Translations:
Synchronous Robotic Interpretations of Mind and Body

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1 Abstract

This paper describes in-progress research investigating the potential of room-scale motion tracking and electroencephalogram (EEG) wavelength biodata to moderate a physical discourse between a human and UR10 (Universal Robots 2020) industrial cobot in the context of live performance. Beyond the traditional experience of a performance, incorporating a synchronous live interpretation of both mind and body metrics reveals novel translations of the performer's movements by providing greater insight into their current mental state. The duality of visualizing both mind and body simultaneously seeks to expand our vision of how robots can operate beyond their common utilitarian role and become active agents in collaborations. Just as we look to machines to respond to our limitations, it is now possible for robots to look to humans to expand theirs.

2 Introduction

Since their implementation in industrial contexts in the early 1960's, robots have played a crucial role in the automation of systems to increase efficiency. Utilizing industrial robots as a tool in a design industry has led to great progress within the field of architecture and fabrication. However, their current use leaves little room for a dialogue to occur between humans and machines, making the design process primarily one directional: from production to product.

The potential for human machine collaboration has expanded over the past years from the use of autonomous curious robots like *Mimus* (Gannon 2016), to collaborative performance pieces such as *OUTPUT* (Cuan et al. 2019), *Are we human, or are we dancer* (Moore 2020), and *Pas de Deux* (Sheppard 2019). These case studies offer a moment of reflection – for both performer and audience – to re-envision the role of machines in augmenting, exposing, and extending human expression beyond the familiar. Furthering the conversation between humans and machine are projects such as Ani Liu's *Mind and Machine*, and Refik Anadol's *Melting Memories*, which look at translating a person's "cognitive signature" (Liu 2017) via EEG waves to capture and interpret fluctuating mental states through both visual and physical productions.

Exploring how to push the use of robotics outside the limitations of what we believe machines to be capable of, this paper proposes a human-machine discourse in which the tool transcends its utilitarian capacity to become a creative partner and an antidote for increasing self-awareness through neurobiological intelligent technology.

3 Methods

In order to highlight the autonomous nature of the robot in real time it was essential to choose interfaces which facilitated rapid parsing and calibration of multiple data streams. This modified data is then fed to the robot to produce interpretations of a person's movements and mental activity in near-real time. Data is primarily generated by two hardware devices: The *HTC Vive Controllers* (Vive 2020) and the *Muse Headband* (InteraXon 2020). Preliminary studies using solely the *HTC Vive Controllers* to track a dancers movements are shown in Figure 1.

Figure 1. Preliminary Explorations of Movement Tracking with UR10 Robot in Collaborations with [BLIND NAMES FOR PEER REVIEW].

3.1 Electroencephalogram Waves

The study of EEG activity in the brain has been ongoing since 1924 when Hans Berger reported the recording of rhythmic electrical activity from the human scalp (Bronzino 1999). Ever since, the presence of EEG waves has grown in both the medical and art worlds providing tangible interpretations of neurobiological feedback (Thompson 2003). Although the spectrum is continuous, ranging from 0 Hz to 100 Hz, the brain state of the individual often makes certain frequencies more dominant (Teplan 2002). Brain waves are categorized into five basic groups: Delta (0.5 – 4 Hz), Theta (4 – 8 Hz), Alpha (8 – 13 Hz), Beta (13 – 32 Hz), and Gamma (32 – 100 Hz). Each group has shown some degree of correlation with certain cognitive states such as relaxation, alertness, dreaming, focus, anxiousness, etc. (InteraXon 2020). For the purpose of this exploration the data focused primarily on Delta, Alpha and Beta wave frequencies.

3.2 System Structure

The *HTC Vive* controllers communicate the position of the dancer in space. This tracking data can be coordinated, scaled and re-oriented to the robots' coordinate system. At the same time, the *Muse Headband* communicates the current EEG frequencies of the dancer, providing the most dominant brainwave at that moment. Communication between these devices and *Processing* (Reas and Fry 2001) occurs through the OSC streaming library *oscP5* (Schlegel 2011), the app *Mind Monitor* (Clutterbuck 2020), and the HTC Vive library *ViveP5* (Pazzi 2020). These applications and libraries allowed for the data to remain continuous and current while the unique capabilities of *Machina* (García del Castillo y López 2018) allows for this communication to dynamically interface with the robot, or simulation software (Figure 2).

