BIO-ROBOTICS: Balancing Hype & pessimism

From memes, articles, to tv shows, robots have integrated themselves into our pop-cultural scope. But what do we actually know about robotics?

An article by
Gina Hong & Eunice Pang

For the past few years, robotics has been hyped up in pop-culture as both humanity's saving grace and future enslavers. And while there have been multiple articles written about the role of robotics in changing global economies and consumer products—via a manufacturing revolution – not much has been written to inform the mainstream audience about the contribution of robotics to research. The closest that biorobotic research got to "mainstream" attention was through a Verge article that listed Harvard's robot bee as one of the "11 best worst and weirdest robots of 2017". Although the mention was equipped with gifs and a comparison to Black Mirror from the writer, the article itself lacks depth and fails to provide the reader with a contextualized understanding of the contribution of biorobotics.

Here we turn to Barbara Webb, a leading biorobotics researcher. In her article, Can Robots Make Good Models of Biological Behaviour?, Webb argues that biorobotics does indeed contribute to biology. Her case mainly consists of three points: first, biorobotics allows realistic simulation of animals, second, it allows for simpler modelling of organisms, and third, biorobotics leads to the development of complete systems. Do these three arguments satisfy the main question: "Can biorobotics improve our understanding of biology?".

In this article we suggest a balanced interpretation of biorobotic's contribution; something between the hype and pessimism surrounding this burgeoning field. While biorobotics is limited by its high cost and potential for unrealistic solutions, we believe that biorobotics does improve our understanding of biology through realistic simulation and functionality-focused research.

^ Sophia the Robot

"Can biorobotics improve our understanding of biology?"

* HBO's Westworld

What Does Everyone Else Think?

The current views surrounding the future of biorobotics can be categorized into three groups:
1) the skeptics who view biorobotics as lacking compared to alternative models, 2) the optimists who view biorobotics as a model with much potential, and 3) those who do not see the need to argue for a "best" model. The term "model" refers to a physical or conceptual representation of a biological organism.

Those who argue against biorobotic's potential as a modelling tool often point out that functional similarity does not equate to further understanding of the process. For example, in Some robotic imitations of biological movements can be counterproductive, Ramesh Balasubramaniam and Anatol G. Feldman argue that while aerodynamics was inspired by birds, the development of airplanes contributes little to our neurophysiological understanding of birds. Other limitations include the lack of emergent patterns in biorobotic models. Unlike naturally emerging mechanisms in biological organisms, behavioural patterns are often "programmed" into biorobotic models which limits the applicability of biorobotics. It is argued that biorobotics would be more applicable to biology if the engineering concepts applied in robotics were indicative of natural biological workings.

In Research, robots, and reality: A statement on current trends in biorobotics, Niebur et. al argues that biorobotics has substantial potential compared to alternative models such as computational and theoretical models. Despite being easier to implement, computational and theoretical models are much more susceptible to oversimplification as a result of abstraction. Some crucial aspects of environments, such as nonlinear friction and requirement for real-time response, are extremely difficult to simulate in software and computational models. A robot model, on the other hand, will, by nature, be exposed to all the natural limitations and restraints of the world.

In The nature and function of models, Ronald N. Giere argues that a "best" model does not exist; computational, theoretical, computer simulated, and biological models all have their advantages and disadvantages. In addition, different models are merely depictions of the real object with varying degrees of accuracy. Due to the fact that a "perfect" model does not exist, we should strive to question what we gain from developing a representational model, rather than argue about which model is the better one.

We ultimately argue that (1) biorobotics CAN improve our understanding of organisms but has (2) limitations like any other model. We emphasize the importance of staying somewhere in between the hype and pessimism surrounding biorobotics. While biorobotics is a useful modelling method, it is not without its downfalls.

We will first address part 1 of our argument--"biorobotics can improve our understanding of organisms"-- through focusing on the two strong points of biorobotics: the generation of simpler solutions by focusing on functionality and how realistic inputs lead to a dynamic relationship between the environment and robot.

"We emphasize the importance of staying somewhere in between the hype and pessimism surrounding biorobotics."

