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RESEARCH REPORT

EXPLORATION OF SCANNING FOR FOOT ORTHOSES IN REMOTE AREAS

INCLUDING INITIAL CONCEPTS

ABSTRACT

This research report explores the functionality and accessibility of 3D imaging software in remote areas for foot orthoses. The project aims to implement a system where a non-technical user can manually scan and send models of their foot and receive the orthotic devices to their remote location. This project aims to understand and investigate how to ensure accuracy in the scanning process for a non-professional user to ensure that public members can receive successful orthotic devices.

Research into existing literature explored the lack of access to health care and orthotic services for people living in remote areas. Current industry scanners and Photogrammetry were explored, and research gaps in their application to foot orthotics were identified.

Primary research and qualitative analysis identified key themes that informed the discussion and potential opportunities that would inform the ideation of the proposed design concepts. Most concepts are hand-held devices that utilize external devices, such as smartphones, for scanning. Concepts also explored interfaces and easy portability.

CONTENTS

SECTION ONE

INTRODUCTION

This report will explore improving the accessibility and functionality of orthotic devices in remote areas of Australia for people in need. The project was introduced by Professor Marianella Chamorro-Koc as an ongoing scientifically-led Queensland University of Technology (QUT) project in collaboration with I-Orthotics. I-Orthotics is an Australian company that designs custom orthotic devices or foot supports for podiatry practices (iOrthotics, n.d).

In more isolated areas of Australia, podiatry/orthotist or physiotherapy practices are limited in resources (Ridgewell et al., 2021). Thus, the scientifically-led project (main project operated by PhD students and Professor Chamorro-koc) are currently focusing on implementing a system where a non-technical user can manually scan and send models of their foot and receive the orthotic devices to their remote location. This report/project aims to understand and investigate how to ensure accuracy in the scanning process for a non-professional user to ensure that public members can receive successful orthotic devices.

The scientifically-led project focuses on implementing three-dimensional imaging software 'Photogrammetry' to use in the context of foot orthoses and ensuring accuracy and successful results of orthotic devices for the relevant stakeholders in remote areas. Photogrammetry is software that can be stored and used on a phone or smart mobile device (Telfer, 2023). A specific design concept was proposed for the design implication shown at the end of the report. The design would be a rig that would hold a camera (smartphone or camera) and take a system of pictures suitable for photogrammetry software.

This report will explore the purpose of foot orthoses and investigate how to ensure the accessibility of an orthotic device delivered to potential clients in need. Through reviewing existing literature and conducting and analyzing primary research with individuals in the field, design implications and a solution that works will be made.

Figure 1 below shows the project's progression over the last seven weeks.

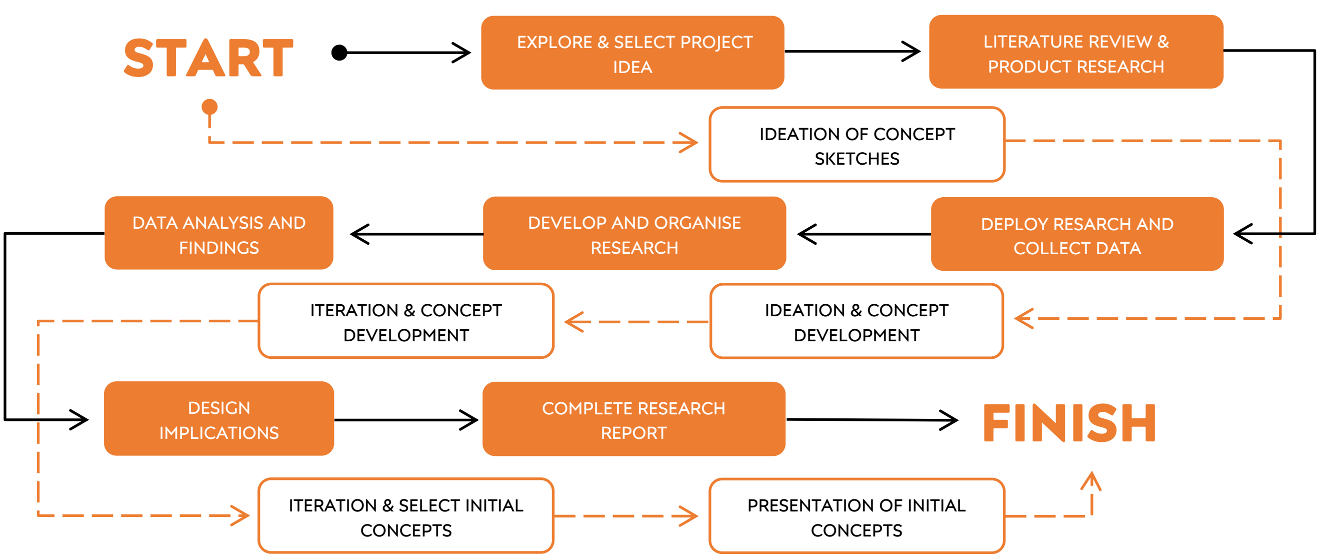


Figure 1: Diagram of project structure.

LITERATURE REVIEW

Based on the project brief given by Professor Marianella Chamorro-Koc, key terms and concepts were identified for further research into understanding the topic. This literature research explores the current condition of foot orthoses in remote areas. As well as the standard manual scanning process of foot orthoses and the application of Photogrammetry and rigs to the industry

Accessibility of Foot Orthoses in Remote Areas.

