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Biyomimikri, Uzay Araştırmaları İçin Robotiklere Nasıl İlham Veriyor?

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ÖZET

Biyomimikri, doğayı taklit etme ve ilham almada insanların birçok problemini çözmede alternatif bir yaklaşımdır. Robotlar ve uzay araştırmaları günümüzde araştırmacılar tarafından en fazla ağırlık verilen konuların başındadır. Uzay araştırmalarında kullanılabilecek robotlar incelendiğinde, doğadaki canlıların özelliklerini ilham alarak yapılan çalışmaları çokça görmekteyiz. Doğa ilhamlı robot teknolojisi, dünyamızdaki canlılarda 3.8 milyar yıldır görülen mekanik incelenerek geliştirilmektedir. Dünyadaki canlıların hareket mekanizmaları ve dengesi, davranışları, iletişimleri gibi birçok özellikleri mühendisler ve sosyal bilimciler tarafından onlarca yıllardır incelenmektedir. Kuşkusuz, robotik bilim de, diğer birçok bilim dalı gibi, doğadaki mevcut sistemleri kaynak olarak kullanmış ve biyomekanik alanındaki araştırmalara önem vermiştir. Ekosistemimizi dikkatle incelediğimizde, gözlem ve uygulama ile sorunlara yönelik çözümlerin 3.8 milyar yıllık geçmişe sahip bir laborotuvarın raflarında durduğunu görüyoruz. Bugüne dek, insan yeryüzündeki sayısız canlıyı inceleme ve dünyada karşılaştığı sorunlara çözüm bulmada bu incelemelerden elde ettiği verileri kullanmada oldukça başarılı sonuçlar elde etmiştir. Bu çalışmada, ekosistemimizdeki canlıların uzay araştırmalarındaki robotik çalışmalarına nasıl ışık tutabileceği, dünyada elde ettiğimiz biyolojik bilgilerin robotik alanlarda kullanımıyla uzay alanındaki çalışmalara sunabileceği katkılar incelenmiştir. Çalışma aynı zamanda biyolojinin bu tasarım alanlarında bilim ve teknolojinin çalışma şeklini aydınlatmayı da amaçlamaktadır.

Anahtar Kelimeler: Biyomimikri, Uzay Araştırmaları, Robotik, Ekosistem, Canlılar.

How Biomimicry Inspires Robotics For Space Research

ABSTRACT

Biomimicry is an alternative approach to solve problems people may encounter in all walks of life by mimicking and being inspired by nature. Robotics and space research are of utmost importance for modern researchers. When it comes to robotics design for space environments, it is seen that the ones usually preferred for space research are mostly inspired by living beings on Earth. Bio-inspired robotic technology is being developed by studying the mechanics of living beings having been seen in our world for 3.8 billion years. The locomotion, balance, behaviour, and communication skills of terrestrial beings have thus been thoroughly studied by engineers and social scientists for decades. Undoubtedly, robotics has also made use of the systems already existing in nature like many other scientific fields and thus considered the studies in biomechanics noteworthy. When we carefully examine our ecosystem, we realize that answers to our questions and solutions to our problems are just there on the shelves of a 3.8-billion-year-old laboratory with complete background on observation and application. So far, man has been quite successful in getting data by studying a splendid variety of species as well as making use of such data to put forward solutions to terrestrial problems. In this study, it has been examined how living beings in our ecosystem can be a source of inspiration for the robotic studies in space research as well as how our knowledge of biology can be put into use in robotics so that it can contribute to space studies. The study also aims to enlighten the way biology works in the areas of design for science and technology.

Keywords: Biomimicry, Space Explorations, Robotics, Ecosystem, Living Beings.

1. INTRODUCTION

Despite being a relatively new science, biomimicry is a product inspired by 3.8-billion-year-old natural process (Akkaya and Yazıcı, 2020; Kim and Park, 2018; Benyus, 1997; Volstad and Boks, 2012; Ginsberg et al., 2013; Kennedy, 2015). Biological characteristics of living beings can be directly seen in innovative designs. Speedo's swimsuits inspired by shark skin, the technology known as Velcro, Shinkansen speed train inspired by the Kingfisher (Akkaya and Yazıcı, 2020), self-cleansing lotus leaves (Altun, 2011; Özdoğan et al., 2006; Primlani, 2013), and Da Vinci's nature inspired vehicle designs are some well-known examples in this scientific approach (Avcı, 2019). With the advent of artificial intelligence and advanced robotics; biomimicry has become an integrated scientific approach (Mattar, 2013). Applying principles of biomimicry onto our existing technologies help us figure out the manoeuvrability and manipulation skills and use such findings to solve our problems (Frishberg, 2015).

