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Title: Do Autonomous Vehicles dream of virtual sheep? The displacement of reality in the hyperreal visions of autonomous vehicles

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Do Autonomous Vehicles dream of virtual sheep? The displacement of reality in the hyperreal visions of autonomous vehicles

‘Oh god,’ Rachael said. ‘That’s awful! Did they really do that? It’s depraved! You mean a live lobster?’ The gauges, however did not respond. Formally a correct response. But simulated.

Phillip K. Dick, *Do Androids Dream of Electric Sheep?*, P42

‘We can stick this [a stereo-camera] on a car and stick a laser in its arse...’

Paul Newman, Founder and CTO of Oxbotica, speaking at Re:Work Cities Summit, London 2014

Amidst the excitement around the development of Autonomous Vehicles (AVs) in recent years, one question persistently appears ‘how does the driverless car see?’ The question has obvious safety concerns. After all, if people are to share the streets with AVs in the future they will want reassurance that the vehicles can actually see them and avoid colliding with them. Whilst societies have been comfortable with the knowledge that photo and video cameras can collect visual data, there has been an understanding that these technologies do not understand the things they are representing. AV developers, however, are keen to stress the sophisticated vision of their vehicles; that they really can be trusted to qualitatively distinguish between a person and a paper bag – and respond appropriately – whilst driving on public highways.

This paper explores the 'vision' or ability of AVs to 'see' with specific reference to a case study based on the Low-carbon Urban Transport Zone, or LUTZ, Pathfinder 'pod' trials run in Milton Keynes, UK from 2016 to 2018. The different forms of vision that are enacted in the project spill out into multiple formats that are central to the project from the use of Virtual Reality (VR) to research Human-Machine Interactions (HMI) to the employment of sensors and cameras to 'see' the road, vehicles and people around the LUTZ pod vehicle. Using this case study, the paper contributes to the literature around 'hybrid geographies' as forwarded Science-Technology Studies (STS) theory as the technologies construct specific cultural versions of nature. Moreover, the paper draws on Baudrillard's (1994) notion of hyperreality, simulation and simulacra, to argue that the construction of these visualised realities from data confuses, conflates and dis-places the real world with the simulation and renders the human and 'nature' of the city as a politically neutralised object of surveillance and control through an artificial version of 'seeing'. This is significant in the wider context of 'smart cities', in which AV trials such as LUTZ are often positioned, as smart cities involve partnerships between governmental, educational and private-sector technologies organisations and are criticised for their lack of public accountability and democracy (Hollands 2008; Vanolo 2014; Kitchin 2014; Goodspeed 2015; Joss, Cook, and Dayot 2017). The paper therefore explores how this political neutrality is enabled in respect of AVs, in this case, through the construction of a hyperreal order of simulacrum.

The next section reviews current literature around visual cultures of 'smart' technologies as well as a discussion of hybrids and hyperrealities constructed through simulation and data. After discussion of the case study and methods,

the empirical section will then draw data from the *Smart Cities in the Making: Learning from Milton Keynes* project (which ran from 2017-2019) which researched the LUTZ and other related 'smart' projects to understand how such projects emerge and constitute the 'smart city'. These forms of smart work to produce a hyperreality in which the world is constituted by data and informed by the logics of technological, commercial intervention, of which the 'seeing' of AVs are one particular manifestation. Within the 'reality', the world and its contents, including human bodies, are classified and ordered according to the simulacra of the AV. Simultaneously, the visualisations construct AVs as the safe and sensible transport choice of the future.

'Seeing' and visual cultures of 'smart' urban technologies

The potential for technology to autonomously understand the significance of the visual data it captures, to develop 'synthetic vision', is a key concern to many visual theorists (Virilo 1994). For a long time, cameras have been able to detect visual conditions and automatically make adjustments such as focus or lighting for an image. More recent facial detection technologies have become available on many cameras and popular websites such as Facebook which can scan photographs uploaded by the user and match the faces to personal accounts. Further public iterations have been employed by police and security organisations at airports or in other public spaces as cameras can detect an individual's characteristics such as gender, ethnicity, age, even emotional expression such as smiling. Writer Adam Greenfield (2017) criticises such technologies and the assumptions they perpetuate. Using the example of such software linked to advertising campaigns, he argues that biases emerge when the value of the (advertising) site is determined by the characteristics of people who walk by and are likely to view the advert. As the most valuable

customer demographic are often white males, the software can be valued according to how many of these individuals look at the advertising (Greenfield 2017). Consequently, the advertising may be trialled and tailored to capture this demographic, leading to a prioritisation of this demographic and their interests above other social groups. Resultantly, decision-making processes become relegated to market-driven algorithms, rooted in these feedback loops (Graham 1998). This form of seeing is rooted within ideological and commercial assumptions that affect the eventual meaning and value of the visual data. This process is emphasised in the shift towards 'smart' cities and technologies, which also provide a wider context for AVs.

There are many definitions of a smart city, but generally a smart city is where governmental, community, educational and commercial organisations gather and analyse large-scale, real-time, integrated datasets in order to increase efficiency, sustainability, citizen engagement and security (Hollands 2008; Kitchin 2014; Goodspeed 2015; Willis and Aurigi 2018). A notable feature of smart cities is the intensive and extensive use of visual materials to firstly, produce visions of future utopic urban landscapes that invite investment, inspire engineering and communicate their ambitions to wider public audiences and; secondly to visualise data produced in and around the smart city from a network of cameras, sensors and devices (Vanolo 2016; Kinsley 2010; Rose 2017; Rose and Willis 2018; Bergman, Schwanen, and Sovacool 2017). Examples of these include urban dashboards that visualise and make 'live' datasets (Barns 2018; Kitchin 2014) to the videos that are used by large corporations to promote their expertise and technologies (Kinsley 2010; Bergman, Schwanen, and Sovacool 2017; Rose 2017); and to make visible

relationships between different datasets and objects (Halpern 2015) that were previously hidden from view.

