Prosthetic Architectures

How does Prosthetic technology transform architectural thinking ?

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Abstract

Historically, we have always designed according to the Vitruvian man, Vitruvius described the human figure as being the principal source of proportion among the classical orders of architecture. If this is true, then current architecture has become out dated. Therefore, with the increased development and integration of two beings partly biological and mechanical, this will certainly transform our current perceptions of architecture and its design standards. However, our thinking in architecture has not been evolving in parallel to these developments in prosthetics which is evident in the inclusive design standards book that still portray a human body as a fully able human body.

The dissertation offers an analysis of prosthetic technologies that allows us to examine the human boody connecting it to technical objects and urban landscapes, creating new relations between humans and nonhumans. We demonstrate the need to analyse the ground as a platform of horizontal and vertical planes which is fundamental in our relations with the built environment. Therefore, this sets up an interesting perspective to study prosthetic technologies , and opens up a new dialogue between technology and nature, and consequently science and spirituality, it also digresses into realms of philosophy, fiction, culture and politics.

The dissertation is a product of our group research topic architecture and technics *refers to the technique in relation to technology* that teaches architectural design by applying a technicity *this is the exploration of technical thought* in the process and application of solutions to technological issues within and outside of the built environment. In the course of this effort we have found ourselves in conflict with rather powerful presumptions about which areas of inquiry are deemed essential to its perpetuation as a field of study.

Declaration

All work presented in this dissertation, except those that have been explicitly mentioned and cited, is original work. No part of this paper has been a submitted as part of another qualification or degree for this or any other educational institution.

Copyright Statement

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Chapter 1

Introduction

1.0 Introduction

Many believe humanity will end disability in this 21st century, extending human capabilities beyond innate, physiological levels. This extension of human potential will lead to a new type of being. Prosthetics technology has advanced significantly in the past two decades, "driven largely by amputees' demand" (Marks and Michael, 2001), advances in surgery and engineering, and "healthcare funding sufficient to sustain development and application of technological solutions" (Marks and Michael, 2001). Some of the more recent innovations are motivated by issues associated with lower limb devices, where reports suggest 35.5% of amputees with a prosthesis did not wear it regularly due to comfort issues (Dejke et al., 2021). It is in these situations that individuals feel pain, and therefore, a lack of mobility in the built environment directly affects their experience and quality of life. Thus, innovation and technological advancements in this field have opened up a new conversation. Insisting on change in the way we live and perceive disability, and while humanity prepares to transcend human consciousness, we can argue that the current speed of innovation has surpassed our ability to fathom such drastic changes in the human body.

This dissertation attempts to connect technical objects in the domain of prosthesis with architectural and urban qualities. The idea of prosthetic architecture sets up an interesting situation, which questions the boundaries between existing and new proposed programs. It can take away compromised structures and replace them with a new formal species, which will set up a new dialogue between old and new. Therefore, this dissertation questions how the 'prosthetic human' can be an architectural catalyst to transform design standards, and in particular our relationship with the built environment. The ground is identified as an underdeveloped field of architectural enquiry. To improve how we think about architecture and how disabled individuals experience space, this dissertation investigates and analyses current design regulations, which include access and mobility through the lens of design.

1.1 Research Aims & Objectives

This dissertation aims to look at the architectural as an expansive field of body-machine-environment relationships through the domain of prosthetics. Study the technical thought (i.e., technics) of enclosing/inscribing/associating bodies with their environments in the figures of the building, the city, and the prosthetic. Explore mediating figures such as prosthetics as technical objectives that embody humans' technical thought and stabilise their relationship with nature. We plan to achieve this aim through the following research objectives:

1. Review the relevant literature on philosophies, which primarily discuss the relationships between man and machine, and explore a body of research on the concept of Cyborgs from architectural humanities, human geography and social sciences. To identify the gaps, the literature is placed against a pragmatist theoretical framework of sociotechnical associations inspired by Gilberto Simondon's philosophy on the ontological distinctions between technical beings and human beings.
2. Collect data on technical inventions from a range of primary sources that have not been previously analysed, as such in architectural studies, along with secondary sources where we can identify situations of disconnect in this area.
3. Analyse the data in four ways:
    a. Analyse how sensing changes from the biological to the mechanical, and examine how the mediation of technical objects (i.e., the prosthetic) proposes a new connection with the environment (Chapter 5).
    b. Unfold the realities of user discomfort by examining a series of technical inventions that present improvements to increase user control, stability, and comfort.
    c. Follow the prosthetic as an object and extension of the human body, and relational to their terrain as a continual evolution that adapts, and eventually becomes a new technological object.
    d. Follow relations where the landscape (people, environment, and infrastructure) is encountered, experienced, and rediscovered in an attempt to determine the success or failure of the prosthetic device (Chapter 6).

1.2 Dissertation Structure

This dissertation is divided into 6 chapters: Introduction, literature review, methodology, two empirical chapters, and discussion. The introduction chapter briefly sets the scene and states the aims and objectives. We begin by reviewing the relevant literature on science, technology, and architecture. We frame this chapter as "Humans and their bodily functions", and review literature that discusses the concept of "the cyborg", which is explored most notably by Donna Haraway and Wolfe, and other works that discuss the relationship between the body and architecture from architectural theorist Albena Yaneva, historian Michelle Murphy. The accounts of this literature explore the physical and psychological impacts of war on humans and their buildings, cities, and infrastructure, to show how architecture is used to alleviate feelings of frustration and anger by creating a sense of "ordinariness" and "familiarity" among others. However, the accounts start from the narrative of the cyborg that fits into known social/power structures. We review this literature, along with a theoretical framework that draws on the ontogenesis, and the philosophy of technology.

Then we outline the method for analysing the functions of the biological modes involved in certain movements, such as sensing, walking, or balancing, followed by the mechanical modes of sensing. This helps conceptualise the prosthetic as an urban object that develops and operates relationally to its urban terrain. Urban areas are concentrated areas of built, paved, and infrastructural. From biological to mechanical sensing, we then shift our focus to prosthetic technological inventions, where we examine how prosthetists improve, develop and transform new systems to increase user control and comfort.

Unable to be on-site and observe prosthetic users, and unable to follow discussions around these prosthetic technologies in real-time, or to engage in ethnography and interviews with prosthetists, amputees, and medics, we adopt a quasi-ethnographic approach that relies on analysing primary and secondary sources. We find our sources in publicly accessible, yet highly specialised online databases, which provide rich content. The empirical sources of this research are divided into primary and secondary sources. The primary sources include patents and studies; the other includes documents/media such as medical journals and governmental policies. Secondary sources include second-hand information, such as news articles, reports, and websites.

This brings us to the empirical chapters, the first empirical (chapter 5) analyses biological systems of balancing and sensing to mechanical systems. We analyse the processes involved in the operation of the biological balance system, and our dependence on sensory inputs, such as spatial awareness, sight, or touch, to input that information into our brain via a multitude of sensorimotor control systems. We equally trace technological systems, as we move from biological to mechanical, we will analyse how these biological senses are simulated in the mechanical. In the final part of (chapter 5), we explore prosthetic technology through a patent analysis to trace innovation patterns. We analyse "open technical objects" (Simondon, 2017). The second (Chapter 6) analyse the adaptation of beings with more than a biological ontology against non-technological breakdowns upon deployment to urban terrains, as found in design publications, governmental documents, and secondary sources.

Finally, we wrap up all the conclusions in the final concluding (chapter 7) the discussion brings together and discusses three research contributions to prosthetic technology, urban studies, and the architectural humanities: 1) How blurring distinctions between man and machine becomes a concern for the way we design and think about architecture; 2) How prosthetic technologies create associations through sensory technology and AI with the prosthetic user and their environment; and, 3) How prosthetics explain a renewed relationship between the body, machine, and architecture. The dissertation concludes by reflecting on prosthetic architecture by drawing upon Simondon's philosophy of equality between human beings and technical beings.

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Chapter 2

Literature Review:
Humans and Their Bodily Functions

2.0 Introduction

In the introduction, we raised three questions that addressed the extending of human capabilities and how this extension of human potential will give birth to a new type of being. One is the historical ideologies of proportions in architecture set by Vitruvius, and how this limits humans with more than a biological ontology. Secondly, how innovation in prosthetic technology driven largely by amputees' demand blurs the boundaries between man and machine. And lastly, how this progression in technology, particularly in the field of prosthetics, challenges the way we think about architecture. It questions our current regulations that set out principles of architectural design standards in an attempt to create better and more inclusive designs. But, with current social stigmas surrounding the notions of 'cyborgs', there is an overall lack of understanding of how we perceive each other, and discrimination against one another has led to confusing boundaries and false allocations of power.