It was not until the late 20th century that there was a significant advancement in space technologies. Space robotics is, indeed, a unique technology that allows man to discover space. Yet, it has been open to a very fierce competition ever since 1958. It all started when Soviet Union launched the first robotic spacecraft and Sputnik before the United States did. This robotic race between two countries – intentionally or not – contributed significantly to the development of space robotics (Launius, 2019). In 1961, NASA built a spacecraft assembly facility and since then, this place has been the birthplace of many technologies in space robotics (NASA, 2019).

Some may wonder why NASA invests so much in space robotics rather than simply sending trained astronauts into space. Indeed, contrary to the popular belief, sending a robot to space is much more costly than manned missions. However, they can survive in space environment longer than man since they do not have basic human needs. In case mankind decides to step on the moon once more in the next 20 years, it should be quite likely to see more robots in our social lives. NASA is working competitively to fulfil that dream. The agency's most ambitious goal is to provide a more sustainable existence for mankind and thus to expand other planets and this can be solely achieved by getting robots collect all scientific data, which makes the cost more reasonable (Robots in space, 2004). Outer space requires an ultimate application of robotics as it is not exactly accessible for man due to its extreme temperatures, vacuum, radiation, gravity, and great distances. Robotic manipulators are quite important in orbit operations to facilitate human activity on space such as constructing space modules and space structures. Besides, robots travelling to and landing on planetary surfaces allow us to realize further expedition possibilities by providing us considerable amount of data on solar system (Yoshida, 2010).

Space explorations are quite costly in terms of tele-operation and remote-control technologies require a supreme level of autonomy. Therefore, it is of utmost importance for these missions to send autonomous systems to explore space (Menon et al., 2007; Yazıcı and Darıcı, 2019).

There are plenty of nature-inspired designs in space and robotics research. Nature is the best source of innovation and it is possible to find the answers when they are as close to us as nature is. This research focuses on how nature inspires robotics to solve space-related problems.

2. WHAT IS BIOMIMICRY?

The term biomimicry was first coined by Janine Benyus in 1997 to refer to nature-inspired approaches (Benyus, 1997). Benyus describes biomimicry as a process to transform biological processes into technologies by mimicking biological samples in the lab and in the field (Marshall and Lozeva, 2009).

There are three types of application in biomimicry. The first approach is biophila, mimicking the form and shape. The second one is to mimic a process such as photosynthesis and the third is to mimic a whole ecosystem such as a complete city. The underlying objective is to find nature-inspired solution. Plants, animals and even microbes are splendid engineers, chemists, and physicists. Therefore, biomimicry makes use of not these living beings' itself but the data they have been using (Vuuren, 2014). These forms, ecosystems and processes have been actively used by natural organism for so long that their efficiency has been already proven with thriving species. And this is what makes the model successful.

Some of the greatest inventions in design and technology are reflections of natural world. These reflections are called "biomimicry" within interdisciplinary framework. Biomimicry or biomimesis can be interpreted as a mirroring of natural systems, procedures, and elements. Its objective is to offer cost effective solutions so that business, social and financial quality can be improved in the long run (Yazıcı, 2020). In other words, sustainability is one of the most efficient outcomes for biomimicry applications.

Studying models, systems, formations, and elements existing in nature and gathering data from it; biomimicry is a trending problem solving approach inspired creatively by nature (İnner, 2019). Bar-Cohen, a prominent designer arguing that nature is a source of information leading to design, suggests that the basic purpose of biomimicry is to use the language of nature as a means of communication for the designer (Bar-Cohen, 2006).

Until now, expeditions have mostly taken place on our Earth to get to know our home better. However, the 21st century is all about getting to know our neighbours: celestial bodies, neighbouring planets, and their moons. As man is getting more and more interested in exploring the untouched and unknown; he is also challenged by the nature of space and thus turns to robotics to overcome them. Space is just another natural atmosphere. Perhaps, it does not have any mountains, lakes, or ponds but its own harsh, wild and unpredictable landscape.