This is not particularly novel. Since the Renaissance era, society has become comfortable with new technologies purporting to show phenomenon that is not visible to the naked eye (Mirzoeff 1999). Improvements in telescope lens-making enabled faraway objects to be viewed as well as stars and planets at unimaginable distances. Later developments focused on the human body as the object of study and representation through magnification of tissue, organs and other products or the use of X-Ray, CAT scans and ultrasound revealing the inside and inner workings of the body. The building blocks of the universe have also been translated from non-visible processes into readable and reproducible representations in charts, graphs and tables. These images usually require specialist training (or technologies) to discern the phenomena of interest, enabling a class of technicians and interpreters to emerge (Pauwels 2006a; Vertesi 2015; Rose 2016). Despite the impossibility of being able to verify the phenomena under observation with the human eye alone, society has come to rely and make decisions based upon the generated data representing non-visible entities and processes. Visual representations are not designed simply to copy reality but to reveal it, as Pauwels argues:

Visual representations in science need to serve a number of distinct purposes that go far beyond the act of reproducing nature. Their value is judged by their functionality for resolving a problem, filling gaps in our knowledge, or facilitating knowledge building or transfer. (2006b, viii)

Visualizations are never neutral but loaded with assumptions, values or messages as they are being constructed to represent non-visual information or actions. Computers generate images in an ontologically different way from the images produced from photography or videography. Digital images are statistical images (Virilo 1994) created by pixels that construct the lines and shapes on the screen with mathematical precision (Gaboury 2015), as Mirzoeff attests:

Unlike photography and film which attested to the necessary presence of some exterior reality, the pixelated image reminds us of its necessary artificiality and absence. (1999, 30)

The artificiality of these images that purport to 'see' things that would be impossible to view without technology characterise Farocki's (2004) notion of 'Phantom images'. These images have a long history within cinema and filmmaking, depicting perspectives that would not normally be possible for a human to observe such as the view of a speeding train passing overhead. Farocki identifies a particular kind of phantom image which he terms as 'operative images' (2004, 17) and their deployment in military contexts: For example, the camera fixed to the tip of a missile as it flies towards its target and ultimate self-destruction. The image from onboard the missile is not intended to represent the outside world but as an aid to view the missile's navigation through the world. The US Army utilised such videos and images during the First Gulf War, making them available to the media to demonstrating their rationalised and precision-based targeting system for their strikes against the Iraqi regime. As these images were published they became politicised, working to construct the humanitarianism of the US Army by employing these dehumanised images designed for human eyes of military

technicians and operatives (Farocki 2004), the motivations for their publication are clear:

Similarly, there are no pictures that do not aim at the human eye. A computer can process pictures, but it needs no pictures to verify or falsify what it reads in the images it processes.
(Farocki 2004, 21)

Operative images are therefore visual representations of the machine or computer at work; a side-product intended to demonstrate to human eyes the current status of the task in progress or a political justification thereby creating value out of the image. As with previous visualising technologies, operative images also depend upon the specialist knowledge of technicians to interpret for public audiences, whom have become politically comfortable with a centralisation of skills. A theme that continues with the visualisations surrounding AV testing.

Operative images have been produced in relation to AVs and more specifically the LUTZ Pathfinder project. These have included images of the 'vision' of the AV itself; how the AV sees the road, the objects and people around it and how this is later re-visualised to academic and non-academic audiences in video footage, laser-point (LIDAR) feeds and other datasets. Recent papers (Stilgoe 2017; 2018; Hind 2019) have noted how the AV 'sees' is actually driven by algorithms and semantic labelling hierarchies that attempt to classify objects of interest into a hierarchy of significance so a pedestrian is seen as more important to avoid than say, a paper bag. Of course this process renders all objects an agency of risk to the AV and the variety within classifications means the recognition is more probabilistic than absolute (Hind 2019; Stilgoe 2018).

It is this process of observation and classification, of translating reality into representation and simulation used to make decisions and create value – as well as the socio-cultural consequences – this paper focuses on. The next section discusses the translation of reality that leads to its succession by representation, first by drawing on STS theory and then the hyperreality of Baudrillard's simulacrum.

Hybrid and hyper-realities

Bruno Latour and other STS theorists have drawn attention to the ways in which the perceived 'objectivity' of science and data, obscured the value-laden infrastructure which enabled scientific work to occur. This 'objectivity' emerges in a modernity that presupposes a separation between 'nature' and 'culture' with the former becoming abstracted, and translated, into the latter (Latour 1993). Yet Latour argues that scientific enquiries into nature always take place within a social-cultural and political context that elevates certain values and demotes others, in line with the interests of those or organise and enable the research to take place (Latour 1993; 2005). Scott's (1998) case study of commercial forestry resonates with this understanding. Commercial forests are grown primarily for the stock of timber they provide, and so the register on which trees are understood is sensitive only to the profit-driven volume of resource, disregarding any social-cultural uses of the forest. The trees in these forests become abstract trees in a dataset with a set of attributes only understandable in a commercial timber context.

Scientific and cultural understanding of nature is never 'pure' or separated from the variability of nature. Instead nature and culture are always co-existent within hybrid objects. The subject of hybrids is later taken up by Sarah Whatmore (2002), also observing the intense separation of nature and culture

through disciplinary division in study, and more specifically human and physical geographies. As scientists, administrators and economists create taxonomies of the world and its contents, these objects of nature become disciplined into categories and resources. Using examples such as the elephants in Paignton Zoo, UK, Whatmore argues that although the animals may share a genetic identity with elephants found in parts of Africa, their upbringing and life within the artificial environment of the zoo renders them to be as much a construction of culture as they are a creation of nature.