Our Points: In Support of Biorobotics

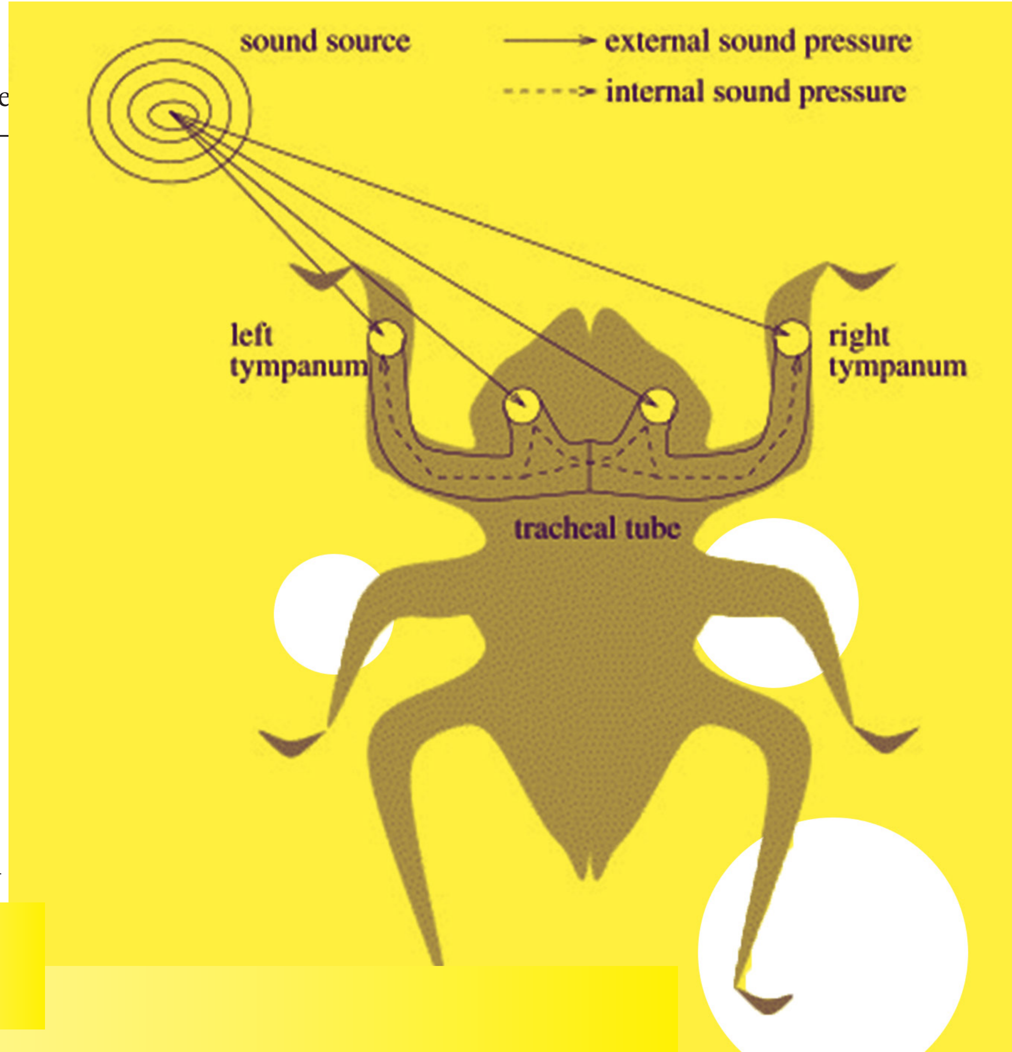
> "... inputs fed into traditional representation models are reflective of an 'idealized' world."

1. Realistic Inputs

In order to make sense of our world, we classify and group the information presented to us. Traditional modelling systems, such as the Physical Symbol System (PSS), attempt to force naturally occuring entities and concepts into a man-made representational system. Due to this fitting, the inputs into the systems are categorized into what we deem to be an appropriate representation of the world. Because of this, the inputs fed into traditional representation models are reflective of an "idealized" world. In reality, there are many exceptional cases and phenomenons that are not accounted for. Computational and theoretical models are susceptible to this.

On the other hand, in biorobotics, robots cannot escape these exceptions that are disregarded due to categorization in other models. Unlike some representative models, biorobotics is able to accurately alter and respond to stimuli in the environment. An example of this is a model of a rat hippocampus implemented on a robot by Burgess et. al in Robotic and neuronal simulation of the hippocampus and rat navigation. By using a robot to model a rat, the researchers assured that the inputs received were identical to those received by a real rat. This allowed the researchers to accurately assess the navigational capacity of the model while maintaining similarities to a real rat. The robot would also provide authentic reactions to the sensory inputs that it receives from the environment.

Additionally, biorobotics allows researchers the luxury of observing an accurate imitation—or as close to it as we can currently get— of organisms without having to worry about the moral or ethical concerns of placing real organisms into certain environments. The precision of cause and effect between the robot and its surroundings allows for a dynamic and authentic interaction between the robot and its environment—something we would not be able to legitimately simulate using merely computational or theoretical models.