On the other hand, the laws of physics are universal. And our knowledge on the nature of terrestrial can help us solve our problems in the extra-terrestrial environment. That is why, robotics always seek for answers and turn to nature for inspiration when it comes to finding out solutions for the complicated and chaotic problems. Here are some examples for nature-inspired robotics designs that can allow man to excel at these studies on space expedition:

2.1. Ostrich Robots

Bipedal robots represent one of the greatest needs in space research. It makes long distance travel easier as such movement include walking, running and even hopping. Institute of Human and Machine Cognition in the USA has recently developed a tiny mechanical ostrich-like robot that will achieve sophisticated bipedal mobility.

Ostriches are good at bipedal locomotion as they require less power to swing the lower limb; which makes their bipedalism 50 per cent more energy efficient through a strong release of elastic energy (Rubenson et al, 2011).

Unlike other bipedal robots, ostrich-inspired robot uses computation and sensor to balance itself to mimick this efficient locomotion. Ostrich-inspired robot has a single engine to move the legs and thus enables a natural balance with its elliptic bipedal movement. Research claims that the robot can run at a speed of 10 miles an hour (Knight, 2017). Extra-terrestrial travelling can be quite dangerous and costly for mankind. Yet, this robot can cut down on the costs, boost the energy savings and mitigate the risks.

2.2. Cockroach Robots

Cockroaches are known for their agile locomotion and thus have been a source of inspiration to robotics for so long. Researchers from John Hopkins designed a robot-bug mimicking cockroach. These robots have superior manoeuvrability and are designed to locate the survivors during natural disasters thanks to their body shape, legs, and mobility. Besides, they can help exploration activities in space research, exoplanetary discoveries and on Mars (Mahon, 2018). Sanchez et al., (2015) inserted a sensor to measure the movements of the bug in the future thanks to its internal compass, accelerometer, and GPS. The bug inserted into a backpack is programmed to send electric stimulants to navigate depending on the feedback from the sensor such as temperature, humidity, and surrounding gas (Sanchez et al., 2015).

Another team of scientists from the UC Berkeley designed another robot inspired by cockroaches called DASH (Dynamic Autonomous Sprawled Hexapod) to make use of agility and manoeuvrability of the insect in biomechanics. They studied the 'fast relay systems' seen in these six-legged insects so that they can comprehend better how they run at a speed of 50 times of its body length (Birkmeyer et al, 2009). This agile locomotion and high skills of manoeuvrability is what is needed for the unpredictable exploration conditions at outer space.

2.3. Snake Robots

Snakes perform rectilinear movement. They have a slender and curvature body enhancing their locomotion performance. Their freedom to move easily on uneven terrains inspired scientists to design robots inspired by them.

Snake robots are inspired by how snakes move in unknown and challenging territories. These mechanisms are designed with connection modules capable of being curved in different environments. While their independency makes them difficult to control, it is also what makes them flexible enough to access on unusual surfaces which cannot be dealt with traditional, wheeled, tracked or bipedal mobility. In terms of mobility, irregular surfaces offer a superior mobility to crawling robots since irregularity on the surface can help with thrust (Liljebäck et al., 2012).

So far, snake robots have not been designed for space research. They are rather for hostile territories and long distances. However, this makes them even more attractive for space research studies. A space snake robot can used for exploration purposes on low gravity objects such as asteroids or Moon Village (the first human settlement) as well as for evaluating the availability of the lava tubes. A snake robot is a robotic mechanism reminiscent of the biological capabilities of snakes. They can be quite a promising alternative for exploration activities which might be challenging for wheeled and tracked robots (Merz et al., 2018). Besides, these serpent-like robots are quite robust and modular. If any of their parts is broken down, it can be simply replaced or removed by shortening the length, which makes them ideal for extra-terrestrial expeditions.

2.4. Invisible Underwater Robots

Hydrogel robots are transparent and therefore undetectable underwater. They can catch a fish without being noticed. Like leptocephali, they have superior agility and can act swiftly underwater. They can camouflage themselves through optic and sonic ways thanks to hydrogel activators and their transparency. They can swim underwater, kick plastic balls, and catch live fish (Yuk et al., 2017).