The hybridisation of nature/culture can also be understood in the context of Baudrillard's (1994) argument that post-modernity creates confusion between the 'real' and the simulated world, or simulacrum. Baudrillard observes the proliferation of images and signs in (western) society as globalised media content dominates the local. Such signs become sequenced to simulate the real. For example, in the quote that opens this paper the character of Rachael attempts to simulate human emotion through a sequence of coded verbal responses. More dramatically, Baudrillard argues, the First Gulf War was not a 'war' but a sequence of coded, signifier events obscuring the reality of an overwhelming invasion of a poorly resourced country by a much better equipped and financed 'superpower'. A simulation enabled through media imagery, reporting and governmental discourse that created a logic and accompanying impression of a 'good' USA (and its allies) being pitted against the 'bad' Saddam Hussein of Iraq. A dualism between good and evil supported by 'operative images' that deliver visions of a 'clean', modern and precisely targeted series of 'exercises' in environments absent of humans, obscuring the death and destruction behind such images (Farocki 2004). For the publics at home, the simulation of war seemed as real as a war itself. The human cost

was associated with the return of US and UK soldiers killed in the conflict and the emotional rituals of repatriation – or sequence of coded signifiers – seen at sites such as Wootton Bassett, UK (Jenkins et al. 2012). The depicted version alludes to a sequence of familiar codes and signs of the invasion that become confused and collapsed into the real, making the distinction between simulation and reality difficult, impossible even, to discern.

The proliferation, or hyperreality, of signs mean that the signifier serves to not just obscure the signified but to obliterate and collapse it into the realm of the signifier (R. G. Smith 2003). Use value of objects within the simulacra become determined by the exchange value as they are drawn to each other (R. G. Smith 2003). For example, in M.W. Smith's (2001) study of public opinion surveys, the polls become not just a representation of the real opinions held by populations (a 'use' value) but a reality in and of themselves and separate from what they signify, presented on the news and consumed as an hybridised object of reality and representation, signified and signifier (or an 'exchange' value). In this confusion, the 'simulacrum' becomes a stabilised and stabilising environment for cultural politics and exchange, run to the logics of consumption-based capitalism. The 'real' in modernity becomes, for Baudrillard, a reproducible and reconfigurable object. Resonating with Mirzoeff's quote from the previous section, Baudrillard states:

The real is produced from miniaturized cells, matrices, and memory banks, models of control – and it can be reproduced an indefinite number of times from these. (1994, 2)

This reproduction on a mass scale and across contexts removes the truth from the real, collapsing the binaries between real and representation, the signified

and the signifiers into simulacrum (M. W. Smith 2001) and ultimately erasing the 'real' from human knowledge. The simulation ceases to be a representation of the real, instead the simulacrum is no longer bound to the real (Baudrillard 1993; Levin 1996; R. G. Smith 2003) but creates a state of 'hyperreality' as Baudrillard continues:

It is no longer anything but operational. In fact, it is no longer really the real, because no imaginary envelops it anymore. It is a hyperreal, produced from a radiating synthesis of combinatory models in a hyperspace without atmosphere.

(1994, 2)

Spatially, hyperreality become organised around key sites of simulacra. Baudrillard gives examples such as hyper (super)markets, Disneyland and the Pompidou Centre of Paris which is 'nothing but a huge effort to transmute this famous traditional culture of meaning into the aleatory order of signs, into an order of simulacra' (1994, 65). These sites import, order and present their objects of culture and consumption to audiences arranged around them. They act to centralize and redistribute regions and populations; to concentrate and rationalise time, trajectories and practices to create a totalising vision of 'their serial, circular, spectacular arrangement - the future model of social relations' (Baudrillard 1994, 77). Politically the deployment of signs and construction of simulacra that maintain the pretence of assumed authority of governance or political projects. For Mbembe (2001, 111), the simulacrum in postcolonial contexts 'explains why dictators can sleep lulled by roars of adulation', yet wake to angry mobs at the door in the morning. The speed of political coups in such countries expose the fragile character – and networked interdependency (Latour 1996; 2005) – of simulacra. Hyperreality, therefore produces an

idealised vision of the real that conceals the contradictions and internal tensions as it produces a stabilised simulacrum (Richardson 2019). Discussing the construction of smart cities in the UK, Caprotti and Cowley (2019) identify orders of simulacra as a key component, often exemplified in flagship sites such as Rio de Janeiro's infamous Centro de Operacoes in Brazil, the Glasgow Operations Centre and Bristol's Data Dome, both in the UK. These sites, emblematic of 'smart cities' receive, interpret and analyse data and act to co-ordinate the local environments that surround them. The often highly stylised architectures, monitors, TV screens and dashboards present a socio-technical logic in which the city becomes an object to be measured, monitored and when necessary, 'operated' upon in order to create perfected versions of the urban. This paper explores how the LUTZ and its visualisations become a flagship site within the smart cities canon: a stylised site which generates, imports, orders and applies data to algorithms and analysis to construct a simulated world in which it operates.