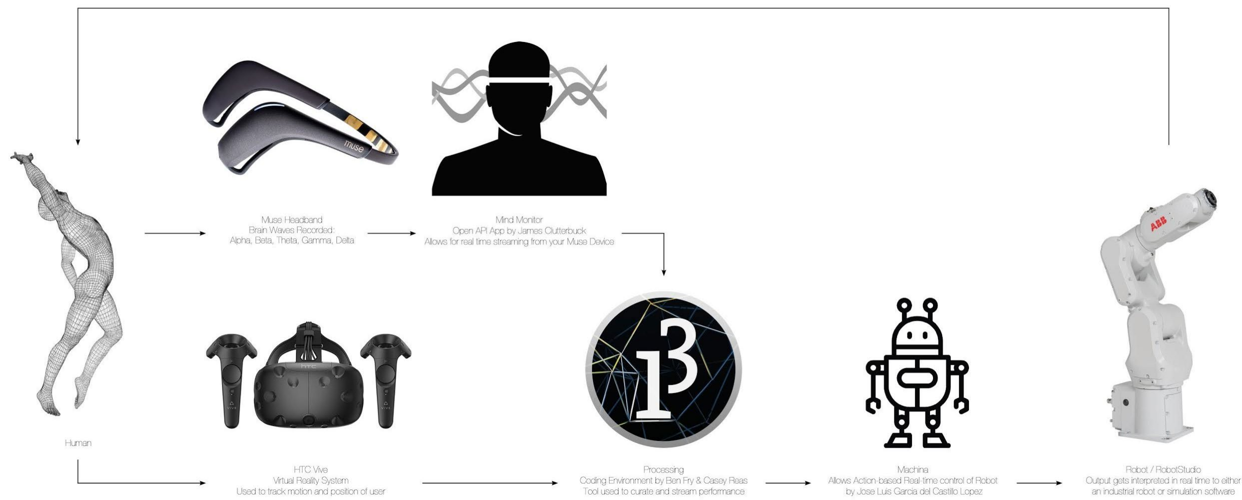

Figure 2. System Diagram

3.3 Filters

A series of “filters”, based on the current performer's most dominant EEG frequency range, influence the nature of the specific commands that are streamed to the robot. These commands include changing the speed of the robot, rotation of the axes, and transformations (change of orientation and position of the TCP). Specifically, each action is associated with the current EEG wavelength and alters the fidelity with which the robot mirrors the performer's movement. For instance, when the performer loses focus or starts to daydream (i.e. enters Delta range frequencies) the robot slows down, decreases the scale of its movements, and rotates its axes towards its origin. In contrast, if the performer enters “Beta frequencies”, which indicate excitement and alertness, the robot accelerates, scales the expansion of its movements up, and rotates its axes outwards. The “Alpha state” is considered as the “high fidelity state” and thus mirrors the performers movements with no alterations. These filters are represented through a series of conditional statements each activated by the frequency range. Each filter instructs a different operational mode for the robot; adjusting the speed, scale joint rotation and transformation coordinates (Figure 3).

```
// Alpha = "Reward State"
// When brainwaves are in Alpha state of mind is calm and concentrated
// thus movements will move at highest "fidelity"
if (currentAlpha > currentDelta && currentAlpha > currentBeta) {
  println(">> ALPHA WAVES");
  bot.SpeedTo(initialSpeed);
  bot.TransformTo(startPoint.x + viveX, startPoint.y + viveY, startPoint.z + viveZ, -1, 0, 0, 0, 1, 0);

  // Delta = "Sleep State" - If Delta brainwaves are highest then the mind is less focused and drowsy
  // thus speed will slow down and movements will become "introverted"
} else if (currentDelta > currentAlpha && currentDelta > currentBeta) {
  println(">> DELTA WAVES");
  float viveX2 = round(center1.x);
  float viveY2 = round(-center1.z);
  bot.SpeedTo(initialSpeed - currentDelta);
  bot.TransformTo(startPoint.x + (viveX2 / 1.5), startPoint.y + (viveY2 / 1.5), startPoint.z + (viveZ / 1.5), -currentDelta, 0, 0, 0, 1, currentDelta);

  // Beta = "Active State" - If Beta brainwaves are highest then the mind is alert and active
  // this speed will increase and movements will become "extroverted"
} else if (currentBeta > currentAlpha && currentBeta > currentDelta) {
  println(">> BETA WAVES");
  float viveX3 = round(-center1.x);
  float viveY3 = round(center1.z);
  bot.SpeedTo(initialSpeed + (currentBeta * 3));
  bot.TransformTo(startPoint.x + (viveX3 * 1.20) , startPoint.y + (viveY3 * 1.20), startPoint.z + (viveZ * 1.20), -currentBeta, 0, 0, 0, 1, -currentBeta);
```

Figure 3. Conditional Statements Sending Commands To The Robot Based On Users Input EEG Data.

