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MONASH
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Monash Partners
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INNOVATORS

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Executive Summary

Gait analysis is an integral tool in the identification and selection of a therapeutic intervention for abnormal (pathological) gait. This importance is emphasised by Skaggs et al., who notes that 52-92% of pediatric patients who underwent gait analysis altered the initial surgical decision [1].

Pathological gait has 9 basic categories, hemiplegic, spastic diplegic, neuropathic, myopathic, Parkinsonian, choreiform, ataxic (cerebellar) and sensory [2]. During the gait analysis process, clinicians observe the patient and collect 3D motion capture, electromyography and force plate data (Clinician interview). This data informs the patients' pathology, their gait cycle events (i.e. heel strike and toe off) and a therapeutic intervention [1,3]. For most pathologies, extracting gait cycle events is automatic [3].

For patients that exhibit foot drop and subsequent toe drag or use assistive walkers, however, force plate measurements may be confounded [3,4], thus increasing the clinician time required to classify gait cycle events, also reducing analysis reliability and repeatability and introducing human subjectivity (Clinician interview). Our aim in this project is thus to develop a solution to improve the time requirement, reliability, and repeatability of gait cycle event detection for patients with pathological gait exhibiting toe drag.

Objectives

- Supports the accurate selection of therapeutic interventions for patients with pathological gait where force plate data is unavailable or unreliable
- Reduces the amount of time required for clinicians to identify gait cycle events
- Reduces the cost of gait analysis by reducing clinician workload
- Reduces human subjectivity in clinical gait analysis via the application of a standardised gait analysis procedure.
- Is more accurate than existing algorithmic solutions in the detection of gait cycle events for pathological gait exhibiting toe drag

Gaps Analysis, Process Diagram

Table 1: Descriptions of existing solutions and their gaps against the clinical need

Solution	1. How and why 2. Solution alignment with patient interest, motivation, and capability 3. Gaps in solutions 4. Failure analysis
Manual gait cycle event detection by clinicians	1. • Allows for granular assessment and thorough visualisation of gait cycle events • Includes scope for gait cycle event timing adjustments at the clinician's discretion 2. • Informs a therapeutic intervention with accurate clinical gait analyses data 3. • 150 hours of clinician time per year could be saved at a clinic that sees only one patient per day [3]. • The time required to manually detect gait cycle events constrains the amount of data that can be analysed to inform a therapy (Clinician interview). 4. • Fails to deliver due to the clinician time required to manually detect gait cycle events [3,4] (Clinician interview).
Existing algorithm-driven gait cycle event detection	1. • Fast and autonomous detection of gait cycle events, thereby saving clinician time. 2. • Reduces data processing time compared to manual detection, thus increased amounts of trial data may be considered when selecting a therapeutic intervention. 3. • Relies upon statistical modelling and threshold filtering of kinematic and kinetic data to automatically classify gait cycle events [4,5,6,7]. • Unreliable for patients with pathological gait exhibiting severe toe drag, where certain gait cycle events are ambiguous and not always present [3]. 4. • Unreliable for patients with pathological gait exhibiting toe drag, necessitating manual data clean-up and gait cycle event detection by clinicians, thereby creating additional time cost [3].