This procession of simulacra becomes operationalised when AVs are contextualised within the smart cities narrative. Much of the rhetoric around smart technologies simulates codes such as longstanding urban problems (such as congestion and road safety in the case of urban mobilities). However, these problems are often defined by very providers of the solutions (Hollands 2008; Vanolo 2014; Soderstrom, Paasche, and Klauser 2014; Kitchin 2014; Gardner and Hespanhol 2018; Willis and Aurigi 2018) as they use their sensors and technologies to extract data to produce 'value' similar to Scott's case study of forestry timber or Whatmore's zoo elephants. Smart city processes and actors within the city become points within a dataset, owned and operated by State and commercial organisations. As Taylor observes:

The visibility produced by the datafication of space has a particular politics. It is a byproduct of informational capitalism: people are seen, and become objects of policy and commercial intervention, through the data they emit by using particular spaces, services, and devices. (2018, 262)

This visibility and site for intervention that Taylor (see also Shelton 2017) refers to bridges the nature/culture divide through a simulated event or situation. In turn, leading policymakers, technology developers and citizens to conflate the real city with its challenges with the datafied city and its opportunities for intervention. With the growth of sensors and surveillance that use 'smart' technologies to automatize decision-making and interventions in the city, the urban becomes a technological operable simulacrum (Graham 1998). As the city becomes constructed or produced through the accumulation and application of data, those who are in control of the metric or who define what the goals and what qualifies as 'better' for the city is in an authoritative position (Zook 2017) even if what is 'better' is produced in a social-cultural vacuum. This is a point that Stilgoe (2017) notes in his study of automation on vehicles such as Tesla and Volvo. Whilst there is an emphasis on autonomous vehicles being 'infrastructure free', the developers are often quick to blame errors of their visual sensors on the (il)legibility of the roads, road markings or unruly pedestrians that don't conform to the developer's expectations. Similarly, in her research of the autonomous pod trials in Milton Keynes, Marres (2020) observes that despite the project being framed as exploring how AVs would navigate social contexts, the public were often politely stopped from walking in the vehicle's path. The social vacuum in which these vehicles are tested leads Stilgoe to argue that claims to autonomy are false as these vehicles and becomes an issue of social justice as:

In order to accommodate the technology our roads and our lives will need to be made machine-readable. As the world around self-driving cars is upgraded in their image, some will be empowered and others disempowered. (Stilgoe 2017, 5)

Urban futures of smart cities therefore simulated on, and are stabilised by, a logic that produces problems and complimentary solutions; a simulacrum that organises city life. Yet it is not just the claims of 'infrastructure-free' technology that are misleading but the manner in which 'operative images' are drawn from the AV sensors to produce simulated visions to seduce audiences into perceiving the technology as safe, secure and smart. As Baudrillard (1994) gestures, simply because reality is simulated does not mean that, as in war, there are no casualties. Following the methods outlines below, the paper will begin to consider the consequences of simulation in this case study.

Case Study and Methods

As part of the *Smart Cities in the Making* project, the case study featured here explored the intersection and deployment of visualisations in the LUTZ Pathfinder project. This section now introduces the case study and methods, before discussing in detail the visualisation produced in relation to these particular AVs. The case study concerns a specific type of AV, the LUTZ Pathfinder, which in its original form was a two-seater electric 'pod' vehicle designed for short distances within an urban setting. The pod was designed to operate at SAE level 4 autonomy (SAE International 2018): the second highest level of autonomous driving. Due to the employment of stereo-cameras and LIDAR, in line with other headline AV projects and their likely application in future autonomous technologies, the visual material generated by this project

provides an excellent insight into how AVs may 'see' and the implications for society in this paper.

LUTZ Pathfinder was run from 2016-2017 before morphing into the Aurrigo-operated pod trials in 2018. LUTZ was the overseen by the consortium of industry, legal and governmental organisations, UK Autodrive, as part of wider AV project funded by Innovate UK (2014). The LUTZ trials were co-ordinated by the Transport Systems Catapult (TSC), a government innovation agency based in Milton Keynes, RDM Group (also operating under the brand 'Aurrigo') built the 'pods' whilst the local authority, MK Council supported the trials with a £250,000 award (Milton Keynes Council 2017). Crucially, the Oxford Robotics Institute (ORI), based at University of Oxford, developed the onboard software that drove the AV. The Institute would later spin-off a commercial entity, Oxbotica with the intention to realise the commercial value of their research.

The AVs used in the LUTZ trials differed from other driverless car trials by Uber and Google in that rather than modifying an existing road car, a new two-seater 'pod' was employed. Additionally, the pods were to use the pavements of Milton Keynes and interact with pedestrians and cyclists rather than drive on the roads with other motorised traffic. Milton Keynes was an ideal environment in this case. As one of the British 'new towns', it has wide pavements, a relatively flat topography and a network of underpasses which enable the pod to move along a motorised traffic-free route.

These public trials on streets of Milton Keynes utilised a range of technologies that would be well-publicised as part of the communication around the project. Videos and images released online showed LIDAR and stereo-camera

data, complemented by a suite of interviews and presentations about the LUTZ and its technology, also publicly available online. Such videos and images present a vision of the socio-technical future; an anticipatory politics that operate as entertainment and information of imaginary that is not yet possible (Kinsley 2010). The research presented here focuses on the images and videos – including the LIDAR and stereo-camera footage as well as footage from ‘inside’ the VR trials provided by TSC – that have been created as part of the communications as well as five interviews with key figures overseeing the project within the TSC and ORI.

The semi-structured interviews were conducted both face-to-face and over the telephone ranging from 35 to 75 minutes in duration and included being invited to see much of the technology being used in the project. Alongside the interviews which were thematically analysed, additional insight has been gathered from filmed conference and workshop presentations of Professors at ORI, Paul Newman and Ingmar Posnar (also co-Founders of Oxbotica) and Martin Pett (Principle Technologist, Human Factors and Advanced Simulation) of TSC. The use of this additional data has supplemented the interviews, as both datasets help to explain the intentions of the developers and their system of sensors, cameras, hardware and software hidden inside the LUTZ vehicles; the signified inside the signifier.

The hyperreality of AVs

The paper now addresses the central question here of how the visuals and simulations of the LUTZ persuade – by the employment of signifiers – the audience of the viability of AVs being able to safely and efficiently interact with the real world. The discussion is illustrated in three different sections. Section

one begins by detailing some of the technology that enables the LUTZ pod to 'see' and the world this 'vision' creates. The second section looks at how the structuring of this world support the separation of nature and culture or the real and its representations. Throughout these first two sections, the use of 'operative images' that go beyond superficial representation but are visualisations of data become central to the construction of this simulacra. Section three then explores the use of VR in understanding how the pod will interact with humans via simulation. By focussing here on how the human in this world is constructed, a story emerges as the real world is overtaken by a series of signs constituted by data, and fades into the background as representation through simulation becomes the hyperreality.

