Athlete Engineering BaseLine Ecosystem: innovative technologies to enhance human performance.

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ABSTRACT

The Athlete engineering BaseLine Ecosystem (AeBLE) is a collection of integrated innovations impacting human performance, health, and wellness. AeBLE integrates artificial intelligence-driven mobile markerless motion capture, embedded wearable sensors, and augmented and virtual immersive technologies to train healthy movements and mitigate at-risk motion patterns which can lead to musculoskeletal injuries. Humans train and perform many open and closed kinetic chain activities, often making unconscious modifications to their movement based on their center of mass, situational environment, object use, clothing and shoes, and ground interactions. Over time, altered movement patterns put undue stress on the weakest links—hands-wrists, feet-ankles, and lower back—resulting in injuries or diminished performance. AeBLE will provide users with information regarding 1) body movements, 2) improvements from past training and performances, and 3) areas of potential risk for injury.

Keywords: soft sensors, artificial intelligence, machine learning, extended reality, human factors

1 INTRODUCTION

According to a 2021 report by Research and Markets, the wearable technology market is still in its infancy, focused on monitoring consumer experiences [1]. Leading the adoption of wearable technology are the fitness trackers from companies like Fitbit, smartwatches from the likes of Garmin, Apple, and Samsung, and now rings from Oura and NFC. Wearables are moving beyond the wrist, and now earphones from Bose are not just for sound but help with falling asleep faster. Smart glasses from Vuzix overlay digital assets within the real world to help with repairs. Smart clothing from Levi's Commuter x Jacquard allows smartphone control via conductive thread. Lastly, head-mounted displays from HP, Meta, and Microsoft offer extended reality games, training, and collaboration.

Companies pushing the next wave of wearable tech forward are integrating artificial intelligence (AI) to enhance functionality and performance. Based on a March 2022 report from Verified Market Research, the global wearable AI market is expected to increase yearly sales to $69.31 billion by 2028 [2]. Factors influencing the growth of wearables programmed with AI models are health awareness, AI assistance, the Internet of Things, and immersive entertainment. The benefits of AI technology embedded into devices stem from machine learning (ML), analytics, and real-time actionable audio, visual, and haptic feedback [2].

Creating the push for wearable AI tech beyond business to consumer is the interest from businesses and industries to improve worker safety and productivity like Operator 4.0 and sustainable factories [3], AI-driven healthcare [4], and professional sports performance [5]. Wearable AI tech offers the opportunity to capture large amounts of data, build models of expert performance, and personalize training. Even though there are positive sentiments about the future of wearable AI, there are many concerns and apprehensions related to the effectiveness of AI. For instance, there was hope in using ML algorithms to help doctors diagnose and understand the impact of COVID-19; however, it did not happen. In an ongoing review in the British Medical Journal evaluating 232 algorithms for analyzing and predicting how sick individuals would get with COVID-19, it was determined that none of them were fit for clinical use [6]. Other issues reported about wearable AI tech include inaccuracies of data collected, not supporting multiple applications, high costs, and not having a plan for data collection and usage [7]. These reported issues offer an opportunity to redefine how wearable AI technology can function for user inspired applications.

2 WEARABLE AI TECH

Even though wearable AI tech did not help with COVID-19 prevention, healthcare wearable AI tech offers one of the most significant market opportunities due to the large amount of data from electronic medical health records, the Internet of Medical Things, and connected devices within health IT infrastructure. AI offers the potential way to personalize patient care and provide efficient treatment planning, leading to improved health outcomes [8]. Another growing wearable AI tech sector is in extended reality (XR) innovations which are made up of four technologies; virtual reality (VR), augmented reality (AR), mixed reality (MR) [9], and deeper immersive experiences with the use of smart textiles ST [10] (see Fig. 1).

Figure **1**. Extended Reality – umbrella term which includes the following technologies:

- **VR** – Virtual reality is the recreation of the real world within an immersive environment displayed in the wearer's headset. VR can be programmed to provide training scenarios, tool manipulation, and movements.
- **AR** – Augmented reality is the real-time overlay of digital objects in a real-world environment.
- **MR** – Mixed Reality combines digital and physical worlds into a programmed experience offering new options and interactions with digital information and design collaborators.
- **ST** – Smart Textiles includes a variety of hardware and soft sensor-embedded clothing, including the likes of clothing interlaced with fiber optics and electrochromic fabrics that change color in response to an electrical charge.