Foot orthoses treat foot ailments and musculoskeletal conditions (Lohman, 2014). Many skilled people prescribe and fabricate orthotic devices (Jorge, 2020). Experienced podiatrists, orthotists and many other clinicians can be responsible for the design and application of foot orthoses (Jorge, 2020). To help with mobility and relief of pain for a person with such conditions, a practitioner or orthotist may develop an orthotic device (footwear) for support (Jorge, 2020). For example, an insole would be designed for therapeutic effect on patients with chronic diabetes (Telfer et al., 2017).

To receive this care in Australia, patients must have access to podiatrists or specialized foot clinicians (Lohman, 2014). Access is a challenge for people living in remote and regional areas of Australia (Ridgewell et al., 2021). People in remote areas exhibit risky behaviours, such as excessive smoking or alcohol consumption (Australian Institute of Health and Welfare (AIHW), 2023). This behaviour puts their life at risk of harm and increases the possibility of disease or illness (AIHW, 2023). According to the Australian Institute of Health and Welfare (2022), "People living in Remote and Very remote areas generally have poorer access to health services than people in regional areas and Major cities." (p.65). This disparity is limited to patients and practitioners and orthotists in the system. Practitioners and healthcare providers also lack retention in remote places (Ridgewell et al., 2021).

To engage and attend to people in distant places, an existing online/mobile health care system is operated in Australia (AIHW). Telehealth is an alternative and digital service that provides healthcare to patients through video calls (AIHW, 2022). With the broad orthotic industry, patients found Telehealth a suitable method of service for their treatment (Dillon et al., 2023). The research found that Telehealth services reduced travel time and the risk of strain on health (Dillon et al., 2023). Patients found satisfaction in choosing between remote or face-to-face care (Dillon et al., 2023). However, a degree of experienced communication and health literacy is necessary for a compelling user experience (Dillon et al., 2023). It should be noted that there is not a lot of existing research on Telehealth in foot orthotics specifically.

Further exploration into the remote prescription of orthotic devices needs to be conducted for the research topic.

Current scanning process for foot orthotics

In the modern era of orthoses, the current protocol for prescribing orthotic devices is for the practitioner or orthortist to diagnose, construct, design, and manufacture the support piece (Jorge, 2020). In Australia, practitioners prescribe custom-designed footwear for their patients (Chapman et al., 2018). Traditionally, custom insoles were made from plaster casting, which is invasive and time-consuming for patients and practitioners (Barrios-Muriel et al., 2020). In recent years, emerging technologies such as additive manufacturing and digital three-dimensional scanning have improved the process of custom foot orthoses (Barrios-Muriel et al., 2020).

The three-dimensional scanners for foot orthoses can be classified as contact and non-contact (Telfer, 2023). In recent years, non-contact scanners such as mobile phones and structure lights have been the new method of obtaining the correct parameters of feet (Telfer, 2023). Structured light scanners are used by clinicians in the industry and are suitable for many applications, not just on the feet (Telfer, 2023). However, industry-standard three-dimensional scanners can vary in size and cost (Telfer, 2023). Additional research into the access to equipment for people in remote areas will be explored in Section Two of the report.

Photogrammetry and Foot orthoses

Photogrammetry is a three-dimensional modelling software that uses imaging technology to create three-dimensional digital models from two-dimensional images (Linder, 2016). The software is simple to use and readily available on any smart device (Telfer, 2023). Photogrammetry software shows excellent success and opportunity in creating three-dimensional human reconstruction (Struck et al., 2019). Most recent literature shows an emergence of the application of photogrammetry software to foot orthotics. The most recent works explore the advantages of Photogrammetry alongside additive manufacturing technologies for orthotic devices (Ravi et al., 2021). Concerning the scanning procedure and manufacturing process of foot orthotics, Photogrammetry provides a noninvasive, simple, and quicker experience for users and patients (Ravi et al., 2021) (Pico et al., 2022).

No prevalent examples or exploration into photogrammetry equipment suitable for foot orthoses exist. Recent studies into applying Photogrammetry for scanning feet conducted research by simply holding multiple phones and moving in a specified path while taking pictures (Ravi et al., 2021) (Starck et al., 2022). In summary, the review covered themes of accessibility and the condition of scanning technology and its application to foot orthotics. Further research into photogrammetry rigs and other considerations about the project will be explored in the rest of the report.

SECTION TWO

RESEARCH

In this report, primary research was required in order to provide further understanding and insight into Photogrammetry with foot orthoses and into other needs and considerations for the design ideation. In order to gain this information, qualitative research was planned for over two weeks and conducted over two days.

Qualitative research aimed to explore the manual scanning process of foot orthotics in remote areas. The experiments will investigate the scanning process and the aspects/ capability of the technology, Photogrammetry, concerning foot orthoses. The aim is to learn more about the potential users, patients with foot ailments, and how to ensure success/accuracy with the technology. The experiments will consist of semi-structured interviews and structured observations. To conduct the research methods, the participants were experts already part of the leading project being orchestrated by QUT. For consistency, the participants were a part of the interviews and present for the observations.

Research structure

Below is a representation of the research workflow.