Optical and sonic camouflage feature of these robots could be quite functional if the expedition rovers come up with any trace of underwater life forms. To study any underwater life form we suspect to exist, robots with sonar detection technology will be of great use. They help us detect and identify such extra-terrestrial life forms without even disturbing them thanks to their camouflage abilities.

2.5. Octopus Robots

Octopus is a cephalopod mollusc with a soft body, living in the oceans and seas. It has eight sucker bearer arms. It does not have any skeleton, shell. It is mostly made up of muscles. Combined with manual skills and effective neural control mechanisms, this body morphology enables octopus to perform an enhanced diversity of movement and behaviour. It has many skills such as elongation, gripping, crawling, and swimming. Its lack of skeleton makes its tentacles flexible, bendable, and extendable (Cianchetti et al., 2015).

Soft robots can be widely accepted for various applications in many areas. They are safe to operate. Bioinspiration is the driving force behind producing new and soft robots. Robots as soft as octopus can not only assist robot arms and manipulators but they also can crawl, walk, jump, roll, or swim. As it is not difficult for them to mimic complicated body movement of underwater creates; they offer several opportunities to many problems (Fras et al., 2018).

The surface of the Red Planet is known to be quite rough and irregular. These soft robots can contribute significantly to the exploration activities thanks to their unique locomotion ability to move without getting stuck. They can be trusted to overcome any obstacles and access into any terrain unknown to man.

A particular soft robot inspired by octopus, PoseiDRONE, is quite well-suited to handle difficult tasks in aquatic and cramped terrains as well as excavation activities on the surface of the Red planet. It uses jet propulsion, elastomeric material and several manipulators which enable the robot to swim, to crawl or to access anywhere (Arienti, 2013).

2.6. Lizard Robots

Lizards can walk on many surfaces thanks to their superior grippers and they leave no trace behind. The mechanism they use is being mimicked by Velcro-like super glues. This strong grip occurs due to attractive and repulsive electric forces between atoms and molecules. (Menon et al., 2007).

This makes them ideal climbers for any obstacle they might encounter on the surface of the Red Planet since they can perform such tasks as inspection, maintenance and cleaning in environments challenging for conventional machinery, without risking human life (Menon et al, 2004).

There is one lizard studied for clearing space junk. Due to their unique gripping capacity, geckos are being mimicked by space engineers to clean up the space debris floating in space. Researchers from Stanford University developed gecko-inspired robotic pincers to easily pick up the space debris in outer space. With its strong adhesive feature, this tiny robot can align itself correctly while making a contact with the target object. And thus, it seems promising that it will be used in the repair and maintenance works of satellites, space telescopes, space stations and in clearing up the space junk that might damage these expensive investments (Jiang et al., 2017).

2.7. Honeybee robots

Honeybees have a reputation for being hardworking, cooperating, and systematic collaboration (Yazıcı, 2020). Some robot-bee swarms are designed to be placed into Mars exploration vehicles together with sensors and wireless communication so that they can gather information on rough Mars territories. These robot-bees are known for being a model for such a great technical innovation that they improve aerodynamics and have low-energy wing structures found in insect world. This gives them accessibility and flexibility in radiation rich Mars atmosphere. They may be able to generate energy and operate on low energy without wasting any extra power (Kang, 2018).

2.8. Eagle robots

Eagles hover on the air from time to time so that they can curb their energy and expand their range while looking for food. This is how many unmanned air vehicles are designed (Lentink, 2014). The Red Planet has a very thin and quite poisonous atmosphere full of carbon dioxide, carbonmonoxy, methane, argon, and nitrogen. Therefore, it is a prerequisite to design drones that can fly across this planet. However, low atmospheric density is not enough to meet the need for low gravity. This search for a proper air vehicle led to the designs of unmanned air vehicles which can fly on high altitudes. Altitudes above 30,5 km on Earth are quite like the conditions on Mars. Therefore, drones designed to fly at this altitude can also fly on Mars, according to laws of aerodynamics (Hassanalian et al., 2018).