'Painting the world with light': creating the visual world of the AV

Like other contemporary AVs, the LUTZ Pathfinder Pod used a combination of instruments to 'see' and navigate its way around Milton Keynes, and importantly to avoid collisions with pedestrians and any other objects in its path. Along with stereo cameras, Laser Imaging, Detection and Ranging (LIDAR) is the primary tool. Working like a radar system, the laser fires a beam of light outwards until it hits an object and is reflected back towards the vehicle sensor. The time interval between emitting and receiving the returned light beam provides a measurement of how far away the object is from the LIDAR device. The LIDAR system is sensitive enough to pick up road-markings in the urban environment or provide asset or infrastructure detection and management for commercial industries (Newman 2014; Posnar 2016). Yet this sensitivity creates added pressure on ensuring the sensor is correctly calibrated, as Paul Newman (2014) states in a presentation, an error of timing to just a millisecond can mean tens of metres in spatial awareness.

The LIDAR system fitted on to the LUTZ pod shot 16 beams, collecting 200,000 points of light per second, as Newman (2014) states to 'paint the world with laser light'. But this is not 'painting' but creating a new world entirely, one that conforms to the logic of the question that drives it (Latour 1993; Pauwels 2006b; Scott 1998; Taylor 2018). Whilst 32 and 64 beam versions of the LIDAR are on the market and used on other forms of AV, M of ORI stated that the 16 beam was sufficient for the low speeds of the LUTZ pod in a semi-controlled trial environment, was cheaper and more readily available for the project as there is a waiting list for higher definition models. Radar was ruled out for use on the pod due to it being slower and noisier than LIDAR. Additionally, there was no microphone for recording or monitoring local sounds despite the use of sound for emergency vehicles. Had an emergency vehicle been encountered during the trials, the human monitors on board the pod would take over control and manoeuvre the vehicle safely out of the way. Visual and visual-like data was prioritised for the navigation of the pod over GPS, discussed further in the next section. Unlike other sensory fields in the road (or in this case, pavement), the visual is a phenomenon that can be made legible in the simulacrum of AVs.

What the pod sees is presented in a visualisation of the LIDAR data. 'MK Scene Prior' (Oxford Robotics Institute 2015) provides nearly 9 minutes of footage as the 'camera' (a virtual rather than physical camera that shows perspective) tracks through central Milton Keynes. As Kroger (2015) observes, videos demonstrating autonomous vehicles are often framed from a birds-eye panoramic view, underlying the vehicle's 'superior' view of the landscape. And this landscape is eerie: with no sound accompaniment, points of light and

colour are visualised against a black background as the LIDAR sensors simply record what is there or physically capable of reflecting the laser beams. Resultantly the features, as seen in Figure 1, are incomplete as portions remain hidden from the laser beams leaving cars, buildings, trees and people dissolving into the black void – illustrating the ‘blank spots’ (McFarlane and Söderström 2017) in the datafied urban landscape where no data has been collected. ‘Blank spots’ in the otherwise totalizing vision of simulacra (Baudrillard 1994; Caprotti and Cowley 2019). The camera provides a view of the model that has been created by the LIDAR rather than showing an actual feed that was available at the time. In other videos, a virtual model of the LUTZ pod has been superimposed into the image (as in Figure 2).

INSERT FIGURE 1 HERE

Where colour is apparent on this video (see Figure 2), it has been retrospectively applied to the image by matching the point of light with the corresponding stereo-camera feed based on the location of the AV at the time. The LIDAR data however is primarily for the navigation of the pod as well as the avoidance of collisions with objects in its path, and so colour is not necessary for driving the vehicle but added for the benefit of the human viewer (Farocki 2004). Constructing this simulation by using data co-ordinated from two different registers – the LIDAR and the stereo-cameras – begins the process of concealing the signified with the signs as both sets of data are representations of realities rather than reality itself.

INSERT FIGURE 2 HERE

LIDAR is not a visual system, instead it is very much grounded in the materialities of the physical world. And the *MK Scene Prior* video emphasises this materiality of the world LUTZ encounter as part of its 'vision video' promotion (Kinsley 2010). Its materiality enables the data generated to also provide information as to the size and depth of the world it 'sees' along XYZ axes. Not only can LIDAR detail the height and width of an object and the depth of a cavity, the onboard software can then classify the object in reference to its known dataset of objects as a car, a building and so on; a narrowing of vision to a value (Scott 1998). Once classified, specified classifications of object can be removed from later images or can be labelled as objects that are static or objects that can potentially move (such as parked cars) which are therefore unreliable for later scene-based navigation (an approach in which the AV identifies its location from visual data rather than GPS or other external-based systems) (Newman 2014). The signs therefore become interchangeable as values rather than references to the real (Baudrillard 1994; R. G. Smith 2003). These features of the LIDAR software, Newman points out, can be applied to different contexts such as asset management as the software is able recognise key assets for a company or organisation. Oxbotica, of which Newman is Founder and CTO, has therefore identified commercial possibilities of the enabling technology behind AVs that exist independently of the driverless car market.

LUTZ does not 'see' the world as a human would but creates a visual scene from the LIDAR system and the data it generates about the world around it, conflating the visual and the topographical. The spooky images that are generated and published online are unnecessary for the workings of the pod. Instead they are images that have been generated from the original polar XY

data of the LIDAR (as shown to the author during interview at ORI), converted into 3D and even colourised for the benefit of the human viewer. The LIDAR feed are therefore an example of Farocki's (2004) 'operative images' in that the images are produced as a side-product to the operation. The AV itself does not rely on upon the visualisation but the underlying data from which the visualisation is generated; an image which is 'no longer anything but operational' (Baudrillard 1994). The image in this case works to reassure the research team behind the LUTZ, that the technology is working correctly and detecting people and objects that may cause a hazard; a functional image that goes beyond superficial representation but is knowledge generating in itself (Pauwels 2006b).