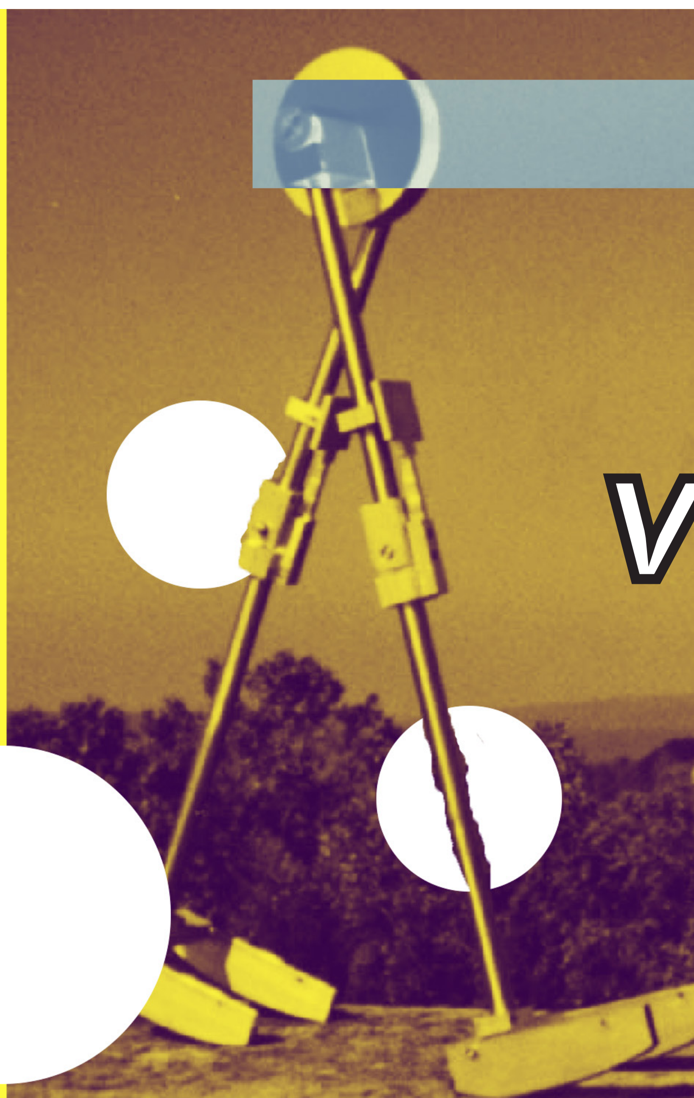
2. Simpler Solutions

Traditional biological models, for the most part, have revolved around a top-down process; unraveling an organism's behavior and inner-workings into subsystems that were then independently researched and tested (Meyer 1997). Although it is undeniable that significant progress has been made through this traditional methodology, we argue that biorobotics offers an opportunity to discover simpler solutions through focusing on overall functionality.

Much of biorobotics research focuses on the behavior of an organism. This focus on behavior allows for a model construction process that is less likely to be bogged down by how certain modules or signals would be represented. Additionally, it allows for systems to be constructed cohesively rather than through independent study of subsystems. Altogether, these effects of biorobotic's focus on functionality allows for a clearer goal for researchers when modelling biological systems.