To address the research aims and research questions, we first review the literature that discusses the concept of the cyborg, not as inventions produced by humans and their engineering, but instead in "A Cyborg manifesto" by Donna Haraway, who expresses that humans aren't so different from cyborgs. This is evident in her ironic use of cyborg-related and non-cyborg-related comparisons in the breakdown of current and historical social structures, such as feminism, despite their superiority. Second, Simondon's ontogenetic perspective on creation, written from the perspective of the inventor, where he rejects previous theories fascinated with the distinction or relationship between human and machine. Simondon purposely speaks about the individual as potentiality of energy, not a static concrete element. This is evident in his work in Modes of Existence of technical objects, and also in the interpretations in LaMarre's Human and Machines. We will also briefly draw upon what he means by "technical objects". This is important first for our understanding, but also because we will be applying this theory to analyse prosthetics later on. We will also see how the technical object has evolved from a tool designed for survivability to a symbiotic ensemble connected through a process of individuation. In the final section, we review the literature that discusses the relationship between the body and architecture, a topic heavily explored in Albena Yaneva ethnographic research and Michelle Murphy's sick building syndrome. Both of these authors analyse architecture from a viewpoint that opens the readers mind into alternative understandings of a building's function and how we experience it. Furthermore, we will also look at the literature of Zoe H Wool in "Life After War", which will give us a deeper understanding and connection with victims of war who have suffered severe life-changing injuries. We will see how their abilities to re-adapt to the concept of "normality" constructed in the Fischer house are hindered by the mental traumas associated with life after war.

> ...The cyborg is a creature in a postgender world; it has no truck with bisexuality, pre-oedipal symbiosis, unalienated labor, or other seductions to organic wholeness through a final appropriation of all the powers of the parts into a higher unity. In a sense, the cyborg has no origin story in the Western sense— a "final" irony since the cyborg is also the awful apocalyptic telos of the "West's" escalating dominations of abstract individuation, an ultimate self untied at last from all dependency, a man in space. (Haraway and Wolfe, 2016, p. 8)

2.1 Humans and their bodily functions

The concept of cyborgs is discussed in literature and other domains, such as film, medicine, science, politics and technology. The term is generally used as a descriptor to imply the formation or combination of something that is part human and part mechanical. But this is just one of the meanings, and to simply give it one definition is an injustice. We first see this in the book "A cyborg manifesto" written by Donna Haraway and Wolfe. The image of the cyborg is generally used as a metaphor to imply implicit assumptions that guide her thoughts. She says, "A cyborg is a cybernetic organism, a hybrid of machine and organism, a creature of social reality as well as a creature of fiction." (Haraway and Wolfe, 2016) The cyborg is described with a fusion of philosophical theory backed by science and cultural understanding. Haraway sees cyborgs as a multiplicity of categories, it is both fiction and reality. This tells us that cyborgs will always be perceived as fictional, but it is only with understanding of our own social structures that we begin to see what Haraway does, and with that we can challenge the current narrative on what it means to be a cyborg.

Furthermore, with the confusing definitions of nature, man and machine, we begin to question whether it's fiction or, as Haraway suggests, a "Hybrid of machine and organism" (Haraway and Wolfe, 2016). But for a cyborg to be considered equal to humans, we would need to accept that they are part of us, and this is exactly what Haraway discusses. It's in her ironic and sometimes conflictual interpretation of current and historical social structures through the construct of a cyborg, that she attempts to create a unified consciousness, stating that "The machine is not an it to be animated, worshipped, and dominated. The machine is us, our processes, an aspect of our embodiment" (Haraway and Wolfe, 2016) Haraway believes that machines like humans should be treated the same, the perception that humans are the dominant/highest level is a misconception and a product of our social and political conditioning.

She further elaborates on this "Gender, race, or class consciousness is an achievement forced on us by the terrible historical experience of the contradictory social realities of patriarchy, colonialism, and capitalism" (Haraway and Wolfe, 2016, p. 16). What we see through her writing is that ironically, we are already cyborgs. For example, Haraway and Wolfe describe how sexual appropriation in society, which is one of the reasons for the feminism movement, has created a culture of objectification in women as a product of our desires. "...sexual objectification, not alienation, is the consequence of the structure of sex/gender. In the realm of knowledge, the result of sexual objectification is illusion and abstraction." (Haraway and Wolfe, 2016 p. 24). Haraway discusses how our social/political attitudes and beliefs, as seen through the feminism movement, subconsciously led to a system that allows control and power of one body over another.

To adress the gap, we draw our theortetical framework fromt the philosophy of technology Gilberto Simondon, Thomas Lamarre and Combes. Similar to Haraway, they discuss the topic of man and machine, although Simondon's fascination with this matter doesn't necessarily lie in the relationship between them, more so in how being comes to exist. Many philosophers have attempted to translate Simondon's philosophy due to its complexity. Lamarre and Combes have had most success in this. In Human and Machines by Thomas Lamarre, he begins to translate Simondon's philosophy. He states that "Rather than blur or collapse the distinction between human and machine, or for that matter, organism and mechanism, he sustains it, but stubbornly refuses to allow it to take on substantialist weight. Thus, for him, humans and machines are different; they can even be said to be ontologically different, but within an ontology that methodologically avoids dualism and substantialism, which is indeed more precisely called ontogenesis."(Lamarre, 2012) This thought can be difficult to comprehend, and even after being interpreted by Lamarre and many others this philosophy can still be misunderstood. But for a moment, let's focus on the word dualism and substantialist, which Haraway also uses. However, Harway uses it to describe the parallels between the body/mind or culture/nature, while Simondon uses this word in a slightly different context. Simondon presents this philosophical understanding with scientific support, allowing the reader to understand the intangible complexity of being more factual. The technical being derives from this thinking, in rejection of external conditioning, and in a positive way acknowledgement of the beginning as essential for growth and advancement, in recognition of the ultimate reality as an experience of equipoise.

To further address the topic of man and machine, it is better understood within Simondon's fascination with the state of form and matter (hylomorphism), where he attempts to combine philosophy with science to address 'individuation'. Simondon speaks about the becoming of physical individuation with metaphoric reference in the process of crystallization. In Thomas Lamarre's translation of Simondon in Human and Machines, he says "Simondon shows the inadequacy of the form-matter opposition for understanding actual processes. He shows that we cannot simply begin with the form or structure (crystal) as a self-identical, autonomous, given individual. Instead, he demonstrates that the individual is always in process" (Combes, 2013) Here he expresses that as a crystal continually changes, we as humans also change, we aren't stable but instead "A physical system is said to be in metastable equilibrium..."(Lamarre, 2012) constantly individuating. This could imply that an individual is never really themselves, and if this is true, how can we assign ourselves as master and controller of something that we have no understanding of? His metaphoric reference to crystallisation shows concern about how we perceive technology, and is important in understanding and grasping the basics of Simondon's philosophy.

As our research attempts to deploy the theoretical framework of Gilberto Simondon, in the examining of prosthetics as a technical object, we will now look at Simondon's description of this. To summarise, Simondon's description of a technical object is this: an object is relatively mobile, as a microphone, as a piece that one can carry with himself. Second is something that has a certain autonomy, an individual destiny. He then describes two types of the technical object: open technical objects VS closed technical objects. Closed means it's a thing, completely new and valid – comes into some sort of aging period, it comes to less, it gets old. Degrades, even if it is no longer used. Degraded due to its closedness. And then, if the object is open, it can be intelligent. If the user can continuously repair or maintain new parts that are used, then there is no obsolescence, and there is no aging. In other words, if something in the object needs replacing, you can install a new part. Therefore, an open object is above all an object that presents itself as fully real, not hidden. Lamarre goes on further and quotes Simondon in the chapter toward a revolution in action: "the human can be coupled with the machine as equal to equal, as a being that participates in its regulation" (Combes, 2013). And individuation means exactly that, it is a realisation of oneself.

2.1.1 The body and architecture

"At its beginnings all architecture is derived from this body-centered sense of space and place." – Kent C. Bloomer and Charles W. Moore5

Whether it's a matter of science or fiction, or a much deeper issue that begins at the origin of life itself, understanding how we are all connected is important to how we live and experience life. We begin by reviewing the literature of Zoe H Wool, which speaks about the connections between architecture and the body. Wool discusses the idea of feeling ordinary for soldiers suffering severe trauma and injuries from war. It is in her description of life after war at Walter Reed that you begin to understand the severity these injuries had on their rehabilitation and search for "the feeling of ordinariness". She says "the heaviness of so much hitting each soldier all at once was matched only by the weight of boredom that, even in the presence of pain and frustration, anger and sadness, was the overriding feeling there" (Wool, 2015). Here Wool describes the mood of Walter Reed, drawing on not only the physical effects of war but also the psychological. She refers to boredom as the common emotion. This shows that disability extends beyond the physical aspects of life, and solving all associated issues is complicated.

Moreover, in chapter 01 Wool discusses more closely about the soldiers experience, but this time in relation to the built environment, and it is shown in the physical formation of "comfort homes". Wool states that "The Fisher House was not only the physical space of our encounters but, in many ways, an allegorical space brimming with the features of the remaking of life after war" (Wool, 2015). Here, she describes how the designed space of the house goes beyond the physical level, and the construction of these homes was much more pragmatic in its attempt to accommodate, rehabilitate and reintegrate soldiers back into a normal life. The once mundane tasks of simply eating or walking became a challenge, leading to immense frustration, even with the design of Comfort houses, whose sole purpose was to combat that. Wool depicts how decoration would be strategically placed to evoke feelings of familiarity and normality through architecture and arrangement of objects. She says "Every house features a small front portico, with decorations that change with the seasons: a scarecrow in fall; a wreath in winter; perhaps some red, white, and blue bunting for the 4th of July." (Wool, 2015). The type of each ornament is carefully considered. Through arrangements and choice of decoration, the Fisher House attempts to be a "home away from home" and creates a sense of nostalgia that can potentially help soldiers re-adapt to normal life.

