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The "Ultimate Selfie": Musings on the Future of our Human Identity

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Abstract: *Identity in today's world is being radically redefined. We now have more personal control than ever for how we present ourselves in social and connected media. As scientists and developers, we make sophisticated simulations, in which we include a range of characters, but the ultimate question is this: how are we ourselves represented within them? What could we be doing differently? This paper presents a plan for embedding ourselves within simulations that is potentially disruptive, but could revolutionize the way we think about our once and future selves.*

1. Introduction

The 2014 movie *Transcendence* revolves around the idea of uploading our consciousness into a computer so that we can live forever, unfettered by our mortal coils. The film treats this in sensationalist ways, but also raises some of the many issues that might arise if such technology becomes possible. By the time a concept like this hits the mainstream movies, it is because a zeitgeist has formed that makes it available and understandable to the general public. This is no exception. Most people have heard of this concept as The Singularity, popularized by Hans Moravec, Ray Kurzweil and others over the last few decades (Moravec 1988, Kurzweil 2005). The Singularity is the prediction that, as our machines become ever more powerful, humanity will merge with them in ways unimaginable to us now, even to the possibility of individuals uploading their consciousness into future computers, thus achieving immortality. However, the idea of the Singularity can be thought of as the newest name for a dream of unfettered consciousness that goes back decades. Science fiction literature provides many examples, even as far back as the 1930s. Olaf Stapeldon's 1937 book *StarMaker*, considered by Science Fiction writers who came after to be one of the finest books in this genre ever written (Stapledon 1937). The premise of this book was that disembodied explorers could transcend space and time by somehow ditching their bodies, enabling them to reach and explore into the far corners of the universe. A more recent science fiction author –Greg Egan– uses similar concepts in several of his books, including preserving one's self not only in a computer, but also in other presentations, such as an avatar (Egan 1998, 2010).

According to the advocates of the Singularity, we will soon reach a point at which technology outpaces human mental capabilities, forcing (or enabling) humanity to evolve in some way, as yet unknown, but most likely in a form where we are much more tightly coupled to our machines. It is speculated that one direction this evolution might take is finding how to upload our working brains to some more permanent receptacle than our frail organic form, some form of technological container like a future computer. The tricky part of the Singularity –one that we might not solve for some time– is the question of consciousness (Naam 2014). If we cannot even define it, or find out what causes it, or where it might reside, how can we transfer it intact to a different form? In this paper I propose a concept: The Ultimate Selfie, which is very different from the Singularity

2. Trends

Unlike the Singularity, the Ultimate Selfie does not require that we find a way to upload our consciousness, nor does it allow us to live forever. It does permit us to leave behind more of our human Self than we have ever been able to do before. There is a vast array of writing, technology development and experience that has helped inform my thoughts to end up with this concept. I will cover some of these areas by looking at recent trends that serve as fuel and background information for my ideas.

The first trend is increased precision in capturing the working data of our bodies. This has manifest most recently in the Quantified Self (QS) movement (Swan

2012). We now have access to consumer grade sensors that can measure everything from our skin conductance to our heart rates to the health of our internal biome. Many of these devices have capabilities near to or beyond those that were medical grade a few years ago. This trend encompasses everything from clipons and wristbands to devices that become part of our everyday attire, woven into clothing. Eventually we may see them implanted in our bodies in a true trans-humanist fashion. In the meantime, some available sensors today may even be swallowed to measure our internal states.

The second trend is increased capturing of our outward form. We now have sophisticated ways to digitize not only our 3D shape in minute detail, but also intricate components of our appearance such as the reflectance qualities of our skin (Li et al. 2013). This can even include the subsurface light scattering that our unique layers of dermis and epidermis exhibit to produce the precise visual form others see when they look at us (Hašan et al. 2010**)**. Three dimensional body data capture may be used for actors in modern films, where the visual effects artists can use such digital doubles within scenes long after primary shooting is complete (Debevec 2012). We may see the time soon, when every person will have a 3D scan made, throughout life and replacing snapshot pictures as the primary type of keepsake.