3 ATHLETE ENGINEERING TEAM

Emerging out of a National Science Foundation Partnerships for Innovation funded project titled: **"From the Ground Up: Using Soft Robotic Sensors to Create a Foot and Ankle Wearable that Accurately Captures Real-time, Kinematic and Kinetic data During Athlete Training"** [11], and to improve upon the previously identified AI application issues and wearable tech gaps, human performance practitioners, multidisciplinary researchers, and scientists at Mississippi State University (MSU) have created the Athlete Engineering (AE) Research Team (see Table 1) and Lab. Supported and mentored by MSU's Center for Advanced Vehicular Systems (CAVS), Bagley College of Engineering, National Strategic Planning and Analysis Research Center, and the MSU Athletic Department, AE's vision is to create an interdisciplinary hub of globally recognized innovators, educators, and entrepreneurs in human performance and ingenuity. AE's mission is to maximize human performance and ingenuity by; (a) advancing knowledge and educating the next generation of scientists and entrepreneurs, (b) transforming research and applied innovation, and (c) creating and nurturing economic development based on entrepreneurship and research commercialization.

AE researchers from Industrial & Systems Engineering, Computer Science & Engineering, Electrical & Computer Engineering, Kinesiology, Fashion Design & Textiles, Agricultural & Biological Engineering, and Data Science recognize that the real work happens in the world, not in the laboratory. Using their expertise in ML, computer vision (CV), cognitive engineering, human and sports performance, augmented and virtual realities, physical therapy, wearable sensor technology, and human factors are developing new wearables, AI models, and validating new vendor solutions against the gold standard of laboratory measurements.

Team Member	Capabilities
Dr. Tony Luczak	Human Factors Engineering, Human Performance, User Experience
David Saucier	Data Analysis and Visualization, Signal Processing, Lab Validation
Dr. Reuben Burch	Human Factors, Human-Computer Interaction, Technology Adoption
Erin Parker	Textile Performance Testing, E-Textiles, and Sensor Integration
Carver Middleton	Electrical Hardware Design, Additive Manufacturing
Dr. Lesley Strawderman	Human Factors & Ergonomics and Consumer Product Design
Dr. Jean Mohammadi-Aragh	Engineering Education and Training, Diversity
Dr. John Ball	Signal Processing, Machine Learning, Software and Hardware Development
Dr. Harish Chander	Biomechanics, Human Factors, Ergonomics, Safety and Human Performance
Dr. Charles Freeman	Material Performance testing, Product Development, Innovation
Dr. Zack Gillen	Kinesiology, Exercise Physiology, Biomechanics
Dr. Adam Jones	Virtual Reality, Extended Reality, Spatial Vision, Human-Computer Interactions

Table 1. Athlete Engineering at MSU Research Team.

To optimize user inspired adoption and ensure that all research conducted fits a vital need to the customer, AE seeks advice and counsel from our external advisory board, and current partners including members from Fortune 500 and regional industries, researchers from national and international research centers, as well as athletic trainers, strength and conditioning coaches, and sports scientists from teams in the National Collegiate Athletic Association, the

National Football League, the National Basketball Association, and Major League Baseball. Knowledge learned from our partners has guided our work to help solve their immediate problems by delivering laboratory-quality data, innovations, and guidance to all types of athlete personas [12, 13].

AE also recognizes that human performance is not limited to sports. Workers experiencing repetitive motion or high cognitive demand in industrial facilities within Mississippi and neighboring states and the military warfighters at home and abroad are all athletes performing physical and mental tasks. For this reason, the AE research team includes former industry, military, and athletic human performance experts. CAVS' primary function is to serve industry and military partners, and while the sports athletes receive much of the attention from this program, everything done through AE is entirely transferrable to everywhere that human movement and performance needs evaluation.

4 ATHLETE ENGINEERING BASELINE ECOSYSTEM

The Athlete engineering BaseLine Ecosystem (AeBLE) was derived from an AE report based on our interviews with sports and conditioning coaches and athletic trainers on the topic of wearable technology: **"State-of-the-art review of athletic wearable technology: What 113 strength and conditioning coaches and athletic trainers from the USA said about technology in sports"** [14]. Findings from the interviewees with wearable experience (72.6%; n = 82/113) spoke to their frustration with wearables and sports training technology due to inaccurate data, lack of meaningful recommendations (or lack of meaning in general), and challenges in getting the technology to work consistently. Unfortunately, (a) some companies are not supplying answers to "what does the data mean," (b) athletes are concerned about "big brother always watching me," and (c) customer service is lacking when devices are not working as needed or advertised. These challenges cause dissatisfaction between the technology users and the technology providers. For example, one prominent Olympic trainer bluntly stated: "Wearables are fool's gold" [11].