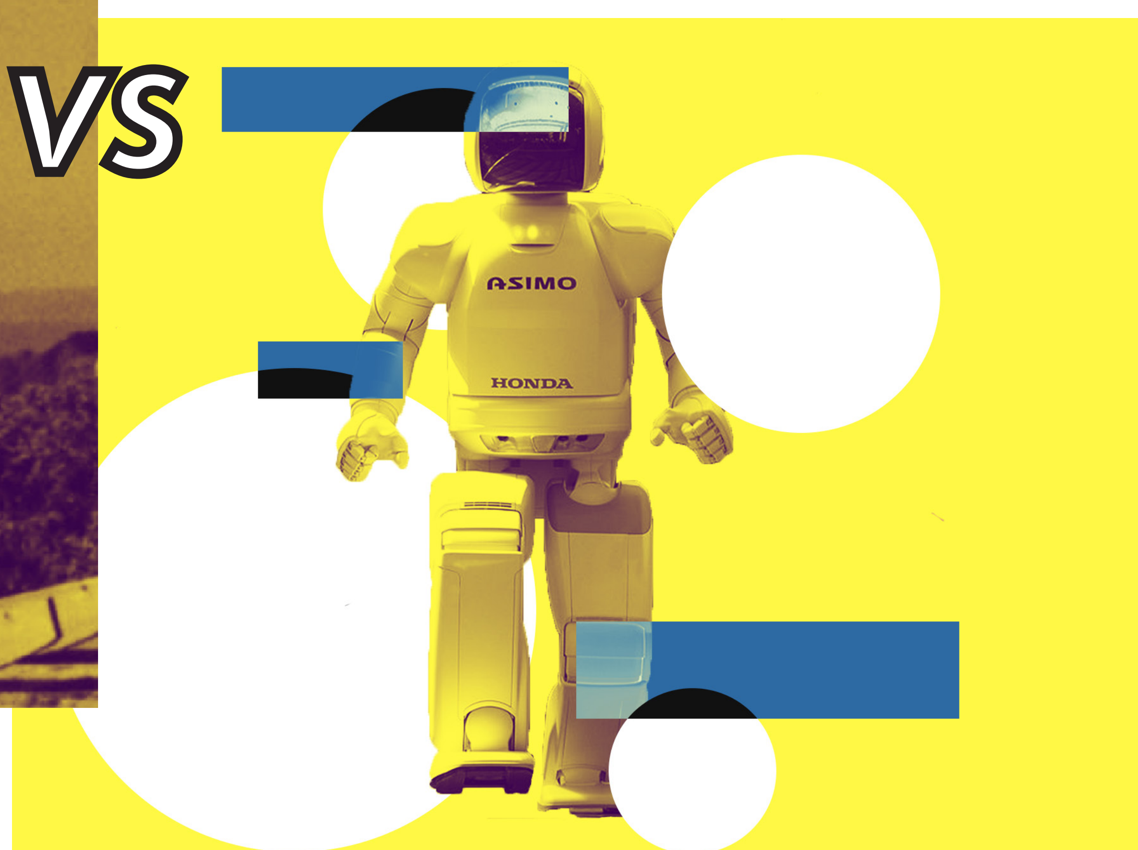
In Barbara Webb's Can robots make good models of biological behaviour?, Webb argues that the abstract approach of biorobotics has yielded in multiple models that successfully represented specific biological hypotheses. She specifically points to a robot-cricket model relating to cricket phonotaxis. Phonotaxis is a process of reliably moving towards a specific signal or sound, and through the robot cricket model, the researchers were able to illustrate that an internal representation was not needed to replicate this behavior. By duplicating the cricket's unique auditory structure, the researchers found that the robots could localize to the cricket calling song. Not only does this model illustrate how traditional biological modelling is not always necessary, it is also an example of how biorobotics has contributed in furthering our understanding of biology.

Additional example of using biorobotic functionality to further our understanding of biology is the comparison between Asimo and passive dynamic walkers. Asimo is a battery-powered humanoid robot that can walk unassisted. Asimo was developed by replicating specific joint-angle movements found in the human body which, while functioning, were found to be highly inefficient. On the other hand, passive dynamic walkers rely on passive dynamics to power its limbs, and were highly efficient compared to Asimo. Considering the efficiency in which humans walk, one can reason that passive dynamic walkers come closest to replicating human walking. This comparison between Asimo and passive dynamic models shows how function-focused biorobotics generated multiple models that helped us identify the integral variables in walking: passive dynamic.



"The comparison between Asimo and passive dynamic models shows how function-focused biorobotics can help us identify simpler solutions."

VS



Our Points: Limitations of Biorobotics

The previous sections have focused on the positives of biorobotics and why we believe it can further our understanding of biology. The following section will focus on the second part of our argument: the limitations of biorobotics. We will first provide a counter-argument for one of the main voices against biorobotics, while also admitting to the limitations.

1. Some May Say...

Some may say that functional similarity, the main goal of biorobotics, does not guarantee further understanding of how something works. In Some robotic imitations of biological movements can be counterproductive, Ramesh Balasubramaniam and Anatol G. Feldman illustrate this using a comparison between an airplane and a bird. Despite building something that exhibits similar behavior to a bird, we have learned little to no information about the neurophysiological principles of the bird. We may have learned about the principles of aerodynamics that apply to both birds and airplanes, but we have gained practically no new knowledge about how the bird's nervous system interacts with the rest of its body.