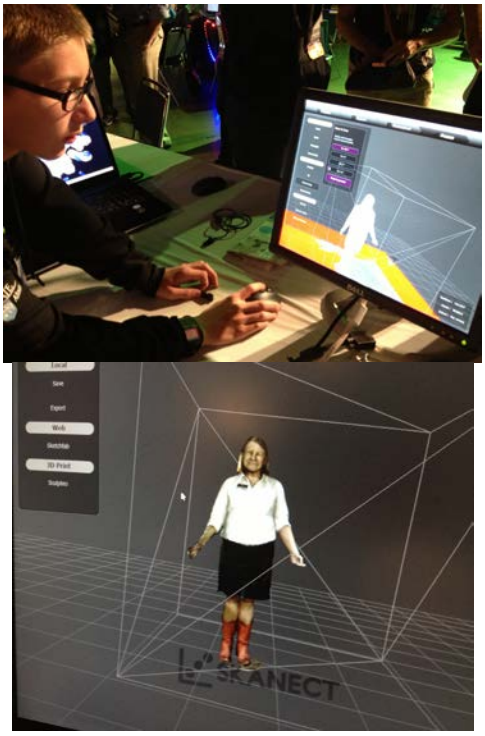
Just as we have developed sophisticated ways to capture our outward form, we can also capture much of our unique behavioral motions with a variety of new sensing devices. The third trend includes the means to capture this behavior. Techniques range from consumer grade depth sensing cameras (e.g., PrimeSense™ or the Kinect™) that are now being used with at-home computer games. More sophisticated systems can record movements with full body instrumented suits, which are frequently employed to capture the motions of actors that "play" computer-generated characters like the Na'vi in the film *Avatar*. While most motion-capture or "Mo-Cap" techniques require markers to be placed on the body, there are also markerless techniques being developed (Root 2010). These systems are progressing, but the fidelity is dependent, in part, of the number of sensors employed, with more sensors needed for finely refined action. For example, facial expressions, which reveal so many of our human emotions, are extremely complex. Basic Mo-Cap for a face alone requires as many or more sensors to be placed there as are typically used on the rest of the body (Le et al. 2013).

The fourth trend focuses on how we display the complex data we can gather, as described above. New ways to see and interact with this digital data are constantly being offered and vetted in a new marketplace hungry for such technologies. Ever since Princess Lea's hologram beamed into the Star Wars space, we have been waiting for the paramount 3D, extreme resolution display. This has led to the development of IMAX and 360° dome theaters, 3D projection systems, and autostereoscopic monitors (Hong et al. 2011). Several research institutes are actively developing new "holographic" displays, such as Dr. Paul Debevec at the University of Southern California's Institute for Creative Technologies. Using a rapidly spinning anisotropic mirror, views from all angles of a subject being projected can be perceived as if an observer is actually seeing an accurate rendition of that subject from their exact location (Jones, et al. 2009). MIT's design is based on anisotropic leaky-mode couplers, which act as waveguides for light (Smalley, et al. 2013). By having these couplers very closely spaced, interference patterns can be created as they emit light, resulting in a digital hologram. Another technique (also developed by Dr. Debevec) uses an array of extremely small "pico" projectors that can display a view for every angle without a spinning mirror. To get the correct angled view from an observer's position, a defusing screen is used (Nagano, et al. 2013).

Trend number five concerns our teleconferencing persona. We have become used to being able to see others with technologies like video conferencing in boardrooms, Skype™ on our computer and Facetime® on our smartphones. We may see many of the display devices mentioned above being pressed into the video conferencing domain in the near future. Beyond more sophisticated displays we are also evolving into methods that allow us mobility while we interact over geographically separated locales. A simple method available now is the Beam™ device (Vance 2012) (as used by Dr. Sheldon Cooper on the TV show the Big Bang theory). Robots may be getting there soon, like the SocioBot robot, where an image is projected on the inside of a formed face (Jona 2014). As robots gain functionality, we can expect to more mobile video applications arise.

We can also use such data to create a physical keepsake – a printed version of our 3D form at a moment in time. At SIGGRAPH 2013 in Anaheim California a 16 year old named Joey demonstrated his own full body data scanning system made with some Aduino code, a PrimeSense™ scanner with parts printed out via a home grown 3D printer. His system, recently made during a Maker Faire™ event, allowed attendees to be scanned in color in just a minute or two. (Figures 1a and 1b.) Afterwards that data could be output on a low cost 3D printer as a 3-4 inch figure, or collected on a flash drive

by the person who had been scanned. This brings up the question of what we do with such data? Do I own it and have the rights to it, or will that be something we have to negotiate? In today's world people are starting to do that, much like that have with copyrights on photographs and writings. The actor Kevin Bacon, rather presciently, was the first to retain control of his digital body double made for the film the Invisible Man, in the relatively ancient days of 2000. According to the Internet Movie Database, the 3D model of Bacon's entire body was anatomically correct, and has since been donated to scientific researchers. But soon, we may all need to think about what happens to our digital double data – as we age, and after we die.