Furthermore, when published online, the videos and images like *MK Scene Prior* work to reassure the public that autonomous vehicles will safely interact with other road users. This is despite the fact that the images signify the topographical rather than the visual which the audience uses as the measure of the safety of the AV; displacing the signified with the signifier. This section has detailed the technology underlying the 'seeing' of the pod and the use of 'operative', functional images for public consumption. The next section explores the reduction of the signified to signifiers through classification in processes of navigation.

If it looks like a human, navigates like a human, it is possibly an AV

Global Positioning System (GPS) has been popular with drivers for general route-finding. However, for practical navigation of the pod, the system was judged by ORI engineers as too imprecise for safety-critical operations – as a difference of just a few centimetres may lead to the pod colliding with a

nearby building or object (Kim et al, 2016; Newman, 2014). Additionally, an underlying theme of the LUTZ project has been to create an 'agnostic' system that can run independently of external signals or communication. Newman, in at least two presentations, makes the point that the software should be 'infrastructure free vision-based localisation' and not reliant on external navigation sources. AV developers cannot expect an infrastructure to be specially built for their products as this is not economically feasible or necessarily reliable (Newman 2014; Guzel 2013). Although, as Stilgoe (2017) and Marres (2020) suggest, the likelihood is infrastructure – such as repainting road markings or improving pedestrian-cyclist-vehicle segregation – will need to be upgraded. The LUTZ should be able to act and make decisions about its actions based upon the data it generates from its own sensors. This is not only due to possible security concerns and issues around signal strength but also as the technology and software that drives the pod is also to be applied (and monetised) in environments with little or no GPS signal such as warehouses or more ambitiously, as suggested by M of ORI, exploration of the Moon or Mars.

In practice, of course, it is highly likely that AVs will require significant upgrades to the existing infrastructure (Stilgoe 2017). Indeed, LUTZ required a very specialised environment in which to operate (Marres 2020). However the developers claim that instead of GPS, the LUTZ pod relies upon experience-based navigation whereby the onboard software recognises the features of the environment from pre-existing datasets. Early phases of the trials involved manually driving the pod around the pre-determined route in Milton Keynes to 'learn' the environment, the route and its features. The 3D LIDAR data generated by the LUTZ is then compared with 2D histograms of certain nodal points along the route (Posnar 2016). Recording everything and developing a

large dataset full of previous experiences of driving this route including in different lighting or climatic conditions or when certain features such as cars have moved (Lowry et al. 2016; Newman 2014), enables the onboard software to recognise and orientate itself as it drives.

INSERT FIGURE 3

Stereo-cameras are mounted on the LUTZ pod, providing video camera data-feed that also aid navigation. A 'live' view is compared with a view from 'memory', as depicted in Figure 3, to orientate the AV in the world. People and objects can be identified on this as well as road markings or features within the environment. Overlays on the video images generated by these cameras outline and box different objects, grading them according to their potential to become an obstacle. In a video shown by Newman (2014) at a workshop presentation, green dots are used to highlight potential obstacles to the human observer.

Of course, the visual recognition system is not perfect; there are some issues identifying different objects (Hind 2019; Posnar 2016) which becomes significant when predicting what the object will do or if it will do anything at all. For example, the LUTZ pod will need to recognise the difference between a tree and a pedestrian, as the latter may move suddenly into the path of the AV. As Stilgoe (2018) notes, AV systems therefore have to make predictions based on the probability of what the entity will do next. Posnar (2016) reports that early in the development there were issues regarding the identification of objects. These were found to be due to the original library of images used to 'learn' different objects being against a snowy (white) backdrop, and therefore

quite different from the urban environment the pod would have to navigate. Humans are in this case just another entry into the dataset as a potential obstacle to disrupt the smooth flow of the pod (Stilgoe 2017); the onboard software thus orders and organises the visual world according to properties of movement. Figure 4 shows a red box framing two pedestrians (from the LUTZ research team), indicating that the objects within the box are moving and likely to be in the path of the pod. The boxes and the green dots are the signs of the human rather than the human itself; the purification of the nature object into the classificatory object of science and culture (Latour 1993; Scott 1998; Whatmore 2002). Importantly though it is the sign of the human, rather than the signified human, that elicits a response from the onboard software, the AV and the developers. The human has no specific value outside what attributes it holds in disturbing the flow of the AV; a potential challenge rather than an object of meaning.

INSERT FIGURE 4

LUTZ, and other AV programmes, rely upon data generated from their onboard sensors and that present with the pre-existing database rather than GPS or other connected forms of navigation and instruction to the vehicle as part of their 'infrastructure free' approach. This factor therefore means the pods have to 'see' the world in order to interact with it and the other entities present within their environment. Yet the notion of 'seeing' here is an anthropomorphic gesture as the pods do not 'see' with their LIDAR nor their stereo-camera systems. The former provides spatialized XY data which is then analysed to develop a terrain map of where the pod can and cannot move into next. The latter analyses clusters of pixels for patterns and shapes leading to

conclusions about the what other physical entities are near the AV, which ones are likely to move and where they are likely to move. Navigation is also produced through place recognition – either spatially comparing the LIDAR data through collapsing the 3D topographical models into 2D histograms or comparing recognisable, permanent clusters of pixels that form landmark features. In neither of these instances of navigation or object avoidance does the pod actually ‘see’ in a visual sense yet the terminology employed in discourses around the pod or other AVs consistently employ this narrative which is reinforced by visualisations of AV ‘sight’. ‘Seeing’ becomes a process marked by intentionality; a specific register for particular values that can be identified from the external environment and recorded within the internal dataset. Moreover, this process and register of seeing acts to organise the spaces and flows around the pod by producing a simulation of space and employing this to navigate the real.