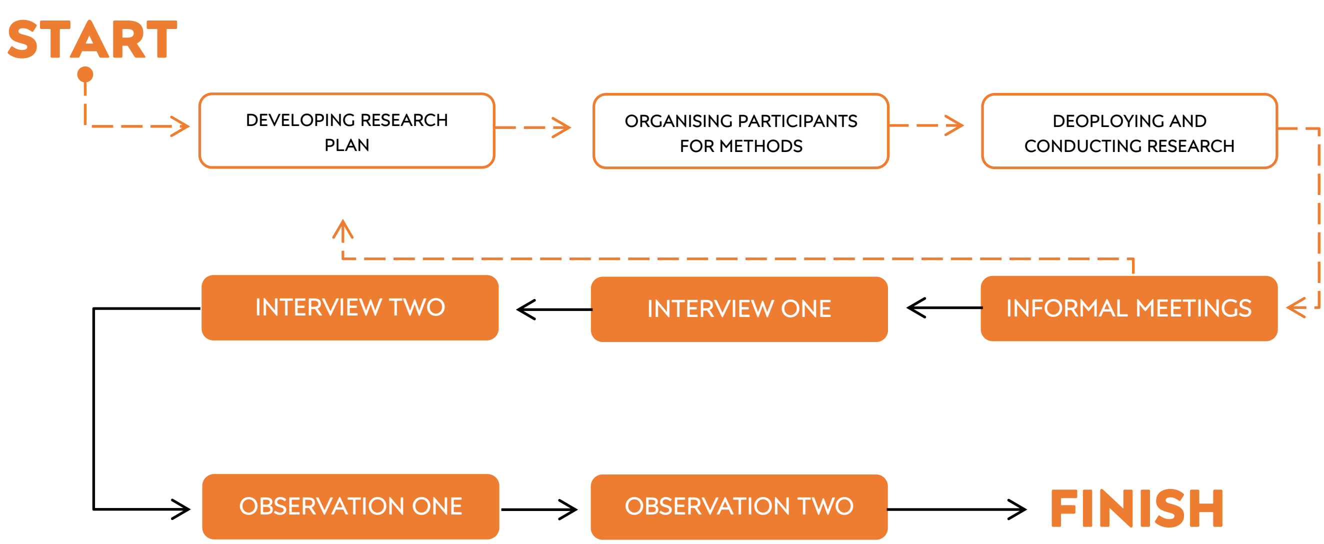


Figure 2: Diagram of research structure

Informal meetings

Before the research was conducted, there were informal meetings with Professor Marianella Chamorro-Koc and the research scientists involved in the project. These informal meetings were for introductions and greetings to the team, explanation of the project and or organization or participation in the research methods. The information from the meetings was not included in the research data analysis. However, evidence of their knowledge is present in the questions asked in the interviews.

Interviews

The semi-structured interviews were conducted over ZOOM for a maximum of thirty minutes. The interviewees were asked at least eighteen questions and any additional follow-up questions based on responses. Two experts were interviewed and mainly asked similar questions for consistency. Questions were changed depending on the interviewee's experience and knowledge of this topic. For instance, the participant for the second interview did not have prior experience with photogrammetry software. Thus, questions were altered for a more informative interview session. Participants will remain anonymous for the report.

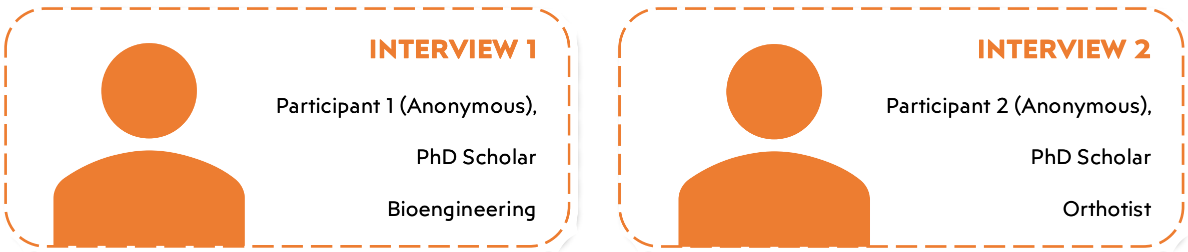


Figure 3: Participants information

The questions focused on better understanding the project direction, understanding and developing the criteria needed for implementing the proposed design concept (supp t device) and finding any other details that need to be considered about the proposed concept.

The main focus and considerations of the questions below are:

- Photogrammetry Software and its application to foot orthotics.
- Experience and criteria of photogrammetry rigs.
- Existing patient scanning experience.
- Design consideration and opportunities to consider for design implications.

Example:

> *"What are the parts of the foot that need scanning for orthotic purposes? Are there areas that need to be accurately scanned? "*

Observations

The observations consisted of two back-to-back sessions demonstrating the scanning process required to collect the data for orthotic devices. The two observations were different, demonstrating the scanning process with a standard three-dimensional laser scanner (Artec Leo). The second observation showcased the process of photogrammetry technology usage for foot orthotics. The observation was conducted in the empty medical room at the Centre for Children's Health Research and was filmed over video. The participants in the interview were present for the observations, and an additional two unknown participants were present for viewing and participation in the demonstration.

Figure 5: Still of first observation (Standard scanner).

Figure 4: Standard scanner in first observation (Artec Leo)

Figure 6: Standard scanner in first observation (Artec Leo)

The observations were chosen as a research method in order to understand and implement a design concept that can be used by the target audience (laypeople) accurately in remote areas of Australia. The effectiveness of a current popular standard of 3D scanning was explored to understand the standard of accuracy and comparison in technology.