Figures 1a: Joey Hurdy working on scanning me.
1b. My 3D scanned self.

These trends allow us to capture and project so much of our human forms, and because the enabling technologies are becoming cheap and ubiquitous, we are able to put them into service to personalize a wide variety of human-centric needs. For example, custom prosthetics and implants, made to precisely fit a person's scanned body part are becoming commonplace. Extreme bionics are not far away (Extreme Tech 2014). There are companies, such as the European Ergoshoe™, that builds custom shoes based on detailed scans of your feet (Piqupaille 2014). The clothing industry too, in starting to offer services to scan you for precise measurements that can then either be matched to ready made clothing or used to tailor exact fitting garments.

All of these trends are very real and happening today. Our data precedes and outlives us in many ways. In fact – we are all using some form of projection/snapshot/persona these days – whether it is your Facebook profile pictures, or a full avatar representation you have created for World of Warcraft® or a virtual world like Second Life®.

And this brings me to the last trend I will explore: that of the increasing use of avatars by people. There is much to report in this trend, so I will begin a new section to cover it all.

3. Avatars

An avatar is defined as a digital, usually 3D representation of one's self for use in a computer generated application, environment or world. Today very few avatars are created with the techniques described above, though that will undoubtedly change in the future. Today they are generally built via tools provided by the individual programs or games that use them. One's avatar can be a close match to one's actual appearance, or sometimes it can diverge to be more in line with an ideal or even a fantasy self. The use of avatars is growing faster than you might think, especially if you haven't been an aficionado of 3D games or virtual worlds. In the virtual world Second Life® alone, millions of avatars have been created, often with one person creating many for a variety of purposes. In 2011 the artist Kristine Shomaker embarked on a project to photograph a thousand of these avatars from Second Life, a popular virtual world. Her resulting book (Figure 2.) is a fascinating snapshot of the range of personal expression in avatar use and design (Shomaker 2011a). So many more people wanted their avatars photographed that she followed this with a second volume of 1000 different avatars (Shomaker 2011b).

Figure 2: Cover of Kristine Shomaker's book containing 1000 avatar portraits done in the virtual world Second Life. Used with permission from Kristine Shomaker.

3.1 Avatars: Facts and figures

The United Kingdom-based research firm KZero Worldswide has been keeping track of avatar use in hundreds of virtual worlds (VWs) at all age levels for several years now. Their numbers show that avatar use continues to increase. They chart this increase in what they call their "Universe Chart", published quarterly each year (KZERO 2013). This chart tracks VWs that have at least 1 million registered users, though most have many more than this number. The chart is circular with each world represented by an orange dot. The circle contains information such as what year the world was launched (early year "rings" start near the center of the circle) and follows the growth or decline of individual worlds (via the relative sizes of the dots) from their start to the current year.

One of the most fascinating aspects of this chart is its four quadrants, which show various age levels for which the worlds have been created. The quadrants are not divided up uniformly by age, however. The upper right quadrant encompasses virtual worlds designed for kids ages 5-10, a brief and very surprising 5 year span. Some of the larger ones include Jumpstart®, Webkinz® and Disney's Club Penguin®.

In the next quadrant, which covers kids age10 through 15 years, we have worlds like Poptropica®, Disney's Infinity® and the recent phenomenon Minecraft®. Minecraft, in the third quarter of 2013, had about 39 million registered users. Stardolls™, an online dress-up and social world, boasted 249 million for the same period.

The last two quadrants are not as populated as the ones covering younger kids, and they also include a wider age range. The lower left quadrant covers virtual worlds aimed at ages 15 to 25, and the final upper left quadrant includes the few worlds built for ages 25 and up that have over one million registered players. This final quadrant includes the most well known virtual world – Second Life, which had 37 million registered avatar users in the 3rd quarter of 2013 (Q3), and as Kzero's research shows, it has continued to increase these registrations every year since it was launched.

Adding up the Q3 2013 numbers for all the worlds in each quadrant gives roughly 500 million avatars accounts for ages 5-10, and 1 billion avatar accounts for the age group 10-15. So in a ten-year spread – ages 5-15 – you have 1.5 billion avatar accounts. Granted, "registered accounts" does not equate with individuals, since almost all kids have accounts in more than one world, and sometimes they even have several accounts within the same world. Even if these numbers are reduced to take these facts into account, we are still looking at quite a phenomenon. These children are not generally on Facebook, (user numbers for that are 1.23 billion (monthly active, December 2013) (Facebook 2014**).** Rather, these kids inhabit virtual worlds with an avatar. What is the appeal, beyond the entertainment value of the specific virtual world? One factor could be the roaming radius kids are allowed these days – that space in which they can roam freely without being driven somewhere or watched over. Over the past four decades this has shrunk to a very small physical area (Derbyshire 2007). It may be that the only free time kids have to test their social skills, to be with their friends without supervision, is within these social connected virtual worlds.