What we see from Wool's literature in Life after War is that architecture has the power to shift and change many things, such as emotions and feelings. However, even with this power, architecture like humans has its limits. And outside of the luxuries of the house the joy would come from "playing with his daughter" however, even this wasn't always plain sailing, as she describes that lack of mobility would sometimes lead to frustration as "she developed a habit of crawling out of the kitchen, around the corner, and nimbly up the Fisher House's carpeted stairs, he was exasperated that he could not climb up the stairs after her and got pissed off when those who could have didn't ". It shows that even with these added comforts, not even the more regular opportunities to be closer to family and loved ones could alleviate these emotions.

Furthermore, Murphy and Albena Yaneva both discuss the relation of the body to the building, one in terms of respiration and the other in terms of movement. They present key concepts that provide us with either an ethnographic exploration or scientific evidence associated with their chosen buildings. Albena Yaneva begins with an ethnographic observation of the Benzie building in the book "Five ways to make architecture political". She follows and observes firsthand how people move through the Benzie building. Yaneva describes her method for tracing these associations through a "slow" ethnographic approach to allow for a detailed and more personal report of the Benzie building.

Albena Yaneva depicts the simple daily activities that occur within the building, such as walking up the stairs or taking the lifts. She explains how each option comes with different experiences and proposes new interactions, some more obvious than the other. It's within her observations that we see how the architects scripted intentions of a particular space interfere with the users' actual experience of it. She begins her study and "follows the interactions of other people in these spaces". She highlights how the "The Benzie atrium invites the creation of new types of connections among academics and students from different art disciplines, and among university people and random visitors" (Yaneva, 2017). There is a political dimension to the way architecture and objects within a space are designed. Architect and designer of the Benzie building FCB studios states how the Benzie was designed with the intention that it would "help students be more interdisciplinary". This is an example of how the design can influence certain behaviours and predict movement through the building.

The relationship between the body and architecture is further elaborated in "Sick Building syndrome and the problem of uncertainty". Murphy's Environmental-politics lens expands the field of architectural research not only into the sciences, but also to a theoretical strand on using the analytical empirical units of fields that study the built environment. Murphy demonstrates how the office building as an internal environment can propose a toxic environment that causes respiratory problems for users. He states "Buildings and bodies were often connected. A building was built with bodies in mind; it became a prosthesis of the body, extending its functions." (Murphy, 2006, p.23) Murphy sees the building as an extension of the human body, however "sick building signalled a confusion of boundaries between buildings and the bodies in them." Murphy, like Yaneva, is fascinated by this connection between architecture and the body, and they both show how closely connected the body and architecture are.

2.1.2 Conclusion

In this chapter, we reviewed the recent literature on humans and their bodily functions and identified a gap. Disability requires physical, environmental and psychological rehabilitation. We saw in the literature of Zoe H Wool, how patients face physical and mental challenges, such as physical pain, new interactions with their environment, immense frustrations and success, and realisation of a new body image. We now offer to study technical objects and sociotechnical associations, drawing theoretical inspiration from the philosophy of Gilberto Simondon. We address the research aims and key research questions by examining advanced technological machines (prosthetics) and its impact on the built environment through human-nonhuman associations and technological change. In the next chapter, we set the methodology for studying biological to mechanical sensing as a relational, evolving, and multiple technical object of prosthetics, and by analysing technological change to examine its sociotechnical relations with those who distribute the script and those who use it or change it, and to understand its associations with landscape/architecture.

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Chapter 3

Methodology

3.0 Methodology

In chapter 4, we'll explore the gap raised in the literature review that addressed the blurring distinction between man and machine, and how this is shaping our understanding of how prosthetic technologies and the inherent notions in the recognition of humans with more than a biological ontology. To address the research aims and the research questions, in the first empirical chapter, we will draw our theoretical framework from the philosophy on technology of Gilberto Simondon (Combes, 2013; Lamarre). We will begin by analysing how sensing changes from biological to mechanical. We will explore the functions of the biological modes involved in the operation of certain movements, such as walking, standing or balancing in relation to the landscape/terrain (Chapter 4). Second, the operation of the mechanical limb, through the lens of the prosthetic (Chapter 4), using primary sources, we will analyse multiple utility patents. The choice of the analysed elements will depend on the following: their interaction with the ground plane, the importance of the chosen system/component in the functioning of the limb, and the success or failure of this in the improvement in giving back full or partial mobility of the user. In chapter 5, we will draw our theoretical framework from the literature of Albena Yaneva and Murphy to further examine the relations between the body and architecture. We will use secondary sources to investigate how prosthetic construction can potentially transform architectural thinking. We will also look at what the prosthetic means to the built environment and analyse the approved documents, with a focus on current design standards and regulations in the UK.

Within the scope of this dissertation, we will focus on the lower limb, as this is reported as most problematic in both user comfort, appearance and mobility. This means we will confront highly complex technological processes, so it will require in-depth knowledge of all the systems we encounter to fully understand it. However, to analyse each part would require extensive research and time, so we will avoid explaining the entire functionality of the prosthetic. Instead, we will analyse what we are most fascinated with in our field of research. This includes how the prosthetic improves user comfort, and what we mean by user is the collective ensemble of everything, human and non-human, the complete entity. And its ability to navigate on various terrains, improve stability and control by using sensing technology and real time monitoring at the stump - socket interface. To address this, we will use primary sources, which include multiple utility patents. When analysing the various patents, we're interested in understanding two things: first how the prosthetic device restores the user's ability to walk, and second to establish a relationship between the body, prosthetic and ground. We will focus on two patents from 2014 and the other 2018. This period is significant in the advancement of prosthetic technology. Each patent and patent application shows improvements to previous iterations and refines the script. The categories we will analyse are; Sensing, this is how the prosthetic detects changes in environmental conditions, such as level or ramped surfaces and balance, this is how the prosthetic device adapts to this change and provides stability.

Moreover, we examine the prosthetic as a technical object, and we will refer to the prosthetic user as a technical being that "individuates" relationally and creates technical individuals (see chapter 2). It is a tool designed to replace a missing body part, an extension of the human body (chapter 2), and therefore an object that moves in relation to the presence of infrastructure. The prosthetic allows us to analyse how technology reduces the landscape to terrain, and restoring an amputee's ability to walk becomes part of body-machine-terrain relations. Therefore, the technical object raises the question of how the architect and their design standards respond through human - nonhuman associations and coordinate the cyborg as an extension of human capabilities. And asks the question: is this a natural process driven by complex networks of individuation, as suggested by Simondon, or is it much simpler in that it is artificial, a man-made object in which we are in complete control and master of?

Unable to be on site and observe prosthetic users, and unable to follow discussions around these prosthetic technologies in real time, or to engage in ethnography and interviews with prosthetists, amputees, and medics, we adopt a quasi-ethnographic approach that relies on analysing primary and secondary sources. We find our sources in publicly accessible, which provides rich content. The empirical sources of this research are divided into primary and secondary sources. The primary sources include: patents and studies; the other includes documents/media such as medical journals and governmental policies. Secondary sources include second-hand information, such as news articles, reports and websites.

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Chapter 4

Empirical

4.0 Introduction

In the first empirical chapter, we analyse processes of sensing, experiencing and anticipating our surroundings within a primary biological mode of operation. This is followed by the mechanical mode of operation in the field: prosthetics, the medical term for an artificial device that replaces a missing body part. This specific mode demonstrates the biological and mechanical heavy reliance on our sensory abilities to scan the environment to predict and avoid danger. This offers us the empirical basis to explore the prosthetic through an architectural lens as a device to restore normal functions and an artificial extension of the human body. We draw the readers focus to the architectural character of the prosthetic limb's major improvements in enhancing the users abilities, although the prosthetic itself is not architectural. These connections become visible in the Patent analysis, as the Prosthetic breaks down and receives improvements to improve its relationship with landscape/terrain. There is a parallel to be drawn with buildings, as prosthetics for restoring the relationship with the built environment. What makes the prosthetic an important and interesting object to study, though, is its potential to provide the user with a renewed relationship with the built environment.

4.1 How sensing changes from the biological to the mechanical

Balance is a skill that we all take for granted, and it is something that we learn early in our adolescence. However, not everyone is born with the full ability, and some even in their adulthood struggle with it. The biological body is highly complex, and we rely on our sensory inputs, such as spatial awareness, sight, or touch, to input that information into our brain via a multitude of sensorimotor control systems. Our sense of balance comes from many systems that combine to create stability in your body and vision. To quickly summarise this, I'll use the various steps. As stated in the "American Physical Therapy Association, section on neurology," it says, "Good balance depends on: 1. Correct sensory information from your eyes (visual system), muscles, tendons, and joints (proprioceptive input), and the balance organs in the inner ear (vestibular system). 2. The brain stem making sense of all this sensory information in combination with other parts of the brain. 3. Movement of your eyes to keep objects in your vision stable and keep your balance (motor output)" (Hoffman, no date). This demonstrates a strong connection and reliance on visual input.