Limitations

A limitation of this research is that only qualitative research was conducted on this research topic. Based on the methodology for the primary research, the methods were chosen to collect insightful and big-picture information on the research topic. Another limitation of the primary research was that people in remote and regional areas did not participate. Instead, expert perspectives were investigated due to their experience and availability. Consent was given in person, and forms were emailed to participants. However, signed forms have not been sent back.

ANALYSIS & FINDINGS

In this part of section two of the report, the findings/results from the primary research conducted earlier will be analyzed using Thematic analysis as required.

Interviews

The dictate function on Microsoft Word was used for the interviews to transcribe the audio material (Microsoft, n.d). However, to identify the key themes and relationships of data, the qualitative analytical free software ATLAST.ti was utilized (ATLAST.ti, 2023). Even though the free analytical software provides AI coding, the transcript from the interview audio was manually coded using the software functions. The software was also used for visualization tools provided on the site (Sankey Chart).

The coding system of the qualitative data consisted of themes and sub-themes. A full table of the thematic analysis is shown in the appendices. Across the two interviews, seven overarching themes were made and a total of 26 sub-themes. The themes are accessibility, audience/user, medical services, motivation, scanning procedure, technology, and design considerations. Overall, in both interviews, the most referenced theme was technology. Most data under the theme 'technology' focused on technology's limitations and current performance in the orthotics industry and Photogrammetry. The following analysis of the interviews will investigate critical areas of concern and identify insights that inform the design ideation of the project.