3.2 To live as an avatar

We know very little about what it means to spend part of one's life as an avatar. How much of a connection is formed between a person and their digital representation? Can a co-dependence form? How does it feel to stop using one, or to abandon one? How does customization fit into our perceptions of our avatars? If I have more opportunities to customize it, will I feel closer to it? Do I aim to make it look just like me? Is it my ideal self, taller or with long black hair, or is it perhaps a fantasy projection like a totem animal or a robot?

Research is beginning to emerge that indicates avatars may be powerful constructs that can have real effects on our actual world behaviors. Dr. Jeremy Bailenson and colleagues (Fox and Bailenson 2009; Yee and Bailenson 2006; Yee and Bailenson 2007) and Mel

Slater and team (González-Franco et al. 2010; Normand et al. 2011) have conducted a variety of experiments that show this potential, but many more studies are needed to confirm, and we must also look at what factors individuals possess that may indicate how they respond to personal avatar use.

The United States Army looked at how a person's physical capabilities could be manifest in an avatar's actions, with the goal of more realistic training in multi-player simulations. Taking data from a soldier's Digital Training Management System, or DTMS database, such as marksmanship, and physical condition, they were able to have avatars that were more accurately mapped with a participant's physical capabilities. Unlike a game, where the person's digital representation has powers that may surpass those of a mere human, in this test, an avatar might only be able to run a mile before having to "take a knee", or might miss a target more often if their marksmanship score from their DTMS was low. Fatigue was also a factor and commanders running a simulation exercise with this system found that the team mission was often compromised by less able members. Having one's avatar tied to physical abilities makes for training that is higher fidelity and more relatable to real world factors that what has been done before (McCaney 2014).

This can be taken a step further. What if the avatar was able to motivate the person inhabiting it to do better, be better? In a side project at the USC Institute for Creative Technologies, researchers scanned a visiting general, expanded his waistline and made his ensuing avatar the star of a short video. In the story, the general was motivated by the less-than-optimal appearance of his avatar to get in shape, and by having his avatar do vigorous workouts along side of what he did in the physical world, he improved not only his physique, but his avatars' as well, as they were connected in characteristics and capabilities. This motivational functionality of avatar use still needs to be tested to see if it is effective and lasting.

3.3 Intelligence in avatars and virtual humans

Beyond avatars, there are often a variety of other characters in virtual worlds and games that can interact with a user. Some of them might be programmed to have some intelligence such as NPCs or game AIs. These characters are slowly becoming more functional. I worked on a project in the virtual world where we created a host of intelligent characters for a checkpoint training exercise. (Figure 3.) These "agent avatars" played the roles of villagers that had intentions and subgoals, and could answer questions or become agitated (Jan et al. 2009).

The characters are not that smart – just programmed to take a few actions or provide responses to certain triggers. But they do exist in a persistent virtual world, and do not always behave the same way when encountered.

Figure 3: NPCs and villagers from the Checkpoint exercise

AI based characters are becoming increasingly sophisticated. If such characters don't have to survive in a persistent environment like a game or virtual world they can appear more photorealistic and are often more controllable and complex in functionality than their online counterparts. Such characters are referred to as Virtual Humans, and I will describe a few that represent

the state of the art in interactive embodied agent research.

DARPA funded a project to help veterans privately look for resources to determine if they needed mental health care, and what type might be beneficial for them to pursue. The project, called SIMCoach, presents a virtual human that talks to a person through a web interface. SIMCoach can be one of several characters, all researched to be familiar to military personnel. The system allows one to type in queries, anonymously, into a chat window, with the SIMCoach answering with voice and specific body movements that have been pre-animated to promote a more open dialogue. Based on what is typed, the coach shows web links or informational pages on topics such as sleep issues, and provides resources where the person can find more help. It is a first step that overcomes some of the issues inherent in taking that first step to getting better (Rizzo et al. 2011).