It is this instinctive biological mechanism, that we can only assume is the result and process of inherited traits within all beings, through matters of evolution, that allows us to scan our surroundings and adjust our body positions to make our interaction with the built environment easier (See Fig 3). As well to the reliance on our sensory inputs, the biological accumulates this information and sends it to other body parts, such as the Menisci. "The Menisci are discs of cartilage that act as shock absorbers, distribute weight, and provide stability". Furthermore, extrinsic muscles are used for controlling the movement of the foot and toes – designed to make the foot less bulky, incapable of fine movements and fewer restrictions, and intrinsic muscles located within or situated deeper in a structure – located in the foot move the toes and support the arch of the foot (See Fig 4). What this shows us is that each element of the limb, both intrinsic and extrinsic, works together to enable a sleeker and more functional operation of the foot.

So how does sensing change from the biological to the mechanical?. Here, we apply the thinking of Bloomer and Moore in their analysis of "Basic-Orientating and Haptic Systems" (Bloomer and Moore, 1977). The haptic sense is the sense of touch. At the most primitive level, after sensing our touch, gives us the ability to feel, and it's this connection where the mechanical can begin to react to its surroundings. For example, Bloomer and Moore state that "you can extend haptic perception with an instrument, such as a cane, in which case the feeling of an object moves out to the end of the cane" (Bloomer and Moore, 1977). [Think: an elderly person walking on uneven terrain]. Their body weight shifts, their arms attempt to regain balance, and their cognitions fight the urge to cut loose from the entire situation. They experience a state of panic and disorientation as they anticipate the worst-case scenario. At this point, the entire body is dependent on the instrument to prevent injury. It becomes a tool for survivability that extends the disabled body and their affects associated with it. Like biological sensing, although the technologies are constantly developing, they rely heavily on sensory inputs and programming to inform how it reacts and adapts to differences in the environment. However, the major difference here is that it is currently only capable of haptic sensing.

We now move to a phase where innovations in prosthetics shifted from passive to active technology. We analyse how specific biological processes of sensing are simulated in the mechanical and progress to alternative advanced technology and new assemblages. Similar to smart Boston Dynamic technologies for robotics (See Fig 6), the new improvements employ advanced materials, environmental sensors, energy computation, and reactive measures. The components of a standard prosthetic are designed to mimic the biological methods of sensing as much as possible. They form basic arrangements, such as socket, knee joint, shin joint, and prosthetic foot and ankle, to restore an amputee's partial ability to walk. What I mean by partial is that it is still a constantly developing field and yet to be completely resolved. This configuration of ability is designed to improve the amputee's life, and also regain independence. However, as highlighted in the literature of Wool in life after war, this isn't easy. An emphasis on the aesthetic appearance of the limb can sometimes take priority over its function. Early examples of prosthetics were all about recreating the image of the biological limb.

The sensing of objects changes through our perception of them, and haptic perception can be extended with an instrument. But, as we shift from biological to mechanical, the relationship with the built environment is renewed. It proposes new questions of how we think, first about our "ontogenesis" (Simondon, 2017, p.13) and how technology scripts urban relations, and second, its architectural connections in human and non-human associations. To gain a detailed analysis of patterns and relations of movement and interactions between the user and the ground. Each patent and patent application shows improvements to the previous iteration and refine the script and with it the connections with the terrain. Yet interestingly, it isn't just a one-way relationship in which the biological informs the technical, but rather, the technical might inform the biological back.

4.1.2 Prosthetics and Its Sensing Technologies

> This invention relates to a lower limb prosthesis including a knee joint and an ankle joint. Both the knee joint and the ankle joint include respective flexion control devices actuated by an electronic control system...
> Known lower limb prostheses for above-knee amputees include prostheses with adaptive control systems for controlling knee flexion during both stance and swing phases of the walking cycle. Such a prosthesis is disclosed in WO99/08621. In this example, the control system includes sensors for sensing shin bending moment and knee flexion angle, corresponding electrical signals being fed to a processing circuit for automatically adjusting hydraulic and pneumatic flexion control devices. Knee flexion is controlled in the stance phase in response to the activity mode of the amputee, i.e. in response to changes between level walking, walking uphill, and walking downhill, and in the swing phase in response to walking speed.

Figure 1 Excerpt from Patent Application 14/364,637 (Zahedi et al, 2014)

Let us begin by analysing the invention in Zahedi et al.'s patent on lower limb prosthesis. It demonstrates the use of device sensors in the lower limb to generate signals related to kinetic movement, including walking or flexion control. It also demonstrates the topological relations between the prosthetic limb and velocity related to architectural elements such as stairs, ramps, surfaces, and obstacles. The new added feature improves the user's ability, allowing greater adaptability to more complex terrain. Previously, prosthetics gave the user little to no ability to walk on uneven surfaces, and they used spring-like structures that could only operate at about one equilibrium point. Using springs to provide flexibility was successful on level surfaces and was a predominant feature of the common prosthetic foot and ankle. With technological advances, sensory technologies were used to detect topological differences. Thus, the inventor's response was to add sensory technology and microprocessors to the prosthetic to increase user mobility.

The increasing number of issues related to user discomfort is the prosthetic industry's key concern and measure of prosthetic breakdown. Additionally, the success or failure of the prosthetic limb itself depends on the biomechanical understanding of the interaction between the prosthetic socket and the residual limb. The above excerpt from the patent application (Figure 1) shows how Zahedi et al rationalise this concern by providing appropriate load transmission, stability, and control. With the design of flesh and metal to connect/fit the prosthetic, the high load transmission associates the amputee's stump and prosthetic limb device through harm. We traced an online medical journal that showed the findings documented in Dejke et al report entitled Development of Prototype Low-Cost QTSS™ Wearable Flexible More Enviro-Friendly Pressure, Shear, and Friction Sensors for Dynamic Prosthetic Fit Monitoring (Dejke et al., 2021). The report investigated different causes of user discomfort among random amputees from the Amputee Coalition, and found that 35.5% of the amputees with a prosthesis did not wear it regularly due to comfort issues. It also found that lower limb amputations are the most problematic, and "This is mainly due to socket-related issues, such as poor comfort, reduced biomechanical functionality, and hampered control" (Dejke et al., 2021). Let us analyse how Zahedi et al resolve comfort issues by increasing controllability from the data in the patent application.

The basic components of the prosthetic limb are shown in the illustration (See Fig 5): the socket, knee joint, shin section, foot, and ankle joint, form the prosthetic limb. Each element is designed to artificially mimic the biological limb, by which they reduce the main features of the biological down to a singular component. The choice of these features depends on the importance it has on rehabilitating the user. This reduction process happens at the most rudimentary levels, and then at the more technical levels. For example, the elements of the built environment, such as ramps, stairs, physical obstacles, environmental conditions, etc., are reduced to a singular component in the ankle joint responsible for taking this information. Through sensory technology, it sends electrical signals to the control system, in which the ankle joint mechanisms adapt accordingly (See Fig 9). The prosthetic limb (See Fig 7) attempts to recreate the biological balance system (See Fig 3), the visual input is a major part of the process and important in recognising differences in the landscape/terrain.

The new control device allows the programming of additional matrices, e.g. for defining control functions associated with additional events or activities. It's in this example that we see the importance and sociotechnical relations between the control system open architecture and the architecture of the environment. The activity mode remains the same on the device until it receives a sensor signal, which is interpreted as indicating a transition to a different mode. The transmission of this signal depends on speed measured by velocity and surface gradient or position concerning the ground. The new feature improves the user's ability to react to the environment and terrain. The table (Fig 8) shows relations between conditions derived, e.g., from sensed kinetic and kinematic parameters of locomotion, and outputs for flexion control devices. Each environmental condition, such as a ramp up or level ground, is related to a controlled setting. It is important to acknowledge the significance of the microprocessors involved in sending and receiving the signals, which allows for a more reflexive design. Without this added feature, the user is limited to simple movements.

Because of these technological advancements, Simondon refers to the prosthetic as a "primitive item." According to Simondon (2017, pp. 29–30), the term "primitive" in this sense refers to an inelegant relationship between the technical and the geographic, in which the technical item is out of step with its geographic surroundings, which requires ongoing regulation by the inventor. Prosthetic technology had to be constantly updated from the 2000s - 2014.

> Most currently available prosthetic ankle devices are spring-like structures that operate about one equilibrium point (i.e., one resting angle). These systems can work nicely on level terrain but cause instabilities when lower limb prosthesis users walk on sloped surfaces... The present invention is generally directed to prosthetic and orthotic devices, and more particularly to an ankle-foot prosthesis for automatic adaptation to level, as well as sloped walking surfaces. Even more particularly, the invention is directed to a device or system for use by lower limb amputees to more easily and safely walk over a variety of sloped terrain, as well as to provide more stability during standing and swaying tasks.

Figure 2 Excerpt from Patent Application 16 / 404,777 (Andrew H. Hansen and Eric A. Nickel, 2018)

Once again, we observe the operationalisation of a new control system, although still a developing one. Yet, a different example of creating a prosthetic that can scan and isolate the terrain in a single mode, allowing the user to walk on various terrains. Let us analyse the invention in Andre Hansen and Eric A's patent on ankle-foot prosthesis for automatic adaptation to sloped walking surfaces. The excerpt (Figure 2) describes mechanisms to improve walking, particularly on uneven surfaces, and is specifically directed towards a device or system for the use of lower limb amputees. As mentioned in the excerpt above, level surfaces are least problematic, with most issues of lower limb prosthesis of this kind associated with uneven terrain. Thus, the invention shows improvements from previous ones, where the attempt to increase adaptability has fallen short, particularly in the stages of detecting level changes. The success of this invention comes with an improved sensory feedback mechanism. The control mechanism for switching dampers between high and low settings detects surfaces on each and every Step (See Fig 10), where previous inventions adapt after they have had multiple steps on a new terrain.