Outside of the academic discussion of AVs, public-facing information regularly employ the vocabulary of seeing. During one promotional video, Newman states:

It’s using both pictures and laser light to see what’s around it. If it doesn’t like any of those things or it thinks it should give way to someone, it will pause, wait for that person or object to move, that cyclist or that dog. Wait for it to move on before moving on, getting you from A to B. (Transport Systems Catapult 2017)

Such language resonates with the metaphors employed by the team behind the Mars Rover missions, where the ‘Hazard Camera’ of the rovers are thought

of as the 'eyes' of the vehicle (Vertesi 2015). Strengthening this anthropomorphic process further are more recent developments of the original LUTZ programme on the Aurriogo pod. In the summer of 2018, JLR and Aurriogo reported that a pair of virtual googly eyes that will provide 'eye' contact with other users – especially pedestrians waiting to cross in front of the pod (Bdaily Business News 2018). The movement of the 'eyes' represent the registering of the road user in the vision of the AV. This addition reflects concerns of that the sociality of motoring – the pre-actions, movements and non-verbal signals that drivers and pedestrians employ or interpret – need to be accommodated for in AVs (Brown 2017). The notion that these vehicles can somehow 'see' then is very important, as it reassures the public that they are safe. As with Farocki's (2004) argument of 'operative images', the videos and photos and (empty) signifiers of 'eyes' of the pod act to politically stabilise their audience. The pod can apparently see and make decisions based upon what it sees. As the process of seeing for humans is an unconscious phenomenon and often taken for granted, using the discourse of sight, provides the pod and other AVs with an agency that is more powerful than relaying the complex processes of live laser and video data, its analysis and subsequent outcomes. Yet the virtual eyes that 'see' and interact with the humans are in themselves a simulation of what it is happening within the AV software.

The first part of this section discussed how the pod recognised and ordered 'nature' or reality into a classification hierarchy of risks and values. The second part then considered how the pod was made more human, how signifiers of nature (how the pod is described or the use of false 'eyes') was inscribed in discourse about the pod in order to gain the trust of other road users. These

actions contribute to the construction of the simulacra or hyperreality in which the pod resides and organises. It is these Human-Machine Interactions (HMI) that are discussed in the final section of the paper with reference to the trialling of the pods in a VR model of Milton Keynes.

Simulated worlds, real responses?

As part of the LUTZ project VR was employed for experimenting and exploring potential interactions and conflicts between the pods and humans around the pavements of Milton Keynes. VR has been heralded as a solution to HMI investigations that is cheap, efficient, repeatable and can be conducted in the relative safety of the laboratory. As well as a high-tech VR headset and hand controller system, the TSC also boast a 360-degree Omnidock manufactured by Omnifinity allowing the user to walk on rollers, as if walking in the virtual world. In addition to the Omnidock which provides insights into the pedestrian experience of the pods, there is passenger experience which comprises a go-kart style seat and steering wheel. Set on a motion platform that replicates the bumps of travel with the headset and hand sensors, this setup is designed to understand the experience of riding in the pods. The participant may also be linked up to a set of sensors that measure perspiration and BPM indicative of signs of anxiety or nervousness when dealing with the VR-rendered pods.

VR 'de-risks' experiment (Pett 2017). Trials can be run on virtual models of the urban environment without risk to people nor the financial expenditure of, in this case, closing down roads, hiring field crew or insurance coverage. VR enables a more intuitive understanding of the scenarios as it presents the situation as if lived rather than an abstract set of ideas of plans (Maffei et al, 2016). As Pett (2017) explains in a conference presentation, VR has the

advantage of creating emotional and physiological responses from the participant that can be measured and analysed from which the experiment can be modified to lead to more positive results. Moreover, this can be reproduced with little additional cost. Behaviour can also be closely observed during these trials. One example of this was explained by J from the TSC in the interview:

[...] we had pods coming along out of one of the underpasses in Milton Keynes, from the right-hand side, an additional pod comes on, we had that originally set that the pod would pull out in front of the user, because the sensors in the pods could communicate, and that would be perfectly fine and safe. What we found was the actual response of the user, their heart rate spiked, they tried to slam on the brakes because they felt as if they were going to hit the side of this [pod].

Whilst the pods were designed to move together in close formation and as connected vehicles could anticipate the movements of the vehicle in front, VR revealed that users unfamiliar with the pods were alarmed by the closing speed and instinctively moved their foot to a brake pedal that didn't exist. Shortly after the interview with J, the author was offered a chance to experience the VR pod ride. Even with this knowledge of previous user reactions, I felt uneasy as the two virtual pods seemed likely to collide with each other until the very last moment. J continues to talk through this issue:

Even though it was a gaming environment, it was virtual reality, it was tense and the level of immersion was that high that they felt stressed and panic, but it also then raised the idea that okay, even if the vehicles are capable of interacting with each

other with this kind of degree of accuracy, we might need to increase the buffer because if the actual user, whenever they first go to sit in them, don't feel comfortable, we need to increase that distance.