Virtual Humans are becoming increasingly attentive to the person with whom they interact, and can seem very responsive and understanding. SIMSensei is one such character being developed at the USC ICT labs. This agent uses a system called MultiSense to gather information about the person's real time emotional state, derived from facial expressions, body movement, eye gave, voice prosody and more. These inputs drive not only what the SIMSensei says, but also the way it moves its body (to establish rapport) and both tacit and spoken acknowledgements that it understands what the participant is feeling (Gratch et al. 2012).

3.4 Can we make them learn?

However, even with this sophistication, these modern AI agents, these virtual humans, are still lacking in one important characteristic. None of them really learn, or accumulate knowledge from the encounters they have. Accomplishing this will take a new architecture that forms the basis of the AI such agents use; the old ways cannot support any real long-term learning. There are researchers working on this task. One of them is Paul Rosenbloom at the ICT. He has embarked on the development of a new fundamental AI architecture called SIGMA so virtual characters will eventually be able to learn as they interact (Rosenbloom 2013).

Advancement in AI technology will take many years. Yet, if an avatar does not know how to learn, it cannot change or evolve, which makes it significantly less useful. A truly useful and functional agent avatar, a virtual human, needs what Kurzweil refers to as "recursive self-improvement."

Especially for avatars that are inhabited, or piloted by human users, the idea of a learning avatar may seem contradictory. If I am driving my avatar I am always there to tell it what to say, and how to behave, except, when I log off I leave my avatar in a sort of limbo. I can control my avatar only when I am logged into it. My friends in the virtual world cannot see me, or interact with me when I am logged out. I am not there for them, but I could be. I want my avatar to become a true surrogate for me, and to act on my behalf when I am not logged on. I want it to be like me, behave like me, and respond like me with others, even if I am not there!

So in some ways, I want to be in two places at once, and there is no good reason why this cannot happen. However, my avatar can only do this if it learns from me when I am using it, so it can continue that behavior when I am not. This goal has practical uses. Here's one example: When future astronauts travel on long duration space missions, which are expected to be a reality in the coming decade, they will not have the capability to video conference with their earth-based friends and family in real time, as they do now when they are deployed to the International Space Station. NASA is investigating using virtual worlds to help with the social and psychological isolation such astronauts may encounter when separated from earth and real time human contact on what could be a three year mission with up to 40 minute communication delays (Wu et al. 2014).

Virtual Worlds on board during long duration space flights can provide the crew with lots of activities to help with the isolation. They can take virtual vacations, play asynchronous games, pop in to a virtual club and more. The social interactions are still going to be asynchronous because of the communication lag once they leave earth orbit. In addition, the virtual world database or server will contain a sizeable amount of data, so the ground-based and craft-based servers will probably only be synchronized once or twice a day.

Social interaction works asynchronously activities like email or chess, but it would be nice if the astronaut could go into a 3D constructed space that resembles a place he or she knows back on earth and actually interact in real time with family members via their avatars that have learned in some ways to behave like them. Such avatars, or "surrogatars" could embody a family member's movements, expressions, speech patterns and more. It could even "record" the interactions with the person at the other end, which could be played back after the synchronization occurs. While this is far from person-to-person real time communication, this arrangement doesn't leave the social interaction totally hanging while waiting for that

delayed response. It allows the immediacy to which we have become accustomed, but in a novel way.

It will take some time before we get to the stage where an avatar can embody our behaviors through any sort of learning mechanism, before they can become true surrogates. However, we can start by recording common actions so they can be scripted to play back when we are not logged into our representations. This is doable today.

4. A Vision for the Future

My vision for the future is to have avatars that know how to learn from us while we inhabit them.

Currently, any avatar is a fairly impoverished representation of our actual self. My avatar in Figure 4 wants to convey to someone in a virtual world that she is embarrassed. In today's virtual worlds, the user pulls down a menu to select a pre-loaded animation that seems to fit what she wants to say. This makes this whole action a rhetorical performance as it must be carefully considered and selected (Verhulsdonck and Morie 2009). It is not intuitive or natural.

Figure 4: My avatar trying to say she is embarrassed

Researchers are starting to address these issues to make non-verbal communication better for our avatars in virtual worlds. A recent book, Nonverbal Communication in Virtual Worlds: Understanding and Designing Expressive Characters contains the latest thinking on new directions to advance avatar communications (Tannenbaum et al. 2014).

