33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

Human Augmentics: *Augmenting Human Evolution*

Robert V. Kenyon and Jason Leigh

Abstract—**Human Augmentics (HA) refers to technologies for expanding the capabilities, and characteristics of humans. One can think of Human Augmentics as the driving force in the non-biological evolution of humans. HA devices will provide technology to compensate for human biological limitations either natural or acquired. The strengths of HA lie in its applicability to all humans. Its interoperability enables the formation of ecosystems whereby augmented humans can draw from other realms such as "the Cloud" and other augmented humans for strength. The exponential growth in new technologies portends such a system but must be designed for interaction through the use of open-standards and open-APIs for system development. We discuss the conditions needed for HA to flourish with an emphasis on devices that provide non-biological rehabilitation.**

I. Introduction

Human Augmentics (HA) refers to technologies for expanding the capabilities, and characteristics of humans. One can think of Human Augmentics as the driving force in the non-biological evolution of humans. Eyeglasses, hearing aids, and pace makers can be considered HA's early progenitors. However, exponential advances in miniaturization, and computing has laid the ground for transforming high tech gadgets into technology whose purpose is to allow humans to act beyond their natural sensory, cognitive and motor abilities. Human Augmentic devices do not modify the biology responsible for our natural limitations but instead compensate for these limitations so that our abilities can be expanded.

Futurist, Ray Kurzweil defines a related term "Singularity" as the technological creation of smarter-than-human intelligence [1]. More recently, his Singularity "movement" has been trending toward life extension through advances in bioengineering.

Human Augmentics shares some similarities to Kurzweil's Singularity in that the augmentation of human intelligence through computing is one of its core interests. However HA distinguishes itself from Singularity in that its goal is not life extension, but improvement in the quality of life. As longevity increases, the quality of life we will lead in these additional years will become more crucial. Will we live independently our whole life or will we extend our lives only to live our last years trapped in bodies that are unable to function as they once did? HA is timely in that it addresses this emerging societal challenge of living longer and living well with emerging opportunities that can meet this challenge. Critical to its success, HA technologies are envisioned to enhance the quality of life for ***all*** individuals and not only persons with a disability, or the aged.

HA can be used to augment the intellect of humans so that we can continue to make exponential leaps in scientific and technological discovery. Other forms of HA can help humans keep pace with a world that is drowning them in data and complexity. The likelihood of such advances is bolstered by the witnessed growth in the capabilities of technologies that have enabled and will continue to enable unprecedented affordability, and hence adoption of these emerging technological advances. For example, as Kurzweil notes, today's smartphone is a million times smaller than the first computer, a million times more affordable and yet a thousand times more powerful.

An important characteristic of HA arises from the distribution of these technologies into the population to form a *Human Augmentics Ecosystem*. We have witnessed, over the past 40 years, the emergence of a patchwork of technologies all filling independent niches (e.g. wearable computers, virtual reality displays, personal robots, mobile computing, and cloud computing), whereas now they have reached a critical mass so that these technologies can be converged to realize the concept of a Human Augmentics Ecosystem. An agenda for HA research and development must be multi-scale, including everything from the development of new technologies to enable HA, to the study of how large scale ecosystems of augmented humans and technology will interact with and learn from each other, and impact society.

This paper discusses the role of Human Augmentics and its application to rehabilitation. HA provides compensatory devices directed at the affected system rather than rehabilitative machines that aid in the biologic repair of the affected human system. The emergence of technologies in computing, miniaturization, sensing, and more makes such inspirational systems a near term reality. Thus, the quality of life in the future might be based as much on our technology as it is on the ability of our biology to repair itself.

II. Rehabilitation as an Inter-Connected System

Just as today humans have become practically inseparable from their smartphones, one can imagine augmentics devices that users will carry almost persistently that can be used to enhance their abilities to visually, aurally, cognitively and physically interact with the world beyond what they would naturally be capable of.

Envision *Steve*, a future augmented human endowed with potentially multiple augmentics devices. One device might

Manuscript received March 26, 2011.This work was supported in part by the National Science Foundation awards: CNS-0420477, 0959053 0703916, 0821121 and the National Institute on Disability and Rehabilitation Research award: H133E070013.

R. V. Kenyon, is with the Electronic Visualization Laboratory, the Department of Computer Science, University of Illinois at Chicago, Chicago, Il 60607 USA (phone: 312-996-0450; fax: 312-413-0214; e-mail: kenyon@uic.edu).

J. Leigh, is Director of the Electronic Visualization Laboratory, the Department of Computer Science, University of Illinois at Chicago, Chicago, Il 60607 USA (e-mail: spiff@uic.edu).

provide visual augmentation through a contact lens display [Fig. 1] [2], another might provide a cognitive enhancement that provides on-demand access to information of one's surrounds, while yet others might provide physical enhancements such as arms and legs injected with minimally invasive BION muscle stimulation devices [3] [Fig. 1] .