Another example brought up by Balasubramaniam and Feldman is the comparison between a robotic arm and a human arm. There is no doubt that with the technology we have today, robotic arms are able to do most, if not all, the practical things that human arms can do. Not only can robotic arms match our human abilities, in many ways, they have surpassed human abilities; with their strength, speed, and precision. We see this increasing trust in robotic arms when we observe the jobs that robots have taken over. Robot arms can perform the same tasks that we can with more precision and accuracy than humans ever will. Although robot arms are modelled after our own body parts, Balasubramaniam and Feldman argue that because robot arms are meant to perform general purpose tasks, they do not give us any meaningful insight into how human arms work. When performing different tasks, our muscles, ligaments and joints must interact with each other in a specific way to allow us to do the things we wish to do. Robot arms, on the other hand, are engineered so that they utilize the same dynamic system to perform all the tasks they are able to do. Because of this, we do not learn anything about the anatomy of human arms.

We agree with Balasubramaniam and Feldman that just because we can imitate an organism in robot form, doesn't mean we actually know the workings of the real object. As mentioned in earlier sections, the skeptics of biorobotics often cited functional similarity not guaranteeing further understanding of the biological organism. However, we disagree with their overall argument that striving for functional similarity does not allow us to gain any new insight. Although understanding and being able to replicate the exact functionalities of organisms would be ideal, our goal is not to produce a perfect replica of the object or organism. Instead, we are striving to search for possible explanations of how the organism functions. While studying and attempting to replicate an organism's behavior, researchers will most likely develop frameworks and various hypotheses that can contribute to explaining the process. Although we agree that replicating behavior in a robot does not guarantee a full understanding of biological systems, we argue that it increases the likelihood of eventually understanding underlying physiological processes that we have set out to study. Continued generation of hypotheses should increase our chances of finding an accurate explanation. An example of this process in biorobotics can be seen in the previously mentioned Asimo and passive dynamic walker comparison. The research and development of multiple walking robots with different focuses – Asimo with its precise joint-angle movement versus passive dynamic walker's focus on passive dynamics – allowed researchers to understand that passive dynamics were integral to the high efficiency of human walking. By continuously searching, speculating and testing models of how the functionality of an organism can be, we can get closer and closer to the truth of how the organism really functions.

2. Costs

Current research in biorobotics are mainly a one-way street from biology to robotics. While biology contributes many insights into potential development of robot mechanisms the opposite is not as frequent. Niebur et al.'s commentary on Webb's article on biorobotics addresses one key limitation that, in part, explains this issue: cost. Given biorobotic's relative novelty, the field itself is quite small. The younger nature of the field leads to a more limited number of researchers, which significantly slows down current research progress and limits the range of research being done. Additionally, the high financial cost of biorobotics is also contributing to "model recidivism"; where researchers begin with both computational models and hardware models, then eventually abandon hardware due to high costs.

We consider this practical limitation of biorobotics to be the modelling method's biggest downside. However, despite this, we believe that the current trend of decreasing robotics-parts cost and increased interest in biorobotics is enough to say that biorobotics will be a viable contributor towards furthering our understanding of biology.

Conclusion

Like any other model, biorobotics has its own limitations. The cost of constructing robots can be quite high, and designing robots based on similarity of functionality may not reveal the underlying neurophysiological processes of organisms. Despite these few shortcomings, biorobotics can make significant contributions to our understanding of biological models. Biorobotics allows us to develop robots that can authentically interact with the environment, and through the use of simple biological structures that form a cohesive physical system, we can avoid models with unnecessarily complex cognitive processes. The use of robotics may not provide us with a perfect solution to designing a foolproof model of organisms, but biorobotics has helped us make significant progress towards understanding how useful the field robotics can potentially be.

Bibliography

Burgess, N., Donnett, J. G., Jeffery, K. J. & O'Keefe, J. (1997) Robotic and neuronal simulation of the hippocampus and rat navigation. *Philosophical Transactions of the Royal Society of London B* 352:1535–43. [aBW]

Clark, Andy. Robots and Artificial Life. (2014). In Mindware: An Introduction to the Philosophy of Cognitive Science (Second ed., pp. 118-128). Newyork, NY: Oxford University Press.

Meyer, J. (1997). From natural to artificial life: Biomimetic mechanisms in animat designs. *Robotics and Autonomous Systems*, 22(1), 3-21. doi:10.1016/s0921-8890(97)00013-4

Webb, B. (2001). Can robots make good models of biological behaviour? Behavioral and Brain Sciences, 24(06). doi:10.1017/s0140525x01000127

Images and illustrations:

Anthropomorphic passive dynamic walker by Wisse and Ruina [unpublished] at Cornell University, USA, 1998.

Skeleton Vector Designed by Freepik