We can also look to advances in neuroscience to assist us in methods to make our connection to our avatars more natural. These ideas may still seem in the realm of science fiction, but if we focus on this topic, we can expect to make functional improvements in just a few years. Commercial off the shelf brain activity devices are gaining traction in gaming and other domains, but they are very primitive compared to what we will be able to do. Rather than having training yourself to produce intent to move or some other arbitrarily mapped action, what if such brain devices could determine your current emotional state? This requires taking not only the brain signals, but combining them with advanced analysis of those signals to extract such information. Right now this has been demonstrated with a 128 lead EEG caps (Onton and Makeig 2009), but the devices promise to only get smaller and more powerful. Another method to convey emotions to one's avatar would be with facial tracking software that reads one's expressions and uses those as a means of control. The works as long as one is situated in front of the camera by the computer screen and has control of their facial muscles. The neural interface works evens if these conditions are not met.

For example, very small sensors such as the epidermal electronics developed by John Rogers and his team at Northwestern University (Kim et al. 2011) allows for a non-invasive, even wireless way to measure brain

activity. In tests comparing the activity derived from placement on a person's forehead (for frontal lobe activity) with signals received from a 128 lead EEG caps, Todd Coleman and his team have found about an high correlation (Coleman et al. 2012).

So imagine a small device the size of a postage stamp you wear when you are using your avatar. This device determines your emotional state and seamlessly tells the avatar to exhibit those emotions, according to some animations you have pre-recorded that show you as you wish to be seen when you are happy, sad, etc. This work would contribute to a more intuitive interface as well as to more life like behavioral representations in our avatars. However, this work could be done in parallel with the efforts to enable avatars to learn, with an eventual merging of the two paths of inquiry.

5. The Ultimate Selfie

What I have been discussing thus far in this thought paper is both current trends in human-based technologies and where they might lead us in relationship to avatars we are increasingly using. These are all steps along the way to what I call "The Ultimate Selfie."

If and when we get to the stage where we have avatars that learn from us while we use them, and can stand in as surrogates for us when we are not there, then why couldn't they continue to exist after we are gone? I am not promoting uploading our consciousness into these digital vehicles, because as I have stated, consciousness is still the ultimate unknown – and being able to produce or contain consciousness in a different entity, whether that is a machine, a robot or an avatar, is beyond our capability to fully understand and therefore implement.

But just as I can see a painting of my great-great-great-grandfather, or a tin type of my great-grandmother, or a black and white cabinet photo of my grand-aunt, or a color photo of my father, or a film of myself as a child, or a video of my own children laughing and playing on one long lost summer's day, I want to leave something of myself behind.

I envision my avatar continuing to exist in some behavioral and interactive form when I am gone. My dream is that it can, and that everyone's avatar can become the representation we leave behind as a 21st Century "tin type." Imagine our descendants talking to their ancestors, asking for advice, or about family history, and more. This then, is the Ultimate Selfie.

We need not be limited to a single selfie either. I can have my scientist selfie, my parent selfie, and my artistic selfie! A brilliant commander can have a selfie that captures his or her tacit knowledge and can continue to serve as advisor or train others long after they die. There are so many possibilities!

In summary, I would like to reiterate that we should not only be paying attention to our current and future capabilities for digitally capturing ourselves, we should be thinking of new ways to use them. We are currently underutilizing such technologies, and therefore limiting the impact they could have in communicating who we are, and recording for future generations the parts of us that conventional means do not capture. Both existing and emerging technologies can be leveraged to connect us "in person" at great distance, by bringing us together in meaningful ways. All that these technologies require is for us to find a way to combine them so to create more faithful representations of ourselves that can live on past our physical lifespan. To do this we can also leverage research on known values to in-person interactions that can be used as benchmarks to measure our success, and steer the way for future research.

I plan to work to make this happen and hope others will join me. This is the start to make the "Ultimate Selfie" a reality.

7. References

Bradley, D., Heidrich, W., Popa, T., & Sheffer, A. (2010). High resolution passive facial performance capture. *ACM Transactions on Graphics (TOG),* 29(4), 41.

Coleman, T.P., Ma, R. Fung, R., Bajema, M., Albright, T. D., Rogers, J. and Gil-da-Costa, R. (2012) Epidermal electronics capture of event-related brain potentials in a real-world target detection task, Society for Neuroscience Annual Meeting, Oct 2012.

Debevec, P. The Light Stages and Their Applications to Photoreal Digital Actors. White paper available online at http://gl.ict.usc.edu/LightStages/SIGGRAPHAsia-2012-Debevec-LightStages.pdf. Accessed January 10, 2013.

Derbyshire, D. (2007). How children lost the right to roam in four generations. Retrieved Feb 2012, from site: http://www.dailymail.co.uk/news/article-462091/How-children-lost-right-roam-generations.html.