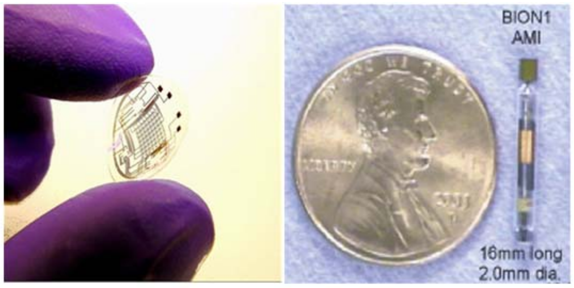

Fig. 1 Left: Contact lens display built using embedded LEDs. Right: Injectable bionic neuron (BION) device.

Today these devices are conceived and controlled entirely independently which is antithetical to the way human biological systems function. Instead we anticipate that these individual devices need to be coordinated as a systemic whole. For example when Steve needs to pick up a heavy object his arms must coordinate with his legs to perform the action as well as to maintain balance. And, when Steve looks at an object through his contact lens display he would like to pass the image of what he is seeing to his cognitive augmentics device to interpret the image, and then display information about the recognized object in his contact lens.

The illustration in figure 2 envisions an ecosystem of future augmented humans, equipped and/or embedded with multiple augmentics devices. These devices can communicate with each other, they are richly embedded with sensors, and they are able to leverage large-scale computing in the "Cloud" for computational assistance. Furthermore data from the augmentics devices could also be shared with the "Cloud" (at the wearer's discretion) to help track the performance and improve the design of future augmentics devices.

III. Open Protocols and Standards

In order to realize a Human Augmentics Ecosystem, standards of interoperability will ultimately need to be developed. This will likely need to occur in two phases. Firstly individual manufacturers of augmentics devices will need to provide access to their devices through open communications protocols, and/or Application Programming Interfaces (APIs). Secondly, when a critical mass of manufacturers producing similar augmentics devices emerges, open protocols will need to be developed to enable the interoperability to scale. This is not a small endeavor. Usually, an economic incentive is needed to spur this on. Consequently, such devices must span a wide range of users and not a small niche in the market.

IV. Leveraging Economies of Scale and Exponential Trends in Technology

Rehabilitation devices today continue to be expensive because they serve a niche market and one-on-one care is usually needed. Furthermore, rehabilitation systems are generally designed so that the user might biologically recover lost functions. However, we are now at a point where complex compensatory devices could be used by Traumatic Brain Injury (TBI) or stroke survivors to provide for lost function. For example, today's high quality hearing aid can cost the hearing-impaired user several thousand dollars and serves only one function - to amplify/process audio for the wearer. However one can imagine an HA

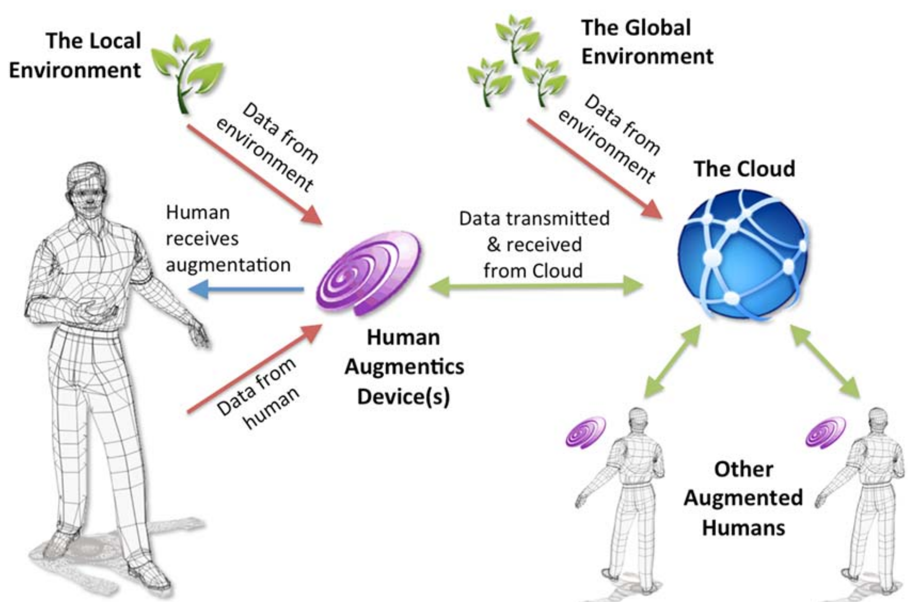

Fig. 2. A Human Augmentics Ecosystem showing 3 environmental levels. Connections can be Personal, Peer-to-Peer, and Population. "Personal" connection refers to the worn augmentics devices communicating among themselves and the user. The "Peer-to-Peer" is where an augmented human communicates to close-in neighbors. The "Population" is where the communication is through the "Cloud" to provide and receive information.

device intended as an audio-based informational device (not too dissimilar from today's Bluetooth earpiece for a Smartphone) can easily amplify audio in the environment as one of its add-on functions. By designing for a broad user base for HA devices on the outset, economies of scale will enable them to become highly affordable, hence making rehabilitative capabilities also affordable.