4 Results and Discussion

Much like an architect, choreographer, or composer develops a creative work, *Translations* can be carefully curated to perform a certain way; however, when dealing with live materials and individuals one can never truly predict the perfect outcome. The unpredictability and constraints of working with an industrial robot as a partner in a performance are both fortuitous and frustrating. While some results provide beautiful, unique renditions of the performers movements, others simply are not captured in a meaningful way. It was, and remains to be, a learning process understanding the constraints of the machine as well as accepting the limited control one has over the output once volatile data, such as brainwave frequencies, are at play. The work presented in this paper remains work in progress and has primarily relied on digital simulations, using *RobotStudio* (ABB Robotics 2020), for testing and proof of concept (Figure 4). With facilities slowly becoming available the hope is to further this research by returning to physical testing in the near future.

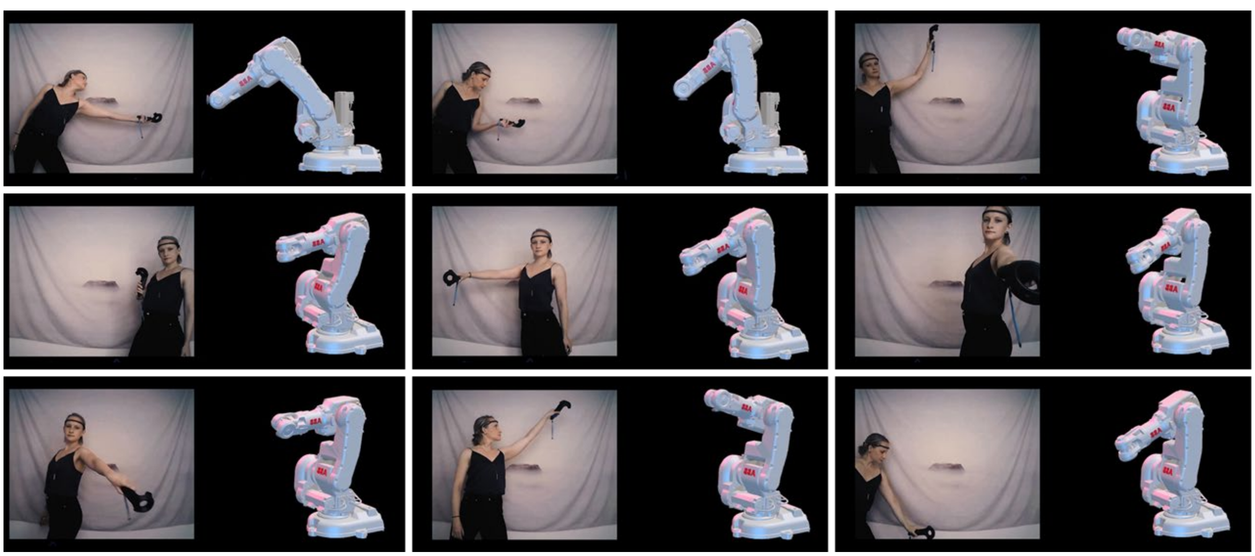

Figure 4. Testing And Proof Of Concept Simulation By [BLIND NAMES FOR PEER REVIEW].

5 Conclusion

Believing to have only just scratched the surface of the potential for synergistic human-robot relationships, these investigations pose the question of how design, science and technology can come together to re-envision the role of robotics in our daily lives. It is not until working with the robot and the Muse device that the true vulnerability of such a project is exposed. The realisation that while one might be in control of your current movements, you might not be as aware of your current state of consciousness. This suggests that at that time, the machine, or the audience, might have greater insight about the performer than they do. By providing new interpretations of human expression through machines the hope is to not only expand the relevance of how technology can expand, enhance and improve our creative capabilities but also speak optimistically to the ever growing concern of technology's role in affecting human well-being.

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