Egan, G. (1998) *Diaspora*. Eos/Harper Collins, New York, NY.

Egan, G. (2010) *Zendegi*. Nightshade Books, San Francisco, CA.

Extreme Tech (2014) Subject thread with several posts at Extreme Tech online. Available at http://www.extremetech.com/tag/bionics, Accessed March 1, 2014.

"Facebook Reports Fourth Quarter and Full Year 2013 Results". Facebook. January 29, 2014. Retrieved February 7, 2014.

Fox, J., & Bailenson, J. N. (2009). Virtual self-modeling: The effects of vicarious reinforcement and identification on exercise behaviors. *Media Psychology*, 12(1), 1-25.

González-Franco, M., Pérez-Marcos, D., Spanlang, B., & Slater, M. (2010, March). The contribution of real-time mirror reflections of motor actions on virtual body ownership in an immersive virtual environment. In Virtual Reality Conference (VR), 2010 IEEE (pp. 111-114). IEEE.

Gratch, J., Morency, L. P., Scherer, S., Stratou, G., Boberg, J., Koenig, S., Adamson, T. & Rizzo, A. (2012). User-State Sensing for Virtual Health Agents and TeleHealth Applications. *Studies in health technology and informatics,* 184: 151-157.

Hašan, M., Fuchs, M., Matusik, W., Pfister, H., & Rusinkiewicz, S. (2010). Physical reproduction of materials with specified subsurface scattering. *ACM Transactions on Graphics (TOG)*, *29*(4), 61.

Hong, J., Kim, Y., Choi, H. J., Hahn, J., Park, J. H., Kim, H., ... & Lee, B. (2011). Three-dimensional display technologies of recent interest: principles, status, and issues [Invited]. *Applied optics*, *50*(34), H87-H115.

Jan, D., Roque, A., Leuski, A., Morie, J., & Traum, D. (2009, January). A virtual tour guide for virtual worlds. In *Intelligent Virtual Agents:* 372-378. Springer Berlin Heidelberg.

Jona, Gabrielle (2014) Meet SocioBot. Published online April 15, 2014 in International Science Times. Available at http://www.isciencetimes.com/articles/7068/20140415/meet-socibot-creepy-social-robot-make-look.htm. Accessed April 14, 2014.

Jones, A., Lang, M., Fyffe, G., Yu, X., Busch, J., McDowall, I., ... & Debevec, P. (2009, August). HeadSPIN: a one-to-many 3D video teleconferencing system. In *ACM SIGGRAPH 2009 Emerging Technologies*: 13. ACM.

Kim, D. H., Lu, N., Ma, R., Kim, Y. S., Kim, R. H., Wang, S., ... Coleman, T. & Rogers, J. A. (2011). Epidermal electronics. *Science*, 333(6044), 838-843.

Kurzweil, R. (2005). The singularity is near: When humans transcend biology. Penguin.

Kzero (2013) Virtual Worlds: Industry and User Data: Universe Chart for Q3, 2013. Available online at http://www.slideshare.net/nicmitham/kzero-universe-q3-2013. Accessed October 14, 20134.

Le, B. H., Zhu, M., & Deng, Z. (2013). Marker Optimization for Facial Motion Acquisition and Deformation. *Visualization and Computer Graphics, IEEE Transactions on*, *19*(11), 1859-187

Li, H., Vouga, E., Gudym, A., Luo, L., Barron, J. T., & Gusev, G. (2013). 3D Self-Portraits. *ACM Transactions on Graphics (TOG)*, *32*(6), 187.

McCaney, Kevin (2014) Virtual Reality Gets Real with Army's 3D Game Update. Defense Systems News. Avaialble online at http://defensesystems.com/articles/2014/04/10/army-vbs3-virtual-training-gets-real.aspx. Accessed March 12, 2014.

Moeslund, T. B., & Granum, E. (2001). A survey of computer vision-based human motion capture. *Computer Vision and Image Understanding*, *81*(3), 231-268.Moravec, H. (1988). *Mind children*. Cambridge, MA: Harvard University Press.

Naam, R. (2014) The Sinuglarity Is Further Than It Appears. Published online at http://www.antipope.org/charlie/blog-static/2014/02/the-singularity-is-further-tha.html. Accessed May 3, 2014.

Nagano, K., Jones, A., Liu, J., Busch, J., Yu, X., Bolas, M., & Debevec, P. (2013, July). An autostereoscopic projector array optimized for 3D facial display. In *ACM SIGGRAPH 2013 Emerging Technologies*: 3. ACM.