4.1.3 Conclusion

In this chapter, we analysed and traced the associations between the body. technology and landscape/terrain. We witness the early stages of emerging associations between a physical domain (mechanical technological properties), an environmental domain (ground-surface interaction), and a biological domain (mechanical being). Mobility is redistributed as synergies among these domains, as the medical / technology industry attempts to adapt the prosthetic to the terrain of its changing role and context. The elements of the built environment, such as stairs or ramps, are controlled again by a similar system as the previous, except this time it provides us with greater sensitivity and speed to which it reacts to the detection of these changes. This account is one of the first attempts at "corrective measures" (Simondon, 2017), i.e., quick fixes to the technical object. In the next chapter, we examine the architectural and urban landscape in which the prosthetic is situated. We scrutinise current architectural regulations to spot disconnects between mechanical beings and architecture.

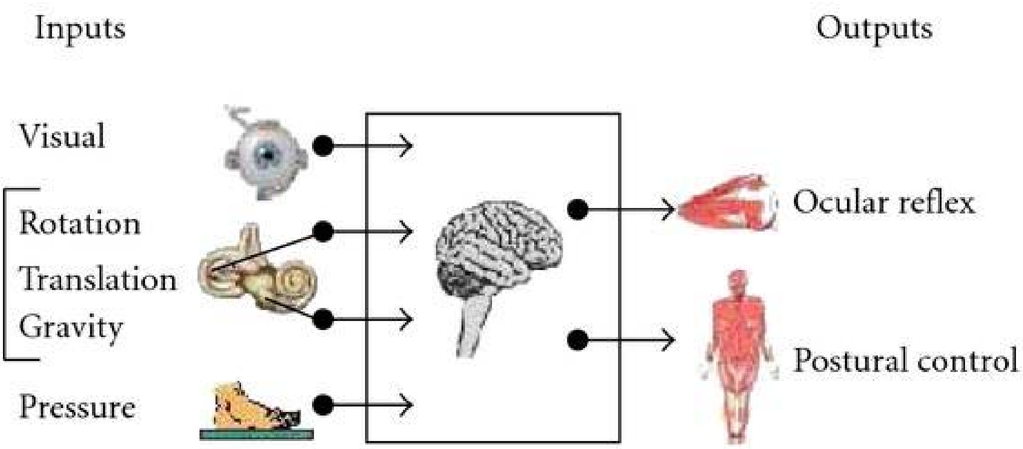

Figure 3 Schematic diagram of the balance system.

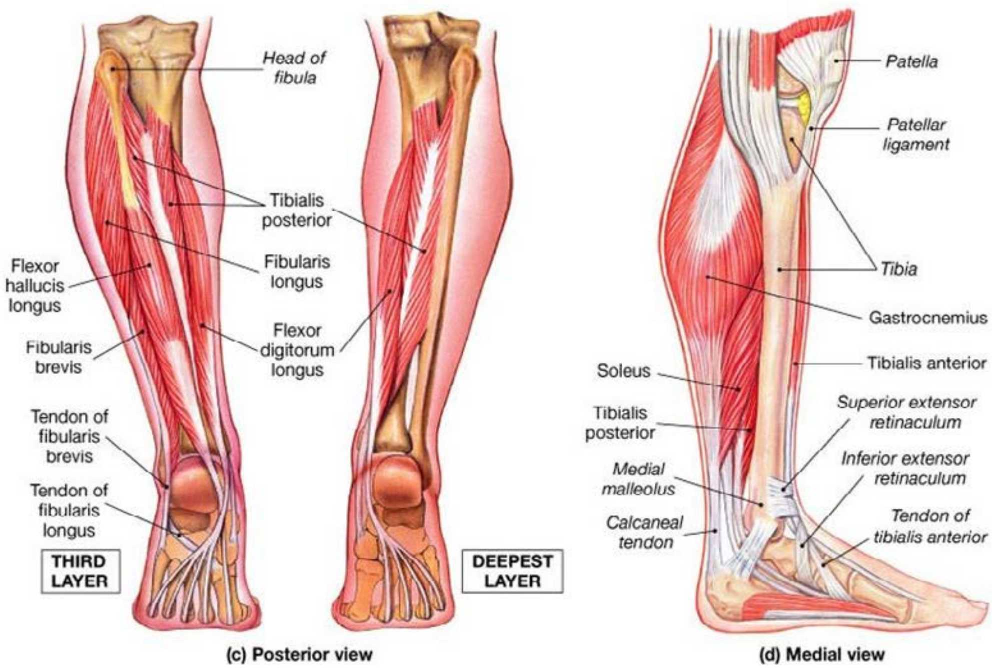

Figure 4 Diagram Shows The biological Extrinsic Muscles That Move The Foot And Toes

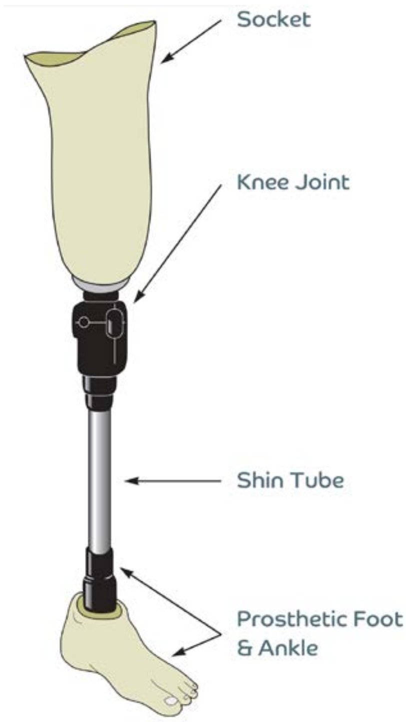

Figure 5 Illustrative diagram showing standard feautures of an above knee prosthesis

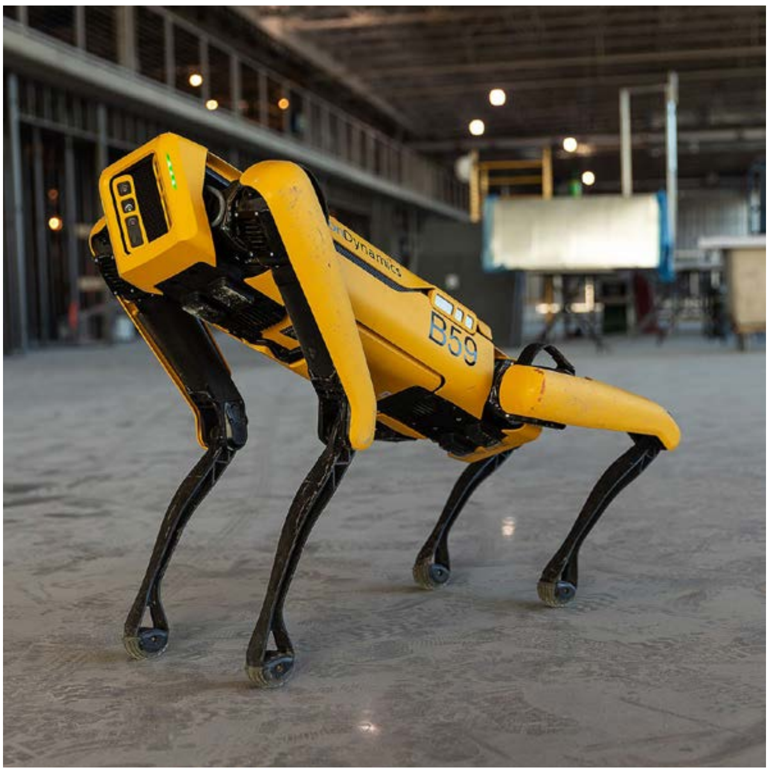

Figure 6 Image showing Boston Dynamics' dog Robot.

