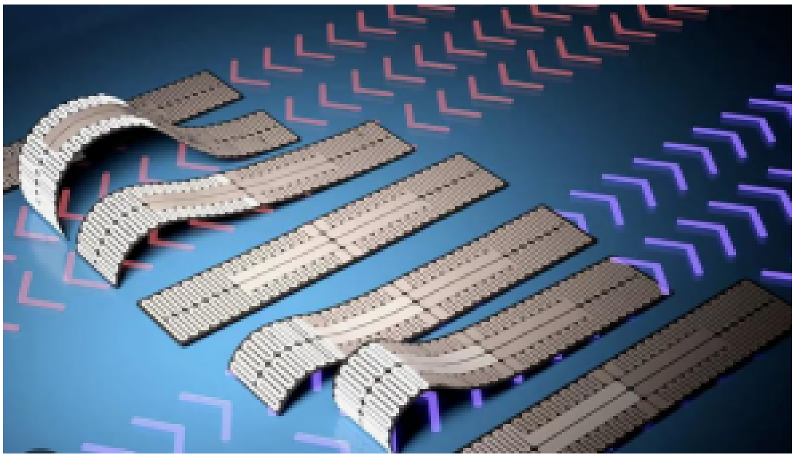

Fig 5: the caterpillar robot which can only move in both directions, the first actuator which could achieve a feat like this

4. Self Regulating Iris

Iris is the tissue that enables vision by changing the aperture of the pupil with the help of its autofocusing ability and large dynamic range. Attempts have been made at making tunable irises but they have required external control by actuators and are incapable of autonomous reaction to varying light stimuli. The sensing and modulation were made a reality through an LCN-based artificial iris by a team of researchers from the project PHOTOTUNE (Tuneable Photonic Structures via Photomechanical Actuation). The required configuration of LCN was made using the photo-alignment technique over the molecular orientation. It does not rely on external power sources nor does it use any external light detection system as is the case in sophisticated digital camera systems. The self-regulating iris should be taken care of as it is a discovery and the material should be safe to use. It should be more flexible and soft to use as it is not much safer now.

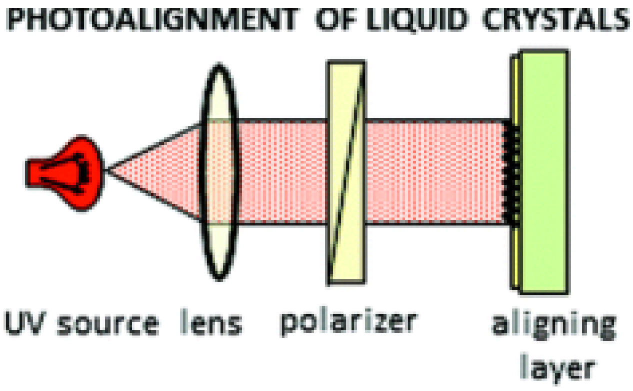

Fig 1 The Iris Fig 2 Photoalignment

5. Liquibots

A very new discovery in the field of liquid robotics is liquibots. They work enormously without the presence of electricity. It may lead to further developments in automated chemical synthesis or drug delivery systems for pharmaceuticals, said researchers, including those from Lawrence Berkeley National Laboratory in the US. According to the journal Nature Chemistry, scientists have observed a tiny slack just 2mm in diameter that is different from a robot instead of using electricity for work continuously it can run on energy from the chemicals in its surroundings. The researchers studied a lot and came up with a way how do they do so. They have seen that feeding them with salt makes them heavier even in the surrounding environment and this in turn generates many reactions and makes oxygen in their body which further helps them to lift to the surface. But being a new field and a recent study it's not showing much positive results. There is a need to work on them and how they can help in the medical field like in drug discoveries and synthesis.

6. Liquid Metal Swimming Nanorobots

It is gallium-based and the liquid metal swimming nanorobots could be made by “top-to-down” construction methods. It has a nanometer thickness and a zinc microsphere layer. It includes a very complex mechanism of breaking the galliumintosmall small droplets and then crushing and many metals that react with it are wrapped around it which works as a stabilizing agent. After that, a high-temperature GaOOH is formed and also in large quantities. The exact dimensions of this robot are 800 nm in length and 200 nm in diameter.

Its applications include the photoluminescence spectra and confocal laser scanning microscopy (CLSM) images of rod-like EGaIn swimming nanorobots to show their photoluminescence properties in ultrasounds and cancer treatment due to their penetrating ability.

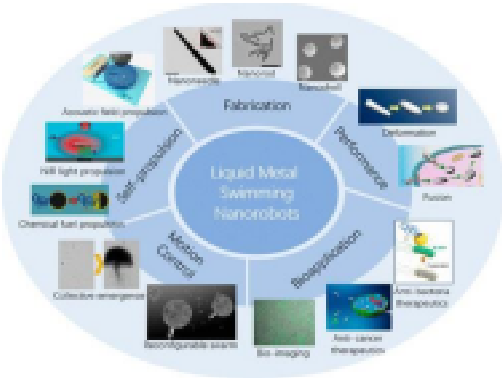

Fig 6: Schematic of gallium-based liquid metal swimming nanorobots- ACS publication

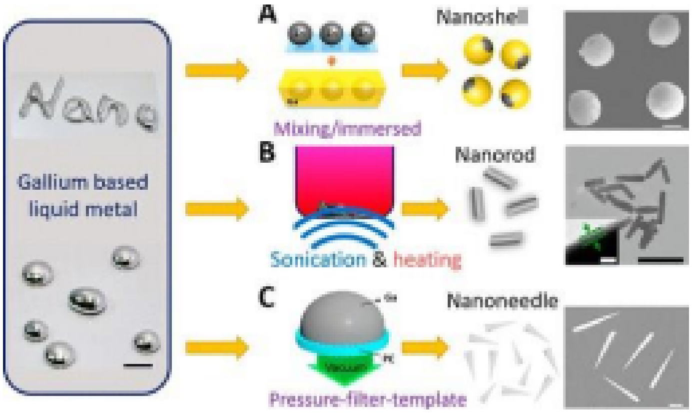

Fig 7: ACS publication- Gallium metal being fabricated and constructed through processes to be used further

Conclusion

The result what we have come to that the recent trends have been a huge breakthrough in the field of liquid robotics and soft robotics. Researchers in this field can further take up the suggestions that we have provided above and they can implement it. This will be an improvement in the fields of drug delivery, biomedical, and nanotechnology. In the future, there might be shape-shifting robots in the form of huge robots. Prosthetic arms will be more realistic and the magnetic slime could be used in places where the rigid materials cannot be used. There must be further research in the field of magnetic slime and soft actuators to develop it from the form of a caterpillar to a proper living being or model to be used for many other purposes, which at present is tough to achieve.

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