Normand, J. M., Giannopoulos, E., Spanlang, B., & Slater, M. (2011). Multisensory stimulation can induce an illusion of larger belly size in immersive virtual reality. *PloS one*, 6(1), e16128.

Onton, J. A., & Makeig, S. (2009). High-frequency broadband modulation of electroencephalographic spectra. *Frontiers in human neuroscience*, *3*, 61.

Piqupaille, Roland (2014) High-tech Custom Made Shoes. ZDNET online. Published January 19, 2006. Available online at http://www.zdnet.com/blog/emergingtech/high-tech-custom-made-shoes/138. Accessed January 12, 2014.

Rizzo, A., Sagae, K., Forbell, E., Kim, J., Lange, B., Buckwalter, J. G., Willaims, J. & Rothbaum, B. O. (2011). SimCoach: an intelligent virtual human system for providing healthcare information and support. In *The Interservice/Industry Training, Simulation & Education Conference (I/ITSEC)* (Vol. 2011, No. 1). National Training Systems Association.

Root, J. (2010) Real-time Motion Capture. In S. Zwerman and J. A. Okun (Eds), *The VES Handbook of Visual Effects: Industry Standard VFX Practices and Procedures (pp. 35-386).* Burlington, MA: Focal Press.

Rosenbloom, P. S. (2013). The Sigma cognitive architecture and system. *AISB Quarterly,* 136, 4-13.
Schomaker, K. (2011a) *1000 Avatars Vol. 1*. Self-Published. Available at http://www.blurb.com/books/2289173.
Schomaker, K. (2011b) 1000 Avatars Vol. 2. Self-published. Available at http://www.blurb.com/books/2828775.
Smalley, D. E., Smithwick, Q. Y. J., Bove, V. M., Barabas, J., & Jolly, S. (2013). Anisotropic leaky-mode modulator for holographic video displays. Nature, 498(7454), 313-317.
Stapledon, O. (1937) *Starmaker*. Methuen, United Kingdom.
Swan, M. (2012). Sensor mania! the internet of things, wearable computing, objective metrics, and the quantified self 2.0. *Journal of Sensor and Actuator Networks*, *1*(3), 217-253.
Tanenbaum, J., Seif El-Nasr, M., & Nixon, M., Eds. (2014). *Nonverbal Communication in Virtual Worlds: Understanding and Designing Expressive Characters*. CMU ETC Press, Pittsburg, PA.
Vance, Ashlee (2012) Beam Yourself Anywhere for $16,000. Published online September 27, 2014 in Bloomberg Business Week available at http://www.businessweek.com/articles/2012-09-27/beam-yourself-anywhere-for-16-000. Accessed July 12, 2013.
Verhulsdonck, G., & Morie, J. F. (2009). Virtual Chironomia: Developing Nonverbal Communication Standards in Virtual Worlds. *Journal of Virtual Worlds Research*, 2(3), 3-10.
Wu, P., Morie, J., Benton, J., Haynes, K., Chance, E., Ott, T., & Schmer-Galunder, S. (2014). Social Maintenance and Psychological Support Using Virtual Worlds. In *Social Computing, Behavioral-Cultural Modeling and Prediction*: 393-402. Springer International Publishing.
Yee, N., & Bailenson, J. N. (2006). Walk a mile in digital shoes: The impact of embodied perspective-taking on the reduction of negative stereotyping in immersive virtual environments. *Proceedings of PRESENCE*, 24-26.
Yee, N., & Bailenson, J. (2007). The Proteus effect: The effect of transformed self-representation on behavior. Human communication research, 33(3), 271-290.

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Jacquelyn Ford Morie is founder and chief scientist at All These Worlds, LLC, a spinoff company she created after 13 years as Senior Researcher at the University of Southern California s Institute for Creative Technologies which she helped start. Her research focuses on the future uses of virtual worlds and how our avatars are affecting our daily lives. Previous to the ICT she worked in the Hollywood animation industry, creating specialized training for all aspects of production at studios such as Walt Disney Feature Animation, VIFX, Blue Sky and Rhythm and Hues. From 1990 to 1994, she was a researcher at the Institute for Simulation and Training in Orlando, FL. Dr. Morie has published broadly and spoken at international venues on her research, and contributed to several books on topics from education to immersive art; from games to health. She is a long-standing member of, and serves on the Strategic Executive Council for, ACM SIGGRAPH. She has Masters degrees in both Fine Art and Computer Science from the University of Florida. Morie's doctorate (University of East London) focused on theories of space and embodiment in immersive virtual environments.