These observations resonate with Turkle et al's (2009) assertion that '...immersion makes it hard to doubt simulation'; the realness of the immersive experience makes the simulation a more realistic scenario for participants and outside observers. The VR experiment enabled TSC to change the parameters of the pods in real life; J attributes the anxiety that the participants felt about this episode down to the level immersion that VR enabled. Elsewhere in the interview J notes that whilst realism is important, it is the degree of immersion that is key to prompting emotional and behavioural responses. Surrounding the participant with the sights, sounds and kinetic stimuli, to allow them to suspend disbelief on some level for the trial. 'Nature' of emotion, anxieties and biophysical reactions are translated into a dataset that can then be (re)tested in the scientific environment of the VR laboratory. Furthermore, the virtual Milton Keynes becomes entangled with the real world as the test subjects have 'real' biophysical and behavioural reactions to a simulated situation; signs of biophysical measurements (heartrate spiking) are understood in the logic of other signs (the virtual pods seeming to collide) in the simulation. Use values become exchange values as the pod is modified to become more comfortable for passengers and therefore more attractive to a targeted customer base. Significantly the interviews with TSC revealed that the participants in the VR trials were recruited internally from members of staff (whom the interviewees admitted was not particularly demographically diverse) rather than a representative sample of people likely to meet the pods on the street. Such an approach risks a myopic feedback in the simulacra. As

Baudrillard (1994) suggests, the distinctions between the real and the simulated are further eroded in this simulacrum of the VR trials. An experience reproduced indefinitely from 'miniaturized cells, matrices and memory banks, modes of control' (1994, 2), thereby rendering the real as a product of technological capitalism and the use value of biophysical human responses into exchange value data.

Conclusion: in the simulacrum of AVs

This paper has contributed to the discussion around AVs in three respects, by drawing on the concept of simulation and simulacra to explore the visualisations and 'operative images' of the LUTZ project. Firstly, the paper has charted how the real or the signified is ultimately displaced by the simulation and the signifier in visuals that purport to represent the world but instead represent the LUTZ pod's view of the world. VR produces a version of reality – or versions of reality where upon the topographical data of the city, the biophysiological and behavioural data of the participant is presented and made legible for the observer. The signifier of VR obscures the reality but to take this a step further, the LIDAR data re-constructs 'reality' as a (very comprehensive) set of laser points denoting the topography and features of the environment. In turn, this becomes reality as a simulation is then primed for intervention and manipulation by State or corporate actors. In this way the nature/culture divide is undermined as the visuals of the world show specific registers relevant to the operation of the pod as well as the presentation of the AV to the wider public.

Secondly the visualisations created in the project provide an output that is designed to subdue public anxiety and even stimulate public excitement over

the prospect of AVs joining the everyday bustle of the streets. In this way the paper resonates with Stilgoe's (2017) argument that these vehicles are never really 'autonomous' but reliant on an infrastructure to be built around them. This paper has argued that the accumulation of visualisations surrounding key AV projects, such as the LUTZ Pathfinder, subdue public anxiety and act to impose the simulation on the reality; the signifier on the signified.

Yet there is the gulf between reality and simulation. By composing a world of signifiers based on VR, LIDAR and other forms of data, the removal of the human constitutes an attempt to impose a totalising techno-determinist hegemony of AVs. In practical terms this might manifest in a domination of public space by AVs. For example, in the video *Aurrigo UK Autodrive* (Aurrigo Driverless Technologies 2018), the pod moves along a sidewalk in Milton Keynes. At 27 seconds into the video, pedestrians are observed moving to the side of the pavement, on to the verge of trees and dirt to make way for the pod. Because the pedestrians remove themselves from the path of the pod before the onboard software would have assessed them as a risk that required the vehicle to stop. Simulations for the project concentrate on stopping the pod when an object comes within a certain proximity yet here the pedestrians automatically disadvantage themselves to enable the smooth flow of the pod. The simulation is therefore successful on one hand, in that the pod has avoided collision, but unsuccessful in that the pod dominates the space, over and above the pedestrian and reinforces existing hierarchies of motorised mobilities (Urry 2007; Jones 2014; Stilgoe 2017). Drawing Baudrillard's concept of simulacra, a critique of the LUTZ trials emerges as reality is observed to bend itself to the will of the simulation, in Latourian terms, 'purifying' nature out of the culture of simulacra.

Thirdly, the AV becomes a signifier of the politics of smart cities. Operation of the LUTZ trials reflects Caprotti and Cowley's (2019) identification of key sites that operate as nodes in organising the networks, flows, power and imaginaries of 'smart cities'. In this case the LUTZ is the simulacrum that creates the imaginary as its image has been used in promotional campaigns for the 'smart city' of Milton Keynes (for example, MK: Smart 2019) and the investment, innovation and engineering potential of the UK (exemplified in the pod's 'GREAT Britain' livery). Further evidence is found for the simulacrum of LUTZ in the organisation of spaces surrounding the trial with the Transport Systems Catapult building that facilitates it, the VR lab that anticipate HMI, the co-ordination of the pavements of Milton Keynes on which the pod was driven requiring modification of local by-laws (Loeb 2017), signage, researchers and members of the public.

Through simulations, in this case VR, LIDAR modelling and stereo-cameras, the 'nature' or reality of the city with its complex processes and sequences become purified into a dataset in order to be classified, sorted, owned and operationalised by various actors that can intervene with management and commercial motivations (Latour 1993; Scott 1998; Graham 1998; Whatmore 2002; Shelton 2017; Zook 2017; Taylor 2018). The city and its people are translated into signs of the signified, and as in the above case, become subject to the modelling as reality and simulation collapse into simulacrum. It is therefore important to recognise this process and to resist the political neutralisation of people – the sheep that AVs may dream of - and the realities they are confronted with when an AV drives down their street.

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Figure 1: Screenshot from 'MK Scene Prior' (© Oxford Robotics Institute), Courtesy of Oxford Robotics Institute

Figure 2: Screenshot from 'MK Scene Prior' (© Oxford Robotics Institute), Courtesy of Oxford Robotics Institute

Figure 3: Screenshot from ‘Self-driving vehicles trialled in UK public space for the first time (© Oxford Robotics Institute), Courtesy of Oxford Robotics Institute

Figure 4: Screenshot from ‘Self-driving vehicles trialled in UK public space for the first time (© Oxford Robotics Institute), Courtesy of Oxford Robotics Institute