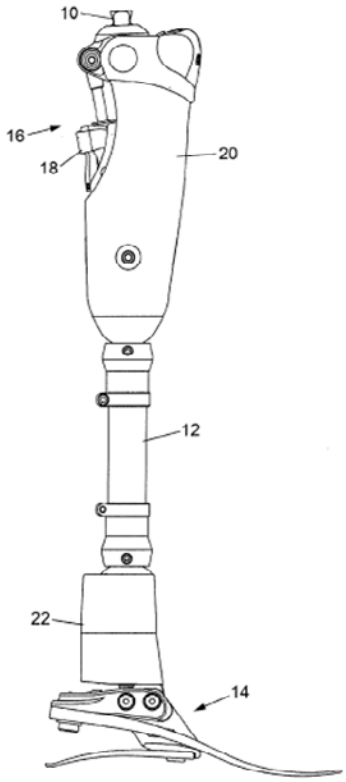

Figure 7 Patent Art showing a lower limb prosthesis and the various attachments

	Knee Hydraulic $ stance	Knee Hydraulic $ swing	Knee Pneumatic	Foot Plantarflexion	Foot Dorsiflexion
Ramp up*	H	L	L,M,H	H or M	L or M
Ramp down*	H,M	L,M,H	L,M,H	L or M	H or M
Level Velocity*	H	L	L,M,H	L,M,H	L,M,H
Stairs down	H	H	H	M	M
Stand Relaxed	H or VH	-	H	Leave chosen setting when on slope else M or H	Leave Chosen setting when on slope else M or H
Sitting	H	H	L	M	M

Figure 8 representations of a multiple layer matrix group defining relationships between input conditions derived, e.g., from sensed kinetic and kinematic parameters of locomotion, and outputs for flexion control devices forming part of the prosthesis of FIG. 7

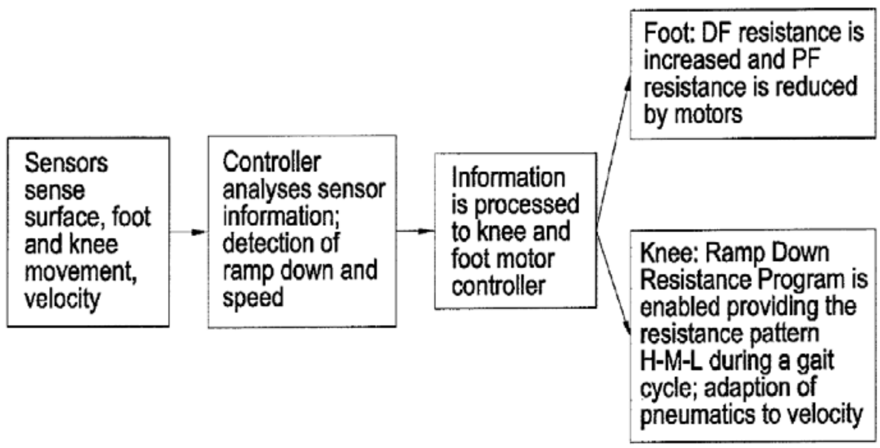

FIG 9 is a flow chart illustrating a typical set of operations performed by the electronic control system and flexion control devices of the prosthesis:

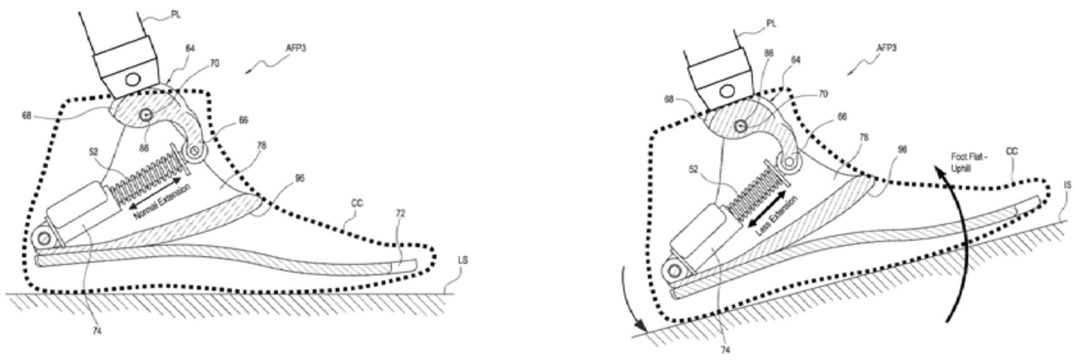

Figure 10 Comparison showing foot flat adapted to a level surface (ankle plantar-flexed relative to a swing phase ankle angle) and foot flat adapted to an inclined surface (ankle dorsiflexed relative to foot flat on a level surface) ;

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Chapter 5

Empirical

5.0 Introduction

In the first empirical chapter, we analyse processes of stabilising, movement, and sensing primarily within a biological mode of operation, and then how this changes in the mechanical. So far, we have collected technical patents on lower limb prosthetic devices, and analysed how emerging concerns for user comfort assembled the prosthetic script as multiple improvements. This offers us the empirical basis to explore the prosthetic through an architectural lens, as an extension of the human body and a mediator between the user and its surrounding. We come across a common thread in the analysed patents that shows how prosthetic technology is concerned with its interaction with the ground as a key point of contact. The ground interaction gave us two types of connections: the first being our sensory connection, and like the biological, the mechanical systems depend on this feature. Without this, there is a breakdown in user control, leading to discomfort and potential harm. Second, there is a disconnect between the mechanical being and the construction of our built environment. As a result, users are limited and restricted to specific movements, particularly when navigating through more complex terrain.

In this chapter, we uncover this process of interaction by analysing how architecture responds to beings with more than a biological ontology. Specifically, we examine how buildings were designed using the human body as a model, which led to the ideal and harmonious interactions between the human body and environment. We start by analysing the ground as an architectural element designed as a platform for mobility through the interior and exterior of buildings, without compromising the user's ability. The first section describes the use of the ground in architecture, and analyses current examples of access and mobility in architecture in the approved documents and inclusive design handbook. We will attempt to understand how architecture could reconstitute conventional concepts by extending the capabilities of architectural elements gained via the examination of site prosthetic devices.

5.1 Access, Mobility & Ground Interface

The ground is arguably overlooked in architecture, and consideration for how we interact with it is limited. However, as we can see from the analysed patents, the ground is important and necessary. Through the use of sensory technologies and microprocessors built within the prosthetic, we can see a strong connection between the prosthetic user and the terrain. So what does prosthetic technology tell us about our relationship with the ground?. The article entitled "Platforms: Architecture and the Use of the Ground" it discusses and refers to a quote by historian Mary B. Hollishead who argued that "[T]he foot's repeated contact with a sequence of horizontal surfaces at regular, predictable intervals translates to a sense of organization and system. Close intervals and compression of steps express the intensity of effort, or conversely, broader spacing brings a slower rhythm." (Platforms: Architecture and the Use of the Ground - Architecture - e-flux, no date) and if we relate this to the patent analysis, we found that the prosthetic limb was much more successful when it took into account and sensed variations in the terrain on each and every step as opposed to adapting after they have had multiple steps on new terrain.

We have already established that humans require flatness to walk, and if they walk on non-flat surfaces, they find it difficult to do so. The building regulations set legal requirements for specific aspects of building design and construction. The approved documents part M provide general guidance for satisfying part M, which is where our interest lies. For example, inclusive provision of ease access to, and circulation within, buildings, together with requirements for facilities for people with disabilities. Approved document M defines a 'suitable ground surface' as an "external ground surface that is firm, even, smooth enough to be wheeled over, is not covered with loose laid materials such as gravel and shingle, and has a maximum cross-fall for 1:40." ('Part M V3.pdf', 2015, 2016). The elevation differences of contour must be no greater than 1:40 (See Fig 11), and material choice of the ground must be firm or even, but this would only work for a fully-able healthy person.

Furthermore, the ground typology is heavily considered throughout the approved documents, not only in terms of its flatness, but also in materiality. It emphasises the importance of a suitable surface "not covered with loose laid materials" ('Part M V3.pdf', 2015, 2016) surfaces, particularly in areas of accessibility both inside and outside of buildings for disabled users. Yet, although the Approved Documents take into account all types of users, including users with a disability, it is still questionable whether there is a consideration for users with more than a biological ontology. For example, to comply with Part M of the approved documents, where the dwelling is defined as wheelchair accessible, and we use the example for wheelchair accessible WC facility, as this is where greater consideration for space is generally required, it states " 1500mm diameter clear turning circle - may overlap max 500mm with shower" ('Part M V3.pdf', 2015, 2016). (See Fig 12). The diameter for the clear turning circle correlates with the average wingspan and physics of a human body, and it states in The Physics Factbook that "It was previously believed the wingspan of a person is equal to the height of that same person" (Size of a Human: Body Proportions - The Physics Factbook, no date) The average wingspan is based on the dimensions of a fully-able human body and therefore it questions first, the architectural design standards in the approved documents and secondly, how we think of architectural design in terms of designing spaces that are accessible for all users biological and mechanical. To further elaborate on this, we examine the drawing of the Vitruvian man by Vitruvius and Leonardo Da Vinci (See Fig 14) which shows the proportions of the human body. As Vitruvius writes, "in perfect buildings, the different members must be in exact symmetrical relations to the whole general scheme." (Designing with Symmetry and Proportion, no date) However, this ideology that humans are the perfect form and scale as a base for all design is controversial, and we can see in Le Corbusier's Modulor Man (See Fig 13) here he improves and devises a new form, instead, he emphasises the importance of 'universality' as a flexible measurement that could adapt and change, rather than be the same.

5.1.2 Prosthetic Architectures

"*We shape our buildings; thereafter they shape us.*" *– Winston Churchill*

Now, we analyse how architecture responds to beings with more than a biological ontology. In the previous section, we analysed the official approved document, which raised a gap between architectural design and human proportions. This section analyses a new improvement that displays increased sensitivity to enhance the connection between the body, technological and architectural. As seen in the preceding section, architecture can be understood as a representation or abstraction of the body. Therefore, further improvements force the environment of the prosthetic to multiply the interactive element of the prosthetic device. The next invention taps into smart technologies for autonomous sensing. It achieves extending the physical body by adding touch and motion sensors to pick up body movements, and radio transmitters are used to transmit the data to a computer that translates it into sound.