Relationship of key themes across the two interviews

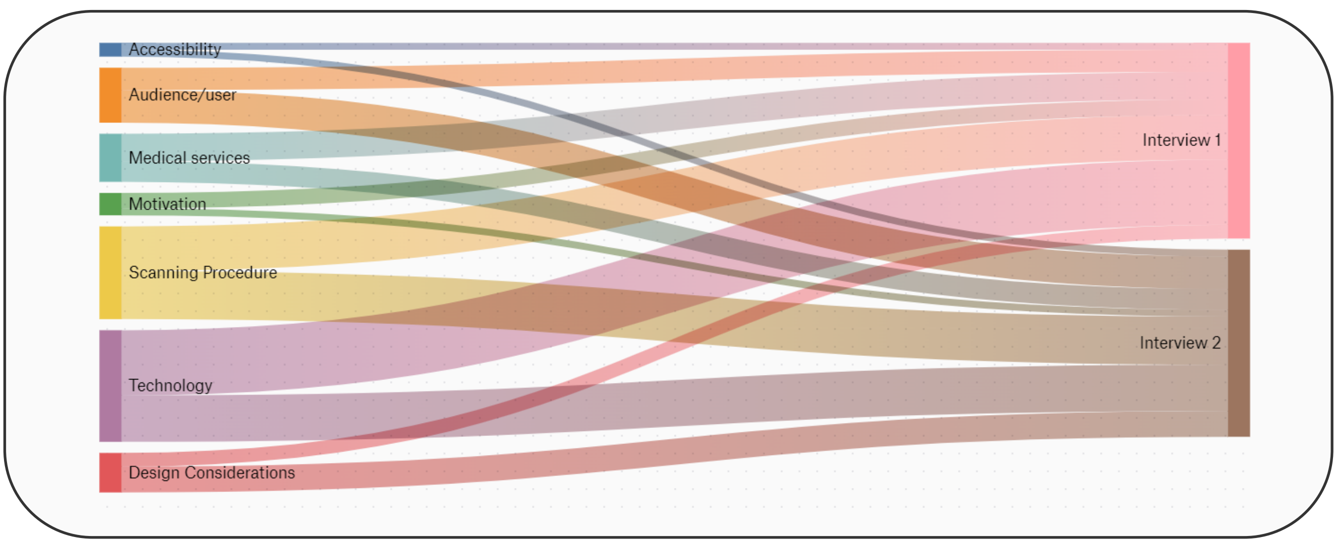


Figure 7: Mentions of themes across the two interviews

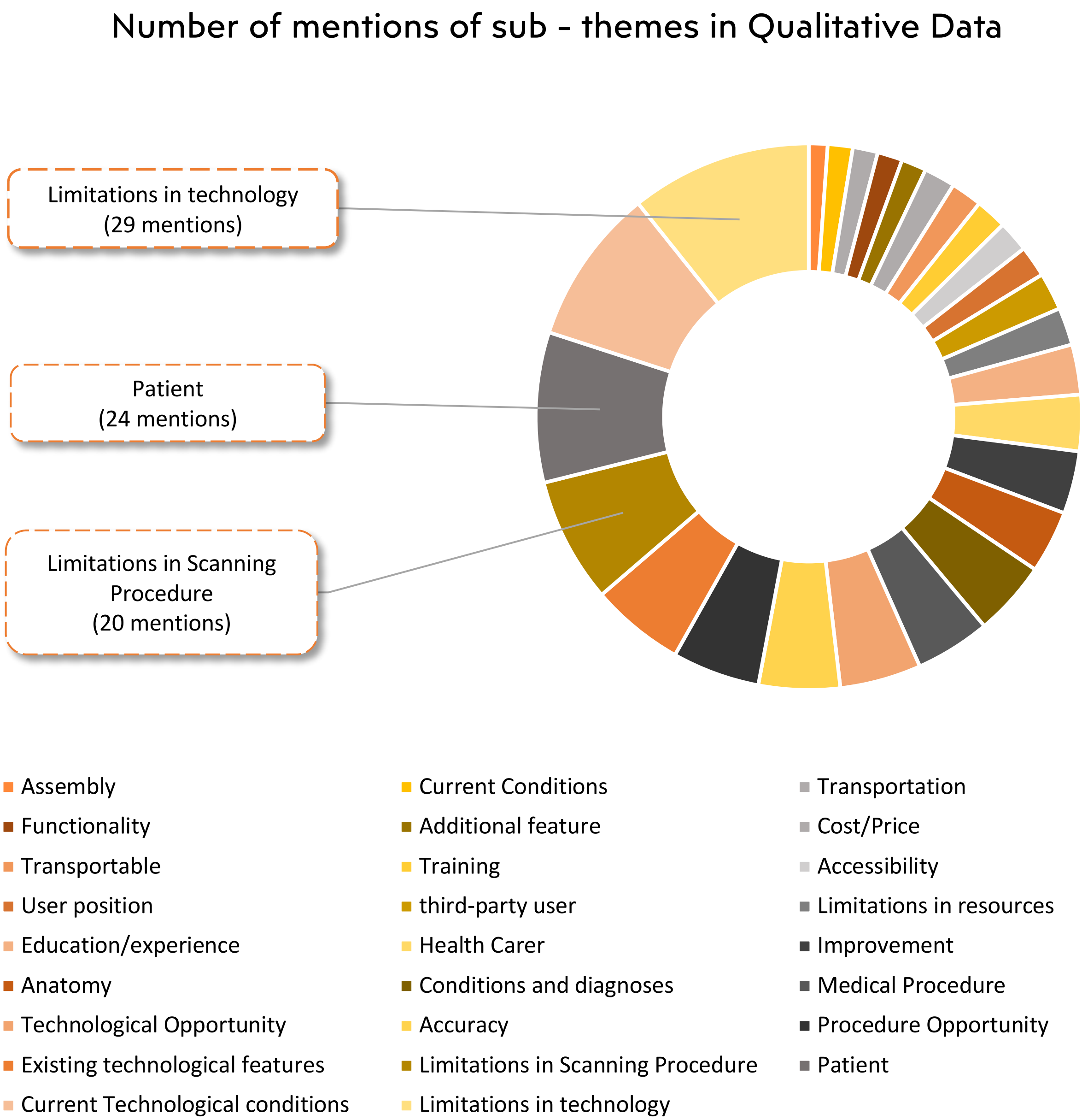


Figure 8: Doughnut chart of prevalent sub-themes of qualitative data

Limitations Of Technology And Scanning Procedure

The findings in the analysis suggest that many factors affect the digital models of orthotic devices. Many phrases in the interviews addressed barriers to using Photogrammetry and industry-level scanners on patients. The quotes relating to the themes of limitations in technology and scanning procedures were often examples of frustrating experiences with patients and mentions of the criteria for using technology.

The main challenges mentioned by participants when scanning individuals for orthotic devices were:

- Movement in patients whilst in position
- Busy and uncontrollable environments for scanning
- The patient's Inability to maintain a still position
- Poor camera operation and quality.
- Required experience and education in scanning.

Example

> *"The really difficult thing in Photogrammetry is if the background changes. It has a hard time relating multiple photos together. So, for example, if you're starting to take photos and a dog is running through, the dog appears in different positions in different photos." - Interview 1*

These key theme insights demonstrate the importance of eliminating human error in scanning. The responses iterated that to ensure a successful reconstructed three-dimensional digital model, Photogrammetry requires high-quality images.

When asked about photogrammetry rigs, participants showed a lack of experience and usage with this equipment.

Patient Education and Retention

Themes of education and patient retention were highly mentioned in the interviews. Retention amongst patients was an area of concern as the participants were worried about the level of effort and responsibility patients would exhibit for self-assembly of the design concept. The need and consideration of patient training for the scanning procedure was also an area of concern. The participants found that non-technical people might fail in their scanning process if unfamiliar with orthotic literacy or Photogrammetry. Ensuring accuracy and successful digital models in scanning might be hard for patients or unskilled health practitioners.

Accessibility

Even though it was one of the least mentioned sub-themes, the accessibility of orthotic treatment to remote areas was brought up in the interviews. Participants outlined the importance of treating people in remote areas. Participants also mentioned the importance of affordability and portability for remote treatment in orthotics. Existing scanners in the industry were described by participants as expensive and more suitable for expert use.

Example:

> *"Podiatry services in these regions are quite sparse, and people have to travel great distances and spend a lot of time and money to get to Podiatry clinics to be prescribed patient-specific orthotic footwear." - Interview 1*

Observations

To analyze the data collected from the observations. The video data was annotated to create a coding scheme of the essential temporal events. The data was put into a sequence, and this visualization of the data can be seen in the appendices.