To address these and other challenges, AeBLE is being developed as a data science-driven interoperable framework. An interoperable framework is both a strategic and tactical maneuver plan to reduce pain points identified with some current wearable technology and applications. The inability of devices to communicate and share data with all parties involved, including the athlete, is a significant problem that AeBLE aims to solve.

AeBLE will integrate our patent-pending **"Wearable Flexible Sensor Motion Capture System"** (#US20200008745A1) to capture and infer kinematic movement and kinetic ground reaction forces during training and performance (see Fig. 2). AE research is also pursuing novel techniques and methods in natural language

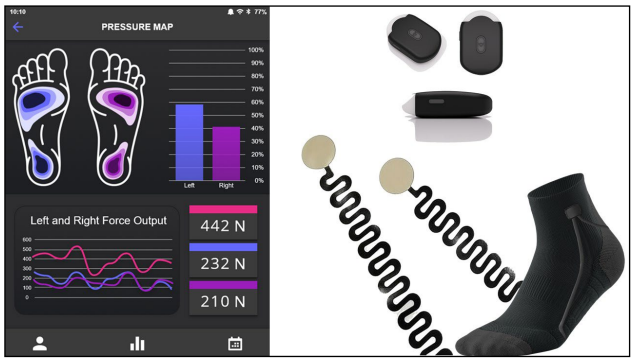

Figure 2. Conceptual Image of the Smart Sock and app.

processing, ML, and CV to create three-dimensional proprietary human pose datasets and human pose estimation models using two-dimensional video (see Fig. 3).

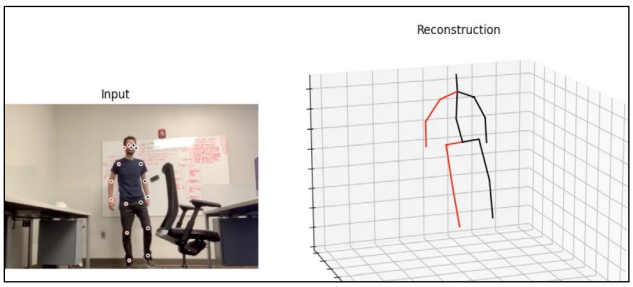

Figure 3. Markerless motion capture using a single camera device.

Collecting, measuring, and assessing human movement will allow AeBLE to characterize, categorize, and individualize tendencies and forces over time that can improve performance and reduce musculoskeletal disorders.

5 INITIAL CUSTOMER SEGMENTS

Use cases for AeBLE are widespread and defined by the individual, task, and activity. The AE research team is focusing on four distinct Human Athlete Personas:

- **Tactical Athlete**: military warfighters and emergency first responders
- **Industrial Athlete**: workers and laborers performing repetitive physical and cognitive tasks
- **At-Risk Athlete**: chiropratic and medical patients in rehabilitation and recovery
- **Sports Athlete**: amateur and professional athletes in competition

This segmentation helps to identify the specific demands for each use case, user design requirements, and contextually relevant models of expert performance. These four personas are not all-encompassing but focus on delivering wearable AI tech that can ease pain points within each market. For example, AeBLE can be used as a pre-habilitative platform to improve training and performance or bridge the gap when an athlete finds themselves in the At-Risk athlete status by providing rehabilitation monitoring and validation.

The AeBLE wearable AI tech product launch will focus on strength and conditioning fitness enthusiasts who train at-home and gyms, prodiving ground reaction pressure and performance outcomes via the Smart Sock (see Fig. 2). In addition, the markerless motion capture solution will focus on sports analysis and performance. Once these systems are combined, AeBLE will provide laboratory quality data capture in the real-world where the activities occur.

6 CONCLUSION

Wearable AI tech is on the brink of offering a wide variety of services, training, and enhanced experiences to the masses. Careful thought and consideration should be taken to communicate and integrate wearable AI tech on its functionality, data privacy and security, and limitations. Slow adoption of wearable AI tech will be due to siloed devices and applications, lack of consumer and company communication, and poor user experiences. The goal of the AE research team is to develop AeBLE for open communication, understanding the user, and optimization of wearable AI technologies across multiple platforms, designs, and use cases.

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