Here is one such invention, dubbed "instrumented bodies" by Dezeen (Joseph Malloch and Ian Hattwick, 2013). This is one of the few attempts to engineer technological devices that accommodate the human body, rather than the other way round. Although the primary use of this device is designed for artistic expression, it demonstrates a new connection between technology, body and its environment by exploring the idea of digital prosthetics by using advanced sensing technologies. It describes a mechanism for sensing to pick up "body movements" and "touch" through the visor headset, which includes touch and motion sensors (Fig 14). This technological improvement informs the sound the instrument makes, and in the interview with PhD researchers Joseph Malloch and Ian Hattwick, they explain how it works. "For sensing, the Spines use inertial measurement units (IMUs) located at each end of the instrument - each a circuit-board including a 3-axis accelerometer, a 3-axis rate gyroscope, a 3-axis magnetometer, and a micro-controller running custom firmware to fuse the sensor data into a stable estimate of orientation using a complementary filter." (Joseph Malloch and Ian Hattwick, 2013). In the details, the spine instrument is made from a lightweight laser-cut transparent acrylic. A thin wire runs through the acrylic connected to the pads (Fig 15). Touch and motion sensors pick up body movements, and radio transmitters are used to transmit that data to a computer, then translate it into sound. The spine instrument prosthetic is attached to the body, but can also be played in a traditional hand-held way.

5.1.3 Conclusion

By tracing associations (sociotechnical, techno-geographic, architectural, and urban) The inventors emerging concerns for primarily user comfort, rehabilitation, and adaptation to variations in terrain highlights a gap in architectural thinking. Through this methodology, we begin to see how prosthetic technology transforms architectural thinking through its use of sensory technologies in the processes of moving and connecting. Furthermore, the concept of prosthetic architecture presented by Joseph Malloc and Ian Hattwick illustrates another way to engineer technology-body-environment relations. It shows us how to use advanced sensory technologies in less conventional ways to craft new connections with our body and the environment. We also learned that architecture is concerned with the body. As seen in Vitruvius's Vitruvian Man and Le Corbusiers Modulor Man, the recognition for improvement in this field emphasises the need for reconfiguration of form, both human and architectural.

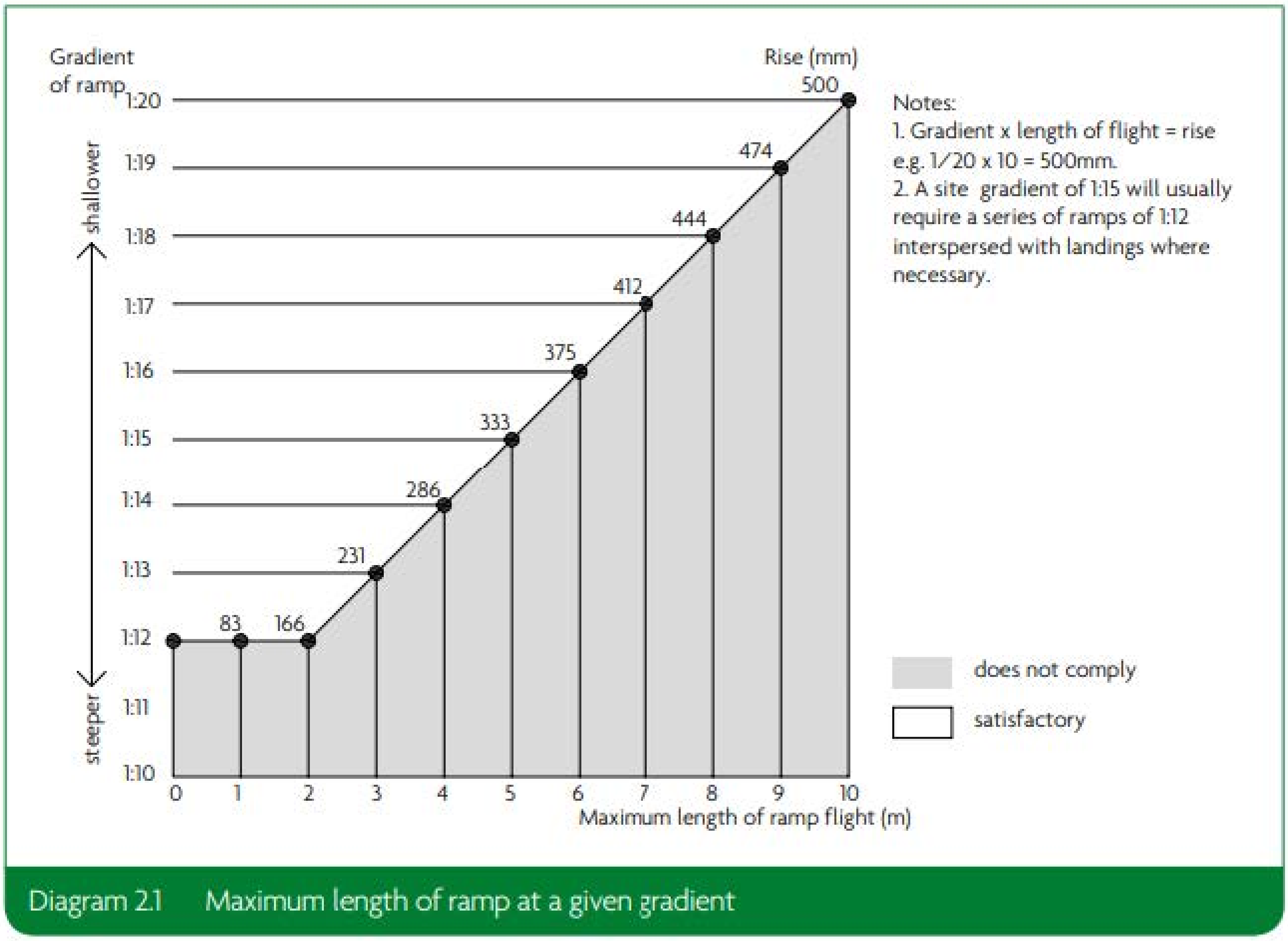
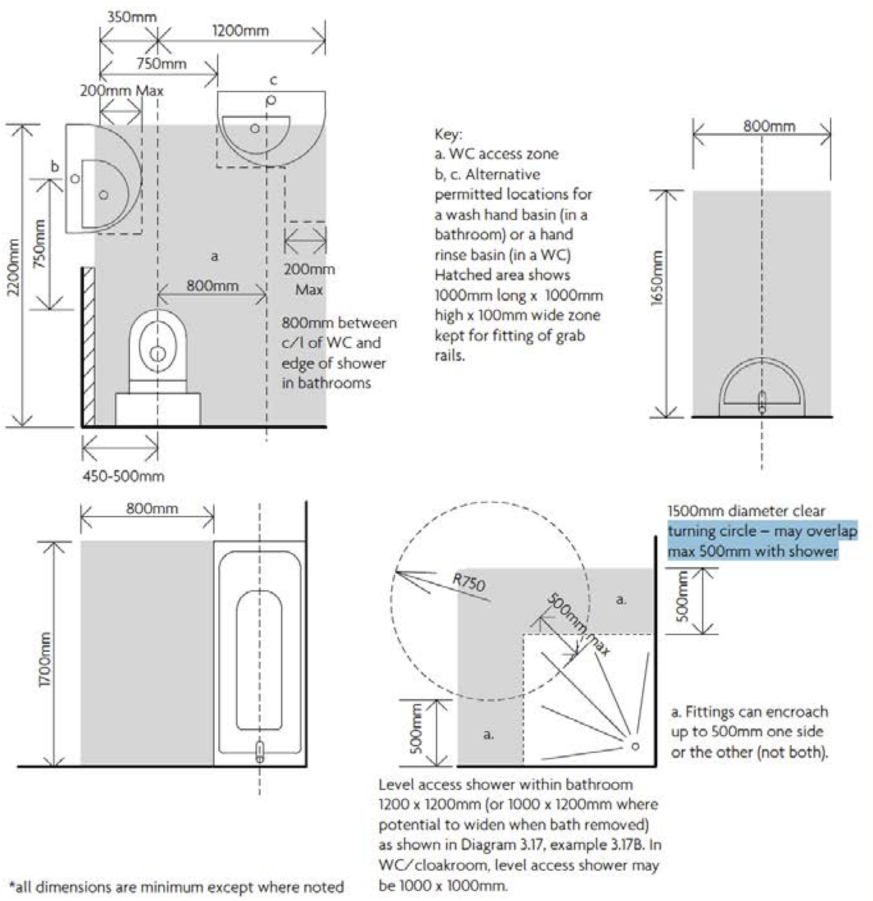


Figure 11 Diagram showing maximum length of ramp at a given gradient.

3.39 Where the dwelling is defined as wheelchair accessible, WC facilities should also comply with all of the following.

a. The WC, basin and shower (and their associated clear access zones) meet the provisions in Diagram 3.11. Examples of compliant designs are shown in Diagram 3.12.



Notes:

1. Sizes of fittings are minima based on the furniture schedule in Appendix D. Other sizes may affect the overall size of a bathroom or WC/cloakroom.
2. Access zones may overlap except where noted.
3. Clear access zone minimum 400mm-600mm high required under all basins other than essential traps and drainage connections providing these do not impede approach by a wheelchair user.
4. Any radiator or towel rail should be clear of all access zones.

Diagram 3.11 Sanitary fittings, associated clear access zones and permitted encroachment of basins – wheelchair accessible

Figure 12 The Approved Documents Part M Volume 1, 2015 edition.

Figure 13 Dezeen. "Instrumented Bodies by Joseph Malloch and Ian Hattwick." Dezeen Magazine, August 12, 2012. http://www.dezeen.com/2013/08/12/instrumented-bodies-by-joseph-malloch-and-ianhattwick/.