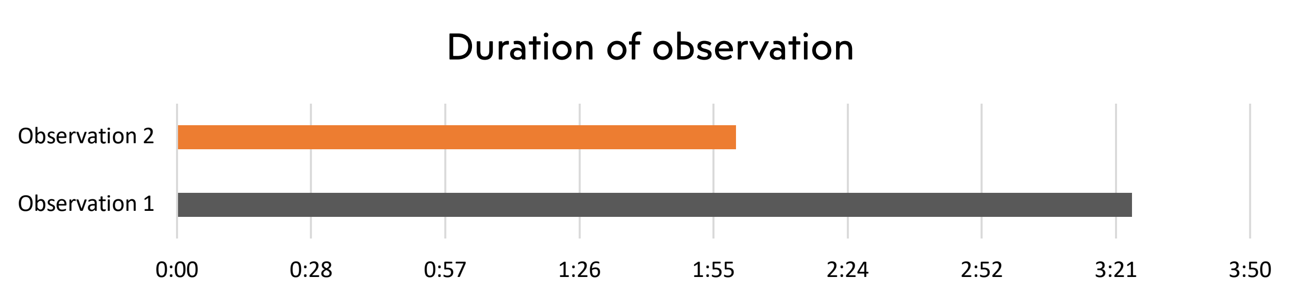


Figure 9: Comparison of the duration of the two different scanning processes

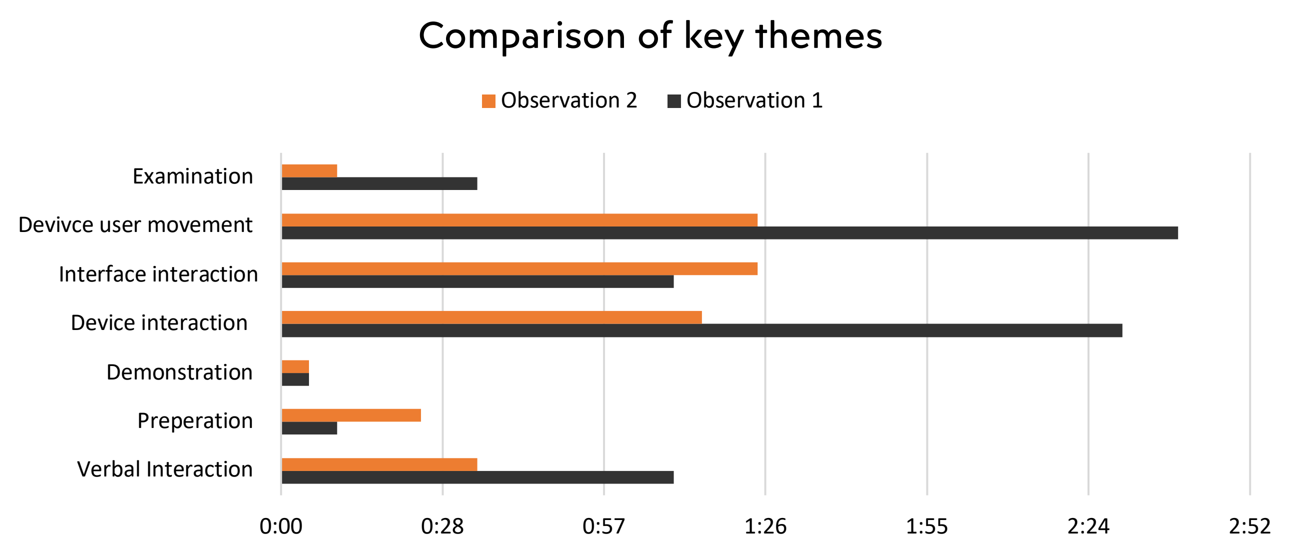


Figure 10: Comparison of the time taken for each temporal event.

The duration of the scanning process with the Artec Leo is nearly double in length. The scanning process for the second observation (Photogrammetry) was shorter and quicker and only consisted of taking pictures of the patient's feet.

Based on the analysis of the temporal events in both observations. The scanning process of Photogrammetry required less movement, examination and interaction with the phone to take pictures. It was also observed in the second observation that numerous pictures were taken at every angle of the feet. Pictures were taken every 2 seconds where participants using the phone would create a dome around the other participants' feet.

In summary, qualitative research looked at the key themes of the interviews and the key moments and efficiency of the scanning process.

SECTION THREE

DISCUSSION

The literature review in section 1 supported most primary research conducted in the report. Through semi-structured interviews and structured observations, further insight into the research topic was explored in depth. It was identified in the review that people in remote areas of Australia do not have adequate access to healthcare services (AWIH, 2022). Contrastingly, the previous study highlighted the success of digital remote access to health care in remote areas for orthotics (Dillon et al., 2023). Telehealth is a validated system that helps improve the treatment and access to health in remote areas.

Studies mentioned the need for helpful communication and health literacy when using Telehealth (Dillon et al., 2023). Participants in primary research mentioned the concern for patient education and retention. This project aimed to implement a system where a non-technical user can manually scan and send models of their foot and receive the orthotic devices to their remote location. Thus, keeping people in remote areas informed and connected to the necessary health services is essential.

Through primary research, further exploration into photogrammetry rigs was needed. Unfortunately, participants involved in the interviews lacked experience in this topic. However, the themes from the interview provided insight into the criteria for the successful use of images for photogrammetry software. For example, the themes relating to the limitations of technology identified the issue of human error and the camera's performance.

Furthermore, recent literature alongside primary research demonstrates the necessity of improving access to care in remote areas and assisting individuals in need.

DESIGN IMPLICATIONS + INITIAL CONCEPT SKETCHES

In this part of the report, sketches and design implications will be discussed. As the introduction mentions, this report follows a scientifically-led project with a proposed design concept. It was proposed that the project focus on designing a rig or support equipment that would ensure accuracy and adhere to the needs for successful three-dimensional reconstruction using photogrammetry software.