2.9. Robonaut

As mentioned earlier, Mars is a challenging environment not only for habitation but also for exploration and research activities. As mankind hopes to make the Red Planet more accessible, it becomes more and more inevitable to look for new models with superior technology. This very quest has paved the way for studying more complex organic systems, particularly known as man. Human body is equipped with such complex systems that certain tasks can only be achieved by man. On the other hand, manned missions to the planet is still a challenge. Therefore, the mere alternative is to engineer robots that can mimic the unique features of human body. Particularly known for its dexterity and flexibility, Robonaut is one such robot. The purpose of the Robonaut project is to have permanent staff at the space station to assist astronauts and perform certain tasks when necessary (NASA, 2014) . This project is of great importance to increase the efficiency within the space station. It creates an ideal atmosphere for a collaboration between the robots and astronauts to get the job done properly and safely (NASA, 2003).

2.10. Valkyrie

When it comes to bipedal locomotion, human mechanics is quite admiring for biomechanical engineers since our species has a splendid performance. In terms of energetics, biomechanics, and kinematics; human bipedal locomotion is truly efficient. In comparison to quadrupedal walking and bipedal chimpanzees, humans use some 75 percent less energy. (Sockol et al., 2007) This high efficiency has attracted the interest of many biomechanical engineers. For a long time, it was their biggest dream to create a bipedal robot as functional as human beings. As to space environment where resources are limited and maintenance work is costly, there is no doubt that efficiency is and will always be a priority. All these factors combined led to the invention of a new generation bipedal humanoid: Valkyrie. Valkyrie is a robot designed to walk like man so that it can be used for deep space exploration. The robot is also thought to be quite practical for rescue missions as well as providing assistance and relief in case of any disaster (NASA, 2016). Nowadays, NASA is trying to have the robot advance its skills and to make it ready for future space explorations with the help of university robotics groups. The more skills Valkyrie acquires as a bipedal humanoid, the more likely it will be for the robot to perform such challenging tasks as space exploration (NASA, 2015).

2.11. Aila

In addition to bipedal locomotion, dexterity, and flexibility; human body is the vault of a much more desired treasure many species lack: Intelligence. Human cognitive skills such as learning, critical thinking and reasoning are the real skills which will be needed most in space. If we ever manage to design an intelligent robot which can walk like a human and be as agile and flexible as a human can be, it will clearly be a significant breakthrough in space robotics. However, Aila – a robot designed by the German Research Center for Artificial Intelligence- helps us to take a step further, at least. Aila is an autonomous robot with improved artificial intelligence skills. It can copy human behaviour and motion by monitoring man. It has strong arms and can lift a weight of 8kg (Lemburg et al., 2011). With this unique ability, Aila looks promising as it can operate inside and outside space stations or perhaps, even become a permanent resident in the Moon village.

2.12. Robobat

Bats are unique living beings who can navigate quite easily at night. In addition to their splendid flight mechanics, they are also able to locate nearby objects or any obstacle on their way simply by emitting sound waves and interpreting the signals echoing back. So far, they have been a source of inspiration as well as a subject of study in many areas of engineering.

When it comes to exploration activities, man has always been eager to develop vehicles that will enable himself to explore even further. Hence, bats have always been studied for the sake of engineering better airplanes, ships and submarines. Furthermore, some types of bats, such as the Egyptian fruit bats, have been studied for the last two years in order to make military sonar and civil surveillance systems better (Lee et al., 2017).

In 2017, a team of scientists from California Institute of Technology managed to design a robot that can fly like a bat to further these studies. They decided to create over 40 artificial wing joints to mimic the mammal's intricate flight and flexible wing moves. The outcome was a 93-gram of autonomous success called Bat Bot (Ramezani et al., 2017).

However, it was a real breakthrough when a research team from Tel Aviv University managed to mimic the echolocation used by bats to design a robot which can map its surroundings based on the sound waves received back. The design included an autonomous robotic technology with two ultrasonic microphones and a bat-like mouth to send the artificial tongue clicks. Despite lacking the flight ability of bats, Robat has been successful in identifying the shape and border of any object available in its surrounding through an internal artificial neural system (Eliakim et al, 2018).

Although Robat and Bat Bot were both designed for this Earth, they can be utilized quite effectively in space exploration activities. Mars has some darker regions which are rich in basalt, a volcanic mineral (ESA, 2019). By mapping its surrounding objects through echolocation, Robat will help scientists unveil more secrets in these darker regions and lead to an acceleration in basalt mining activities once it is colonized. The basalt retrieved may be used by the colonists as a construction material for building settlements, roads, stations on the surface of the Red Planet. However, Bat Bot will also support scientists with its flight ability. Thanks to its vantage point, it may carry out aerial expedition activities on the surface of the Red Planet.