Fig. 3. Top: Low cost (~$7,000) Consumer VR in 2011 vs. Bottom: EVL's CAVE VR from 1991 (~$800,000).

Time and time again we see this evolution from single-purpose niche devices to general-purpose devices. For example, in the late 90s, the PC revolution replaced expensive niche supercomputers with cluster computers built from low cost commodity PCs. Today, Smartphones are beginning to replace GPS navigation units, laptops are replacing desktop computers, and lightweight tablet computers are starting to replace laptops. Another excellent example is that of the Microsoft Kinect tracker, which was designed for video games but has also found a niche as an all-purpose body tracking system and replacing more expensive tracking systems. In fact, Virtual Reality (VR) today is a technology that has been benefiting from exponential technology curves. VR technology once the domain of research labs and Hollywood can now be created using components that are orders of magnitude less expensive than what was previously available [4]. By combining a 3D TV, a Microsoft Kinect tracker, and a low cost computer, and you have a consumer priced one wall version of the CAVE [5] [Fig. 3].

V. Virtual Simulation

The considerable affordability of VR makes it an attractive technology for augmenting learning, training as well as rehabilitation. For example today we are able to create intelligent avatars (virtual humans) with unprecedented realism [6]. Using an optical sensor such as the Kinect, an avatar can "see" the person they are speaking to, maintain proper eye contact, as well as interpret and convey appropriate body language [Fig. 4]. Furthermore, the ethnicity, sex, age, and clothing of the avatar can be customized to better align with the preferences of the user. Most importantly, intelligent avatars provide a means to expand the reach of individuals who may be frequently in high demand. For example, while a human physical therapist can only work for 9 hours a day and must serve multiple clients, an intelligent avatar-based therapist could reside in your home and be available to you all the time. Today avatars are already being used to simulate patients for standardized patient training for medical students [7].

Due to the emergent nature of HA, in many instances

Fig. 4. Top: A physical person (Left) and is lifelike avatar (Right). Below: A user, on the left, converses with an avatar, on the right.

there will be scenarios that cannot be tested because a piece of technology is not yet available. Or one might wish to evaluate how an augmentics device (particularly visual and cognitive ones) might be designed to enhance a real world condition. The virtual prototyping capabilities of VR lend themselves to this role in HA development. The rapid changes needed in cost-effective prototyping combined with "Wizard of Oz" methodology [8] can enhance and speed deployment. At EVL we are now building the Next Generation CAVE [Fig. 5] with image resolution that matches that of the human visual system [9]. The NG-CAVE will use flat near-seamless 3D LCD panels which will provide an order of magnitude greater image brightness and contrast over previous projector-based CAVEs, and at half the cost. This will enable the creation of simulation environments that are more realistic than was previously possible.

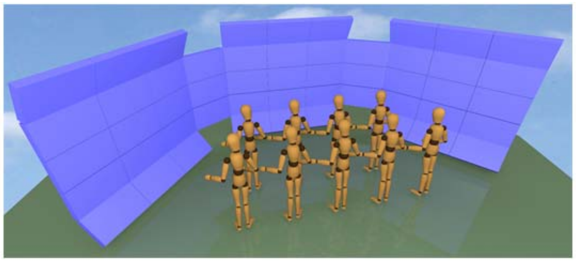

Fig. 5. EVL's Next Generation CAVE.

VI. Challenges Yet To Be Solved

The advancements in computing have made computer based HA more attractive than ever. However, HA is not just about computers but also about haptics. Physical appliances in human augmentics have lagged the trend found in computers. Robotics has certainly advanced in their control and the range of applications. However, the robot itself is still very expensive and sometimes dangerous in certain forms such as when having the strength and dexterity needed for augmenting human activities such as walking, lifting, or working [10]. However, we do see some progress where robots are not imitating humans but rather being worn by humans [Fig. 6]. The Honda Stride Management Assist device prototype [11] has the potential for anyone to wear it like a pair of pants and have the robot augment one's ambulatory abilities. Another system being designed for the military is an exoskeleton that can augment the strength of the user with motors attached to the outer body. In rehabilitation we find other robots such as the KineAssist [12] which attaches to the user and follows behind the subject and can add or subtract forces to the user. We might consider robots at the same stage of development as was VR until the explosion of gaming drove the price point for these device components to affordable levels. It may take a similar economic incentive for robots to be as approachable to the average person price point.