Opportunities

Eliminating human error

Primary and secondary research identified that human error, such as shaking and camera movement, affects the quality of the images. The quality of the camera limits Photogrammetry, and designing for the stability and easy usability of the concepts will benefit users in remote areas.

Interfaces and information

Patient education and training were mentioned as a concern for potential users in remote areas. Interfaces or online systems would provide easy storage and ready information for people in remote areas. A system that allows the patient to track and monitor the surface condition of their feet could also benefit outside practitioners or health careers for treatment.

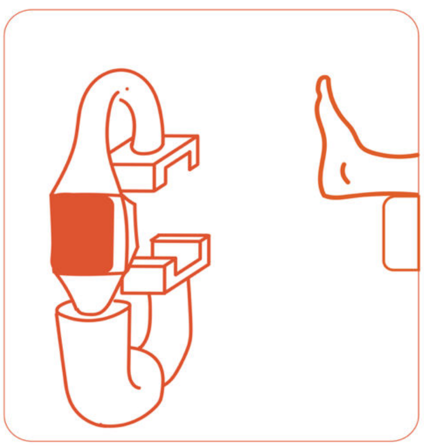
Easy assembly and portability

It was proposed that people in remote areas would have the design concept delivered and operated by them or third-party supporters who could assist with scanning photogrammetry software. Thus, the design must be easy to assemble and transport.

Initial concepts

Sketches of initial concepts were developed from the opportunities identified above and shown below. The device was introduced at the start of the project, and most of the concepts incorporate some similarities. Most of the designs address portability as a hand-held device. Additional screens, buttons and voice interfaces were introduced to store data from the scans or help with picture-taking (instructions).

Claw: Concept 1



Eliminating human error

Clasps the external device for stability and to limit shaking

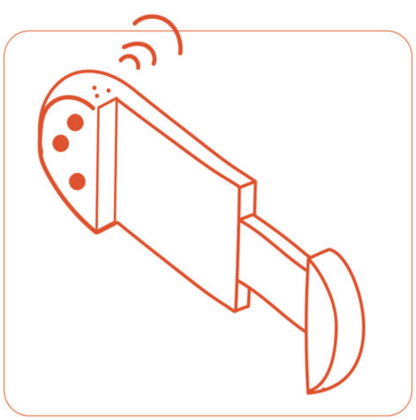
Interfaces and information

Connects to an interface that helps with the positioning, and quality of the pictures being taken.

Easy assembly and portability.

Hand-held device, that can bend for adjustability to an external device.

Grasp: Concept 2



Eliminating human error

The external device would be placed in the design, with the edges securing the device with a retractable extension.

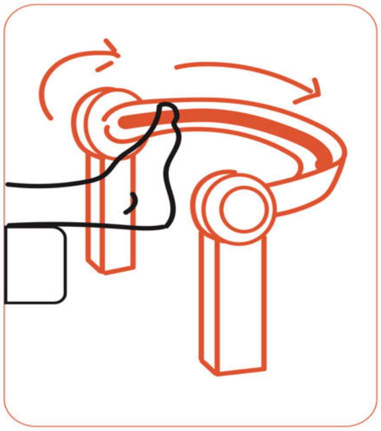
Interfaces and information

Buttons on the edge would help with taking the pictures. To help with taking the best pictures and needed pictures from all angles, and audio is played out with instructions.

Easy assembly and portability.

Would not require assembly from the end user.

Dome: Concept 3



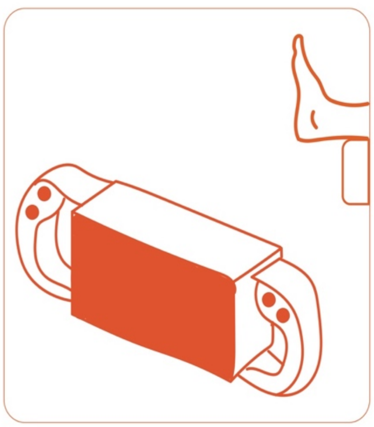
Eliminating human error

Attach the phone to the belt, and it will take the pictures for you buy connecting to the device on its own. The belt shifts the external device back and forth around the feet one at a time. The belt also rotates up and down. The device moves on its own and timed on its own to ensure quality pictures at every angle.

Easy assembly and portability.

Foldable and wouldn't need at assembly from the end users.

Grip: Concept 4



Eliminating human error

Attach the phone to the design to back of the device. The end user grips the handles and users the buttons to navigate the focus and interface.

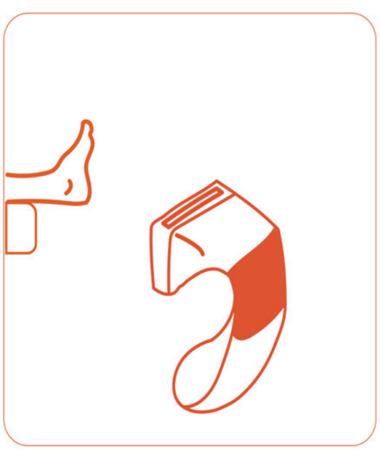
Interfaces and information

A second interface covers the phone screen from the other side, the interface helps with storage of images and relevant details of the patient.

Easy assembly and portability.

Handheld device that wouldn't need assemblage from user but would require average size of smartphone.

Holder: Concept 5



Eliminating human error

The external device is held in one hand, and the phone is placed in the slot at the top.