2.13. Robots Inspired by Click Beetles

Although starting a colony may sound challenging, it is even more challenging to continue expeditions and create a sustainable environment on the Red Planet. Conducting exploration and colonization activities under harsh atmospheric conditions will eventually lead to unexpected failures, major accidents and, in some cases, disasters. This is the exact reason why scientists have been looking for more advanced technologies in robotics so that these smart machines can assist mankind when needed.

Meteor impacts, seismic tremors, extreme atmospheric conditions are some disastrous phenomenon future colonists may encounter. When the disaster strikes, rescue missions must be carried out. Yet, the little population on the Red Planet makes human intervention almost impossible.

Robots can certainly provide assistance in such rescue missions. A smart rescue robot that can jump to rescue others will certainly be efficient under these circumstances. Yet, it was not known how to design such robots until the idea of mimicking the mechanics of click beetles emerged (Witze, 2017).

The jumping mechanism of click beetles is so complex that they can jump without using their legs by using a hinge-like mechanism to launch them back onto their feet (Ribak, 2011).

These robots can have active roles in rescue missions to be conducted on Mars. Their unique jumping feature will allow them to access the area more easily. Accessing the disaster zone to retrieve the victims is not the only issue. It is also challenging them to bring them into safety. These robots' agility will enable man to conduct successful rescue missions to retrieve and save disaster victims from pits, cliffs and wreckages which are known to be blind alley (Witze, 2017).

2.14. Salamandra Robotica

Salamanders are a species with a remarkable locomotion capability. They can swim in aquatic environments. While on land or in trees; they can walk or crawl. They can switch from swimming to walking so easily that this range of motion inspired scientists to develop a new robot with an artificial neural system. Robotics engineers from Ecole Polytechnique Federale de Lausanne used a 'central pattern generator' circuit to create rhythmic neural activity through electrical stimulation to mimic the function of the animal's spinal cord (Ijspeert et al., 2007). This makes Salamandra Robotica a major breakthrough in robotics as its locomotion is being controlled by an artificial nervous system. However, this robot can indeed offer us a lot more in extra-terrestrial environments. It can help scientists achieve even greater if it is sent to space for exploration missions.

The search for liquid water in our solar system is considered important as it is essential to any colonial activity. However, liquid water is also a means of studying other life forms on neighbouring planets and satellites. For instance, Jupiter's moon, Europa has been found to have a salty ocean with a larger aquatic capacity than that of Earth's. It is thought to have the right chemical nutrients and a proper level of radiation under the surface to harbour microbial life in its oceans (NASA, 2017).

Such semi-aquatic robots can be of great use in the search of microbial life forms living under water on such celestial bodies. They can help us uncover one of the biggest questions in the history of mankind: Does life exist on other planets? The answer to this question can alter the way we explore, study, and colonize space forever.

3. CONCLUSION

This article studies biomimicry models applicable to space research by translating the world of biology into space robotics. It also makes recommendations for the models which can be used in space studies. Although these are the theories with the highest probability, further study is required. For now, the most ideal inventions seem to be cockroach robots, hovering robot-bee swarms, and humanoid robots. They all offer energy efficient and cost-effective solutions man might encounter in extra-terrestrial environments. Regardless of the future consequences, there is no doubt that a bioinspired approach will offer numerous benefits to space robotics when compared with traditional interpretation of robotics. They can access areas where traditional machinery can never reach. They offer vantage point in exploration activities. They pose no risk to human life. On the contrary, they minimize the risks for man.

Robots may not be living beings. Yet, when it comes to offering the comfort of working with living-beings, biomechanics is the next best thing. Bio-inspired technologies can be successful in extra-terrestrial exploration projects to a greater extent and it can lead to more scientific discoveries. It seems that humans do not really have any other choice than relying on robotics and biomechanics until the space becomes more human-friendly. Until then, we must keep on studying nature to look for solutions so that we can improve our robotics technology for space environment.

This work is primarily meant to demonstrate the potentially successful use of biomechanics in space environment, which can offer better control strategies upon encountering challenges. By translating biology into engineering and robotics, biomimicry can also offer cost effective solutions since it is based on mere design and inspiration, which is proven to be functional and optimal for billions of years.

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