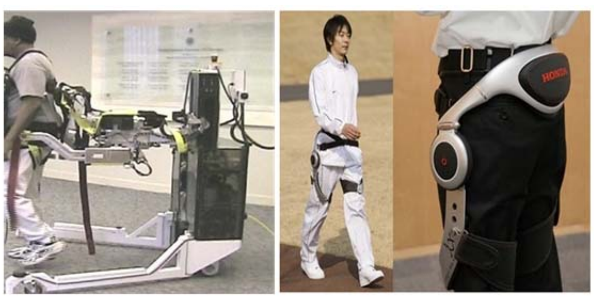

Fig. 6. Left**:** KineAssist used for standing balance, ambulation and dynamic balance therapy allows therapists to focus on useful tasks with reduced fear of falls. Right**:** Honda Stride Management Assist device. For those with weakened leg muscles who are still able to walk.

VII. Conclusion

Human Augmentics is a call to arms for the rehabilitation community to think outside of their boundaries - to think of the problem in terms of a larger interconnected ecosystem of augmented humans rather than a patchwork of disconnected sub-systems.

By rethinking rehabilitation devices as Human Augmentics devices intended for *all* humans, the economies of scale will enable the cost of rehabilitative capabilities to reduce to near zero. By establishing interoperability standards for human augmentics devices and software, developers can build systems that are compatible and can interact with each other in a coherent ecosystem. This will enable users to purchase augmentics capabilities as easily as buying an App on the iTunes store.

By leveraging exponential technology trends such as rapid miniaturization and large-scale parallelization (Cloud Computing) one can bring unprecedented levels of intelligence to extremely small Human Augmentics devices. Additionally, where technologies have not yet been invented, virtual reality environments can be used to simulate them. Human Augmentics maybe the vehicle for augmenting the non-biological evolution of mankind.

References

[1] R. Kurzweil, *The Singularity Is Near: When Humans Transcend Biology*: Penguin, 2006.

[2] B. Parviz. (2009, Augmented Reality in a Contact Lens. *IEEE Spectrum (September)*. Available: http://spectrum.ieee.org/biomedical/bionics/augmented-reality-in-a-contact-lens

[3] G. E. Loeb, F. J. Richmond, and L. L. Baker, "The BION devices: injectable interfaces with peripheral nerves and muscles," *Neurosurg. Focus,* vol. 20, pp. 1-9, May 2006.

[4] R. Kooima. (2011, Kinect + 3D TV = Virtual Reality. Available: http://www.youtube.com/watch?v=2MX1RinEXUM

[5] C. Cruz-Neira, D. Sandin, T. Defanti, R. Kenyon, and J. Hart, "The CAVE Audio-Visual Environment.," *ACM Transactions on Graphics,* vol. 35, pp. 65-72, 1992.

[6] S. Lee, G. Carlson, S. Jones, A. Johnson, J. Leigh, and L. Renambot, "Designing an Expressive Avatar of a Real Person," presented at the Proceedings of the 10th International Conf., Philadelphia, PA 2010.

[7] K. Johnsen, R. Dickerson, A. Raij, B. Lok, J. Jackson, M. Shin, J. Hernandez, A. Stevens, and D. S. Lind, "Experiences in using immersive virtual characters to educate medical communication skills," presented at the IEEE Virtual Reality, 2005.

[8] J. F. Kelley, "An iterative design methodology for user-friendly natural language office information applications," *ACM Trans. Inf. Syst.,* vol. 2, pp. 26-41, 1984.

[9] J. Leigh, A. Johnson, L. Renambot, T. DeFanti, M. Brown, B. Jeong, R. Jagodic, C. Krumbholz, D. Svistula, H. Hur, R. Kooima, T. Peterka, J. Ge, and C. Falk, "Emerging from the CAVE: Collaboration in Ultra High Resolution Environments," presented at the Proceedings of the First International Symposium on Universal Communication, Kyoto, Japan, 2007.

[10] Raytheon. (2011, XOS2 Second Generation Exoskeleton. Available: http://www.raytheon.com/newsroom/technology/rtn08_exoskeleton

[11] Honda. *Freedom of Motion: Walking Assist Device with Stride Management Assist*. Available: http://corporate.honda.com/innovation/walk-assist/StrideManagementAssist.pdf

[12] M. Peshkin, D. A. Brown, J. J. Santos-Munné, A. Makhlin, E. Lewis, J. E. Colgate, J. L. Patton, and D. Schwandt, "KineAssist: A robotic overground gait and balance training device," in *IEEE-International Conference on Rehabilitation Robotics (ICORR)*, Chicago, IL, 2005.