Assignment#2: Investigating animal locomotion using robots and neuromechanical simulations

General Feedback on the lecture

The lecture on bioinspired robotics presented by Auke was engaging and intellectually stimulating. It introduced us to the world of bio-robots. The videos demonstrating the functioning of robots enhanced the engagement level, making complex concepts more digestible. And it was quite clear that Central Pattern Generators (CPGs) is a focal point of Auke's research.

The paleontology section in the end was quite an exciting topic and it seemed more comprehensible compared to the intricate details surrounding CPGs. Hence, introducing the paleontology segment earlier might serve as a gentle segue into the more complex discussions on CPGs, ensuring a smoother transition for the audience in grappling with the core content of the lecture.

Take home messages from the lecture

1. **Evolutionary Changes in Neural Control**: The nervous system's role in locomotion has likely evolved over time, with feedback and feedforward controls adjusting to various species' needs and environmental challenges.
2. **Mechanical Stability and Neural Control**: The roles of feedback and feedforward control within the nervous system are heavily influenced by an animal's mechanical stability. Factors like size, locomotor period, and the time to locomotor maturity also play pivotal roles.
3. **Gradients of Control in Limbs**: Especially in mammals, there might exist a proximal-distal gradient in the limbs where feedforward and feedback controls are implemented differently based on the specific region of the limb.
4. **Spinal Cord and Learning**: The spinal cord serves as a significant substrate for learning, suggesting its importance not just in reflexes but also in more complex, learned locomotor behaviors.
5. **Central Pattern Generators (CPGs)**: Central Pattern Generators play a crucial role in locomotion, driving rhythmic motor patterns. Auke's research underscores the importance of CPGs in understanding both animal locomotion and potential applications in robotics and neuromechanical simulations.

Identify and describe a recent publication that illustrates the use of biorobots to advance our understanding of human biology/physiology or the application of robotics in drug delivery, surgical procedures and medicine

Summary: The paper dives into the transformative influence of versatile robot technology on endoluminal procedures, which are minimally invasive surgeries performed within hollow organs or blood vessels. The study emphasizes the advancements brought about by multipurpose robot technology, enhancing the precision, maneuverability, and outcomes for patients. The paper also discusses the potential of flexible surgical robots in navigating tight spaces, thereby possibly reducing the number of incisions required.

Why Interesting: The paper explores the integration of versatile robot technology in endoluminal procedures. It not only highlights the technical breakthroughs but also underscores the clinical benefits,

making it a valuable resource for understanding the synergy between robotics and minimally invasive surgeries.

Main Take-Home Messages:

1. Endoluminal procedures, being minimally invasive, offer advantages like shorter recovery times and reduced risks compared to traditional surgeries.
2. The advent of multipurpose robot technology has significantly improved the precision and outcomes of various treatments.
3. The development of flexible surgical robots, which can navigate tight spaces, has the potential to increase the accessibility of robotic surgery and reduce the number of incisions.
4. The paper emphasizes the importance of form and force sensing in flexible robots, highlighting the challenges and recent developments in these areas.

Reference:

- **Title**: Improvement in endoluminal procedures using versatile robot technology
- **Authors**: Ramkumar Krishnamoorthy, Sujeet Kumar, Rupal Gupta
- **Journal**: Multidisciplinary Science Journal

Questions on Topics covered

Briefly (1-2 short paragraphs) explain how bioinspired robotics could be used to advance our understanding of the biology of locomotion and biomechanics. Provide specific concise examples.

Bioinspired robotics combines principles from biology with robotics to create machines capable of emulating biological locomotion. By analyzing the agile and complex locomotion of animals, which is the outcome of a synergy between the nervous systems, musculoskeletal system, and the environment, researchers aim to design robots that can mimic such movements. A specific example of this is the work done by Prof. Auke Jan Ijspeert and his group at EPFL, who developed Pleurobot, a robot modeled after a salamander, to understand vertebrate locomotion better.

Bioinspired robotics provides a unique lens to delve into the biomechanics of locomotion. For instance, the research on Pleurobot not only aids in understanding the neural control of locomotion in animals but also provides insights for designing robots capable of more natural, agile movement in complex environments. Moreover, the bidirectional relationship between neuroscience and robotics facilitates a deeper understanding of sensorimotor navigation and learning in both insects and vertebrates, thus enriching both fields substantially.

Briefly explain some of the remaining challenges for developing bioinspired robotics that faithfully recapitulate locomotion in humans.

Biomechanical Complexity: Human locomotion is a result of a complex interplay between the skeletal, muscular, and nervous systems. Translating the intricacies of human biomechanics to robotics remains a significant challenge, especially when designing lower-limb robotic devices for gait assistance like exoskeletons.

Material Limitations: The development of bioinspired soft robots faces challenges due to the intrinsic material properties. The mechanical coupling of actuators, sensors, and controlling electronics, along with

accurate deformation modeling and advanced data processing algorithms, is quite challenging.

Learning and Adaptation: Humans continually learn and adapt to new locomotion challenges, which is a level of sophistication not yet fully achieved in bioinspired robotics.

Briefly describe one example of the use of biology-inspired robotics in medicine today

In medicine, bioinspired robotics has begun making a significant impact. For instance, the development of a parasitic wasp-inspired needle showcases how biomimicry can lead to innovative medical technologies. This needle, designed mimicking a wasp's ovipositor, could be used for precise medical procedures. Specifically, this type of flexible steerable needles enable surgeons to reach targets that are deep inside the human body. Furthermore, compared to rigid needles, it offers higher accuracy and lower risk of tissue damage.

- Title: Ovipositor-inspired steerable needle: Design and preliminary experimental evaluation
- Authors: M Scali, TP Pusch, P Breedveld, D Dodou
- Journal: Bioinspiration & Biomimetics