

# Creation of an Integrated Multisensory Wearable Story:

costume embedded haptics-vr using a  
considered eco-ethical design approach

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In this paper, Burge will summarise the journey of iterative technological and creative development to produce a multi-sensory story. Burge created a multi-component system, using ethical considerations at every step of the design process (including circular design methodology, supplier, material and process choice) without compromising on creative or technological innovation. She will reflect on the pros and cons of using this considered approach on user-centred emergent technology and its impact on multi-sensory story-telling.

This project is called GhostNet, developed as part of the WearSustain network to create sustainable wearable technology (Funded by EU Horizon 2020 research & innovation grant No 732098 Mar – Dec 2018). GhostNet is an interactive wearable experience which raises the awareness of ocean plastic pollution. GhostNet refers to the huge problem caused by plastic fishing net, lost or discarded, so-called "ghost gear and ghost nets" which has led to the death and injury of millions of marine mammals.

This artistic experience consists of a dystopian underwater VR scene, animated in Unity, providing visualisation of scientific data (Imperial College) and built on the most recent untethered 6 degrees of freedom headsets (Lenovo Mirage Solo with Google daydream platform). This is integrated with pneumatic haptics made of recycled pvc air pouches and handcrafted sculptural silicon tentacles developed by BB Studio. The air pouches and tentacles inflate and deflate to touch the wearer, and is animated in the VR or can be controlled by the controller. The haptics are embedded (and project from) eco-ethically made costume jackets.

Strong garment aesthetics created encloded cognition and a strong mental imagery altering self-perception (Adam, H. & Galinsky, A. 2012). The couture style jackets are central to the experiential narrative with reflective outer hems to represent the ghost nets and textile prints painted in VR using Google poly, and also appear in the VR animation. The jackets which hold the electronics have been produced by immigrant charity Heba using sustainable fabrics including organic cotton and seaweed

fabric. Additionally, BB Studio followed a circular economy design methodology to ensure all the components are modular, so that they can be reused, recycled and repaired easily.

GhostNet is Burge’s fourth costume-spectacle wearable VR-haptic experience developed as a continuation from experiential themes around costume wearables as a reference for ‘transformation and exploration of the pathways to narrative and ludic (playful) (Isbister & Abe 2015).

This grant facilitated Burge to incorporate her previous findings (Burge 2018) and develop all areas of innovation and creativity under the mentorship of V Frascolla (Intel, Director Research and Innovation) and Dr. R. Hunt (researcher in sustainability) with team members Dr. H. Boys (researcher in smart materials for enhanced human computer interaction), A Baker (creative Unity developer), F. Akmal (Wearables Consultant) and E. Cohrt (design futurist).

*VR. Haptics. Costume. Storytelling. Multisensory. Interactivity. Sustainability.*

## 1. INTRODUCTION

BB Studio embarked on developing learnings from previous VR-haptics projects into a more sustainable and complex innovative framework with an objective to create an engaging multisensory story to raise awareness of ocean plastic pollution. In contrast to BB Studio’s previous work, this was its first wireless interactive VR experience integrating untethered headsets of 6 degrees of freedom with its improved proprietary inflatable wearable haptics developed using a circular design methodology.



**Figure 1:** Deming GhostNet at Imperial Lates, February 2019 Burge’s own photo

**Table 1:** GhostNet components

Haptic Actuators	VR	Sensors	Communication	Electronics	Multiplayer	Garment
Silicon tentacles	Ocean-plastic pollution story	Air pressure sensors	Audio - Sound	Arduino	Visibility	VR inspired print design
PVC Air Pouches	Ocean plastic pollution themed assets	Accelerometers	Avatar representation	Pump/valve control		
	Engaging Sea-Scape		Interaction with visuals	Bluetooth/Wifi		Structured 3D garment design

## 2. VR EXPERIENCE AND ARTWORK

The VR experience is an animation created in Unity about ocean plastics with extensive research about issues from team member Dr R Hunt, audio proof from The Conservation Society, and data visualization as Unity particles in VR directly from ‘Plastic Drift’ simulating the probability of ocean plastic pollution. Burge wanted to create a visually stunning ocean sci-fi dystopia driven by fabric print within the constraints of untethered android headset capability; particularly with added

processing complexity of multiplayer and haptic interactivity and animation tracks.