Interfaces and information

The phone device would be placed in the design and held upright in the slot. The interface on the front of the handle will help with the focus, and stability of the pictures. Also, the storage of the images.

Easy assembly and portability.

Handheld and travel size, doesn't require external assemblage.

CONCLUSION

In conclusion, this report explored the implementation of three-dimensional imaging software for people needing orthotic purposes. Through research on the existing literature and primary data, analysis was conducted and found supporting data on the need to treat and provide care to people living in remote places. Research into this topic revealed the many possibilities and opportunities for design. Many initial concept designs are portable, affordable and easy to use. Many technologies, such as sound and user screen interfaces, were incorporated to eliminate human error and store important information for the patient.

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APPENDICES

Thematic analysis table for section 2:

Themes	Sub-themes	Examples
Motivation	Improvement	"The motivation behind this is that we can improve medical services in rural and remote regions." - Interview 1
	Current Conditions	"Podiatry services in these regions are quite sparse, and people have to travel great distances and spend a lot of time and money to get to Podiatry clinics to be prescribed patient-specific orthotic footwear." - Interview 1
Technology	Current Technological conditions	"So arctec is. All that is not that big. It's a hand-held scanner. It is not that big, but the weight is there." - Interview 2
	Limitations in technology	"The really difficult thing in Photogrammetry is if the background changes. It has a hard time relating multiple photos together. So, for example, if you're starting to take photos and a dog is running through, the dog appears in different positions in different photos." - Interview 1
	Technological Opportunity	"Regular, frequent visits to the clinic, which is nearly impossible for the rural people because it is like you can estimate 100 kilometres for a clinic, so it's hard for them to travel. So if they get one thing designed for themselves and they reach the clinic, they try it on, it might not fit." - Interview 2
	Existing technological features	"I do like white light. 3D scanning that equipment is nice. Because it captures everything in real-time, you can see what part of the object you have not captured yet and go over it again. It has a tracking system, so it tries to put all the frames together in context. It is also scaled." - Interview 1
Accessibility	Transportation	"Well, the important is definitely because we are so far from the catchment areas of clinics. So, the primary reason is that for designing an orthotics." - Interview 2
	Cost/Price	"The only thing is that the equipment is expensive and it is heavy." - Interview 1
Audience/user	Patient	"Didn't work so well because they were not able to see their feet." - Interview 2
	third-party user	"Place certain extra devices like something that holds at the heel like a cup where they can place their foot, and then we scan them. But then we have to erase that part. So it erases the foot geometry as well." - Interview 2
	Health Carer	"You can't just tell anyone to use the scanner alone. You need a clinician or a podiatrist or a trained person to use it." - Interview 2
Medical services	Conditions and diagnoses	"But essentially anything that requires monitoring of the skin surface or external shape." - Interview 1
	Medical Procedure	"It's difficult to design for the designer the height of the arch; it's always a problem, and if you take it in weight bearing, if the person is flat, you have to decide yourself how much raise in the arch you are going to give" - Interview 2
	Limitations in resources	"Transferred from the patient's phone to like the research facility or the Podiatry clinic or whatever, whoever is doing the reconstructions, they need to have like secure storage for patient data and many times clinics are not equipped to save this amount of photo data."
Scanning Procedure	Accuracy	"That gives you the ability to measure the angle between the lower leg and the foot, and that's quite important for foot alignment. So they may choose to increase or decrease arch support based on this angle." - Interview 1
	Education/experience	"I think this is where the like the patient education comes in. So there is a very structured way to take photos and Photogrammetry and." -Interview 1
	Procedure Opportunity	"But it might not be easy for people with conditions to maintain that strength. However, this is the easiest out of all those three where the foot is free. And you can just grab the scanner and. Just take the scan, and even for Photogrammetry, I think it will be easy if the foot is free, so you can just go like." - Interview 2
	Limitations in Scanning Procedure	"So it becomes challenging, and we have to interfere in the scanning process, maybe hold our hands or tell them. Like, maybe buy some any other assistance like a stick or something?" - Interview 2
	Anatomy	"The most important part of the foot that we want to scan is the plantar surface, which is the bottom like the sole." - Interview 1
Design Considerations	Transportable	"I would expect that the podiatrist, when they decide they need a particular device, we would send them the kit. Yeah, potentially. We would like to have them, like have stock of it or something in the clinics." - Interview 1
	Functionality	"It has to be cheap, and it has to be easily portable, like transportable, and it has to be easy to use." - Interview 1
	Additional feature	"If there is something which can dictate, dictate them to maintain the foot position for." - Interview 2
	Training	"So it could be difficult for people at home to understand what is required in the photos and in what manner they should be taken so that you get a good 3D model out of it." - Interview 1 I think patients should be made aware that their background needs to be at least still if it's less busy like you know, just like a, it's probably easier for the foot, right? You can tell them to keep it near the floor." - Interview 1
	Accessibility	"There will be no travelling at all, no cost spent on travel. The purpose is to send them the insoles or the foot orthotics at their home so we can we can just." - Interview 2
	Assembly	"Much they're willing to assemble it and use it. Because you know everyone uses it differently" - Interview 2
	User position	"They might not be able to sit properly, and so it will affect the position of the foot." - Interview 2

Sequence of first observation

Time (seconds)	Verbal Interaction	Preparation	Demonstration	Device interaction	Interface interaction	Device user movement	Examination
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Sequence of the second observation

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