Figure 14 Dezeen. "Instrumented Bodies by Joseph Malloch and Ian Hattwick." Dezeen Magazine, August 12, 2012. http://www.dezeen.com/2013/08/12/instrumented-bodies-by-joseph-malloch-and-ianhattwick/.

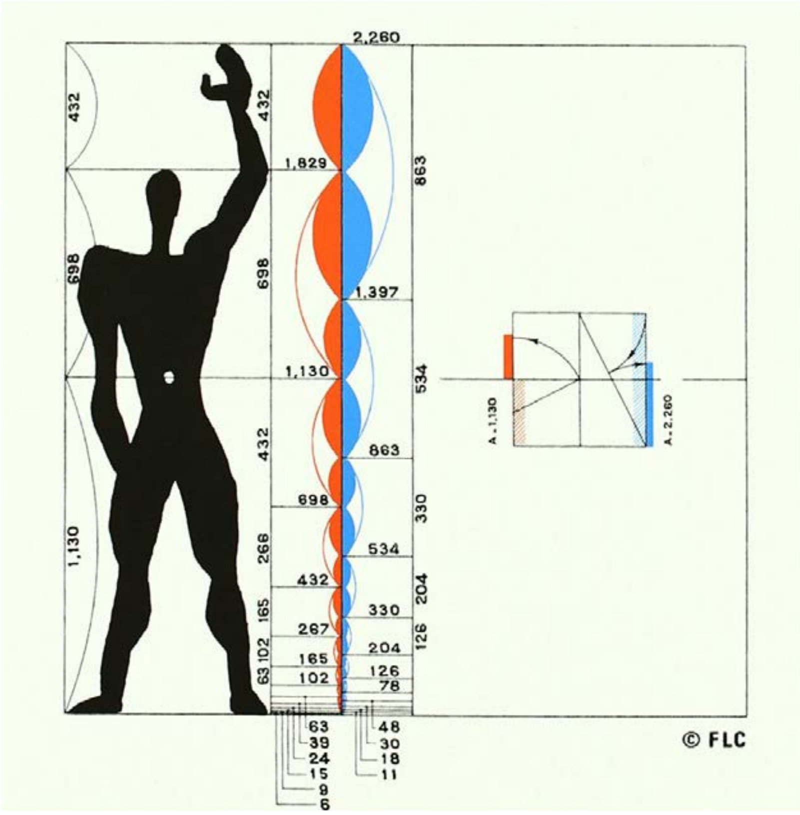


Figure 15 Wiles, William. "Modulor Man." Icon I: International Design, Architecture and Culture, 2014. http://www.iconeye.com/component/k2/item/3815-modulor-man.

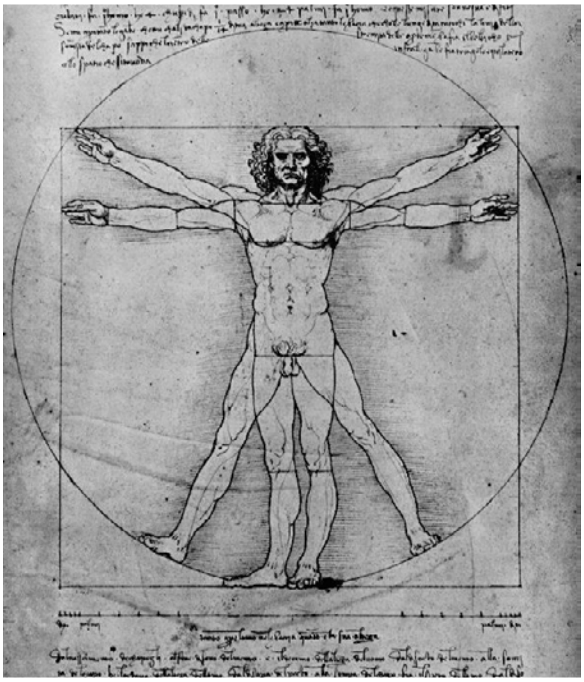


Figure 16 BBC. "Leonardo DaVinci: Vitruvian Man." BBC:Science & Nature, September 7, 2014. http://www.bbc.co.uk/science/leonardo/gallery/vitruvian.shtml.

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Chapter 6

Discussion

6.0 Introduction

Throughout the research, there was concern about equality between human beings and technical beings. This created a complication with how we perceive and distinguish beings with more than a biological ontology. In the first part of (Chapter 2), we established our theoretical understandings to address the gap in the literature on science, technology, and architectures. We gathered inspiration from concepts from the philosophy of technology, the sociology of innovation, and science to create an in-depth understanding of technicity in the prosthetic domain, as part of the broader technological change (to move beyond the prosthetic-nature technology divide) and about the ground/terrain/landscape (to link to urban and architectural research). The body of work discussed three key concepts: the ontology of beings and the general divide established between the technical object and their users; as well as the link devised in the process of technical functioning.

In the final chapter, we bring together the analysed accounts of prosthetic technologies where we examined how biological sensing changes to mechanical resulting in a renewed relationship between the body and its environment. The research discussed three key topics, the body as fully-able (biological), the prosthetic i.e. mechanical and lastly its relation to the built environment. In the final (Chapter 5) we analysed the ground where we argued how it had been under explored in architectural studies. The main contributions from this analysis are as follows. First, the research expands on the relational theory of the architectural and the urban extending the field beyond the concrete element. Second, the research shows the technical thought (i.e., technics) of enclosing/inscribing/associating bodies with their environments in the figures of the building, the city, and the prosthetic. Third, it answers methodological questions about how we can use technical objects to study the built environment and the reduction of the landscape into terrain. The following sections discuss the main findings.

6.1 First Contribution: Man and machine as concern

This research's first finding is in the importance of prosthetic technology first in terms of rehabilitating the user and secondly, the ability to provoke new insights into relations with the body and ground. The prosthetic offers a lens to examine the urban/rural landscape primarily as a terrain of interaction to allow ease of mobility and comfort. The body is heavily reliant on its biological ability to sense, this works in conjunction with the nervous system and various muscles and similarly in the mechanical systems, the prosthetic uses sensory technologies to detect changes in the environment and where encountered with more complex terrain the integration of sensors increased user control and consequently user comfort, by alleviating load pressure at the socket-stump connection. In both examples, the biological and mechanical systems of sensing are extended upon immediate concerns for ease of mobility through sociotechnical associations between humans and nonhuman infrastructure.

6.2 Second Contribution: A Method For Studying Associations

The second finding of this research is methodological insights into studying prosthetic technology as a constantly evolving technical object. Primary sources like the utility patents offered us with a detailed insight into prosthetic technology. It highlighted the interdependence and responsibility of the ground as an element of the built environment. This method analysed two sets of associations (Chapter 4): sociotechnical ones between human and nonhuman, and techno-geographic ones that stabilise the technical object. We started from a situation where these associations improved user control and comfort. Strengths and weaknesses were explored as to whether the prosthetic device stabilised and increased the users ability to walk on varying terrains. We deployed a quasi-ethnographic approach to observe and follow these associations. This method has two advantages.

One of the first advantages of this method is that it allows us to study relational connections through the prosthetic's technical evolution processes. The patents allow us to study technological change, it shows us how each improvement refines and reduces the limitations set by previous versions. This is seen in how each patent attempts to resolve the varying degree of complexity in the terrain, both examples allow us to follow these improvements across time and domains. Therefore, the prosthetic becomes a technical gives us the ability to study the effectiveness of technical progress in producing suitable prosthetics.

The second and less-obvious advantage of this method is that it allows us to analyse human-technology relations. Through sensory technologies and computer software, we can engage with the built environment in a much more critical way, their response to adding a sensory device to the prosthetic that articulates both concerns: eliminate user discomfort and increase the adaptability of the prosthetic device on complex terrain.

6.3 Third Contribution: A renewed connection

This research's third finding is how prosthetics explain a renewed relationship between the body, machine and architecture. The research transforms the theory of the architectural and the urban as renewed relationships driven by connections that stabilise or change our interactions. It draws on the Simondons theory of associations, specifically the work of Albena Yaneva, Michelle Murphy and on Simondon's philosophy of individuation, especially its concern with technical objects as technical beings. From our analysis of prosthetic technology and relations with the ground, it sets up an argument for developing the notions of architectural and urban thinking.

This research highlights the gap raised in (chapter 5) current design standards, and as seen in the approved documents, the ground is a highly important factor. The technical object can be used to approach and reshape architectural thinking in many ways, for example as discussed in chapter 6 the understanding of the biological senses in relation to the way we interact with the built environment, like our perception, constantly requires an active relationship between humans and non-humans. It is through the mediation of technical objects that the connection can be analysed.

6.4 Conclusion

The prosthetic as a technical object and extension of the human body tells us a lot (as urbanists and architects) about the landscape, including buildings, infrastructure, organisation and people. Prosthetic technology is very important in restoring their mobility and improving the way they experience the world. It also tells us about the human body's relations to the prosthetic device, particularly ones that are engineered to be more sensitive and tolerate various terrains, be they man-made or naturally existing. However, more importantly the prosthetic as a technical object tells us even more about our changing association to technology in everyday life and it has rarely been considered how we can learn from technology as opposed to just using them for our own needs.

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