The constraints led BB Studio to research optimized and generative 3D assets in particular cinder medusae squid alongside Burge’s painted Google Blocks assets. This was also developed into fabric prints to create a visual association across the different mediums. A haptic tentacle animation appeared in the scene and was also as a real silicon inflatable tentacle made by Cohrt.

Inevitably, with every addition of asset or complexity, the Apk compiled on the headset would become suboptimal and glitch or output unpredictable errors, so there as a constant editing and deleting with development.

The VR story was iteratively developed with animation tracks structured around the audio script. The headset controller has been instructed to increase and decrease the Ghost Nets within the VR experience at the same time as the haptics inflating and deflating respectively.

### 3. GARMENT



**Figure 2:** GhostNet Garments with VR assets as textile prints on organic cotton and seaweed fabric produced partly by Heba Women's Charity. Author's own photo.

A critical part of the multisensory story has been the design and development of the 2 outer garments. The original inspiration came from polygonal style of VR combined with origami-esque and sculptural kimono silhouettes of the previous BB Studio vr-haptic-costume story, The Great Wave, which in itself was inspired by an art residency Burge completed in Ikisa, Japan in 2016. Evaluation from the previous BB Studio projects showed that the costume wearable was a reference for 'transformation and exploration of the pathways to narrative and ludic (playful) (Isbister & Abe 2015). and people wanted:

- the garment to be literally represented and abstracted in the VR story;
- to see *touch* both virtually and in real life through the garment" (Burge 2018)".

The role of the wearer's outer garment is deliberately captivating providing a performative experience for onlookers was explored, leading to a more structured garment design complete with reflective tape creating a shape of a ghostly net.

VR assets Burge painted in Google blocks were developed into textile prints and digitally printed onto sustainable fabrics such as organic cotton and seaweed fabric. An inner garment to hold electronics and tubing and haptics were made out of reclaimed fabrics. This componentization to allow for easier reuse and repair in line with circular design methodologies. Immigrant charity Heba were employed for part production.

### 4. HAPTICS

BB Studio team experimented with materials, surface design and types of construction for inflation and deflation as well as testing different effects achieved through inflation (triggered by bespoke electronics through flexible hosing), placement on the body and size and shape variations. Still there is little in terms haptic vocabulary to refer to and we use it as a Feel Effect to enhance an interaction by creating a loose narrative to connect it to a meaningful event within the VR (Israr, A et al 2014).

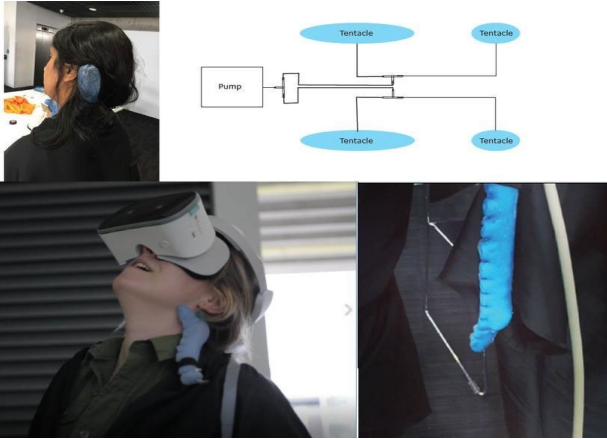
The bespoke electronics are created from reclaimed blood pressure machines with extra booster elements for increased pumping and additional electronics for messaging from the VR controller.

**Haptic type 1** was created by PVC cured (not stitched) into different shapes referencing soft robotics with an outer sleeve to prevent air breakages and allow for fabric manipulation and different textures which would create its own haptic sensation. Bespoke connectors were 3d printed to the connect air pipes. PVC as a material is not sustainable and the pouches were restrictive in shape-construction always requiring an outer sleeve.

**Haptic type 2** was created to 'See touch', to show movement and a more visually engaging haptic, Cohrt with a background in soft robotics and wearables crafted different coloured tentacles using silicon. The silicon tentacle haptics were highly performative, unique and had a biomorphic quality which made an immediate impact during demos. The silicon itself felt quite heavy and had to be adjusted for best placement.

After multiple use at demos, there were issues of air breakages with both haptic types. For future developments we would add air pressure sensors or code a maximum point with the Unity in the VR scene to prevent future damage.





**Figure 3:** Handcrafted inflatable blue tentacle attached to BB Studio proprietary pump. Author's own photo.

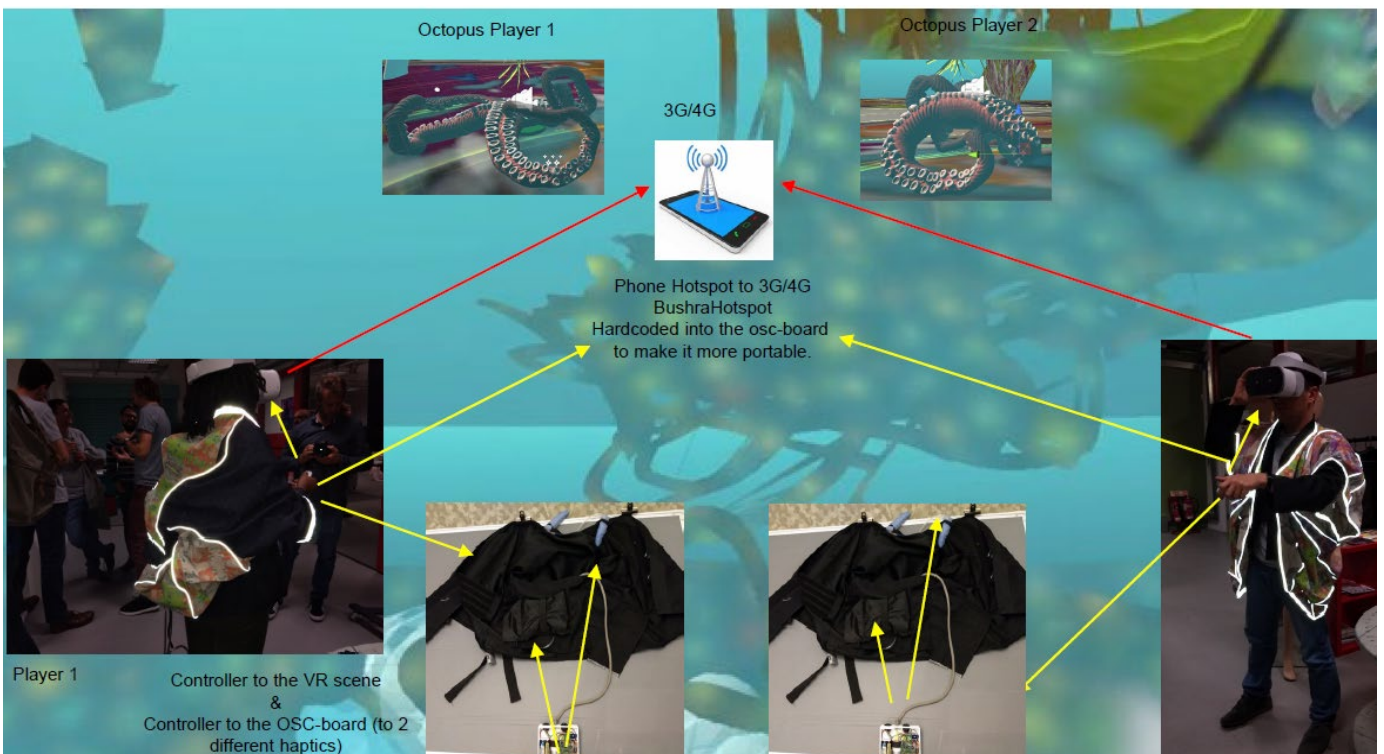
#### 4. ELECTRONICS, INTEGRATION, ARCHITECTURE

From the outset, Burge wanted to create a rich visual story which interacted with BB Studio electronics in an untethered headset with a light 6 degrees of freedom. The platform was a daydream on an android operating system. There the controller which comes with the headset is blue tooth paired.

Having worked with Bluetooth, we researched within our network for a more robust solution and was recommend the WIFI -protocol XIO-biard to send messages to the pump to inflate the haptics. The board also held other parameters such as having its own accelerometer so one-story development was having a VR body which moved independently to the VR headset accelerometer. The board would connect through a hotspot on an inhouse app. Additionally the app was developed to be able to test and override the controller.

For multiplayer, a Unity package called Photon Room which allowed players to enter interact in an internet VR room. For efficiency, the players would effectively spawn and appear as the connection happened through the WIFI (either through mobile network of the phone or a normal WIFI). The multiplayer aspect was a challenge during public demos, sometimes because of firewall issues and sometimes because the bandwidth was crowded. BB Studio tried some work arounds like a dedicated modem or networked phone but it would be still be unstable.

The final architecture of GhostNet has been revised to be much simpler, and currently shown as a single player experience.



**Figure 4:** Multiplayer Architecture of GhostNet.

## **5. SUSTAINABILITY**

The IDEO and Ellen MacArthur Foundation 'Circular Design Guide' had been referenced throughout the project particularly in choice of materials (reclaimed, reused, organic and seaweed fabrics (Sea-cell, biodegradable) and componentizing as much of the system as possible. Digital printing which is less water wasting and polluting than traditional printing methods. Bio plastics such as hemp was investigated in the production of electronics casings and will be used in surface design of future iterations. BB Studio had partnered with HEBA women's charity to produce a large portion of the garment sewing (the most technically advanced aspects have been carried out in house by fashion designer carried out).

Sourcing sustainable electronic components proved challenging for small quantities. Excess factory stock and discontinued lines were a potential source for reclaimed components and also buy from second hand outlets such as Ebay. Other options were to source electronics made by reputable suppliers with associated accreditations and standards.

The story itself was to raise awareness of a sustainability issue and data was visualized from public datasets (downloaded to CSV) shown to us by Dr Erik Van Sebille, Faculty of Natural Sciences, The Grantham Institute for Climate Change who told us about <http://plasticadrift.org/> which simulates the probability of plastic pollution in the sea at a particular longitude and latitude.

## **5. CHALLENGES**

The sheer complexity of component of the experience from couture style garments to multiplayer caused unpredictable issues. For instance, production of the garment required revisions because of quality problems due to such a complicated design. Another example was that the soft-robotic silicone tentacles would contort appropriately in test but when demoed would burst, and the PVC air pouches developed holes. Future solutions would need the haptics to have a pressure sensors or controls in place within the Unity scene.

There was also issues regarding the lack of interoperability between the app and the latest boards across the multiplayer systems. The boards required unique IP addresses. Furthermore, the system worked well in testing but in a public event environment with lots of people the multiplayer wifi systems became unstable. It has resulted in reducing the demos to single player as the multiplayer versions are further trouble-shooted and developed.

The biggest challenge has been to create a cohesive story-experience from so many bespoke components created by a semi-remote team. The BB Studio team attempted to keep synergies through shared virtual channels.

## **5. CONCLUSION**

With GhostNet, BB studio set out to design an immersive, multisensory storytelling experience using a fully integrated and aesthetically striking wearable technology garment, and Virtual Reality (VR) using sustainable design methodologies where possible. BB Studio demoed the experience at different stages of development at a number of events such as ICT Austria, December 2018 and Imperial Lates, February 2019 as well being shortlisted for '2019 SXSW Alternate to Finalists at Style & Wearable Tech in the Interactive Innovation category' and awarded the Worth Grant (EU) for a future VR-craft experience.

This project allowed BB Studio to build a considerable experience (Table 2) and a range of solutions, including electronics, sensors, actuators, haptic elements, communications, VR assets, wearables and garments which they are recombining and adapting to other experiences and stories.

**Table 2:** Learnings components

Haptic Actuators	VR	Sensors	Communication	Electronics	Multiplayer	Garment
Soft robotics	Original environments	Pressure	Interaction with visuals	Arduino	Visual representation	Print design
Pneumatics	Original assets	Acceleration	Avatar representation	Bluetooth wifi	Alternatives may include (e.g. interactivity)	Pattern cutting / Tailoring
Alternatives may include (e.g. electro-muscle stimulation)	Data visualisation	Alternatives may include (e.g. orientation)	Environment representation	Pump/valve control	(e.g. additional gestural controllers)	Alternatives may include (e.g. different sensory materials)
(e.g. vibration / buzzers)		(e.g. temperature)	Interaction sound			(e.g. articulated elements)
(e.g. mechanical resistance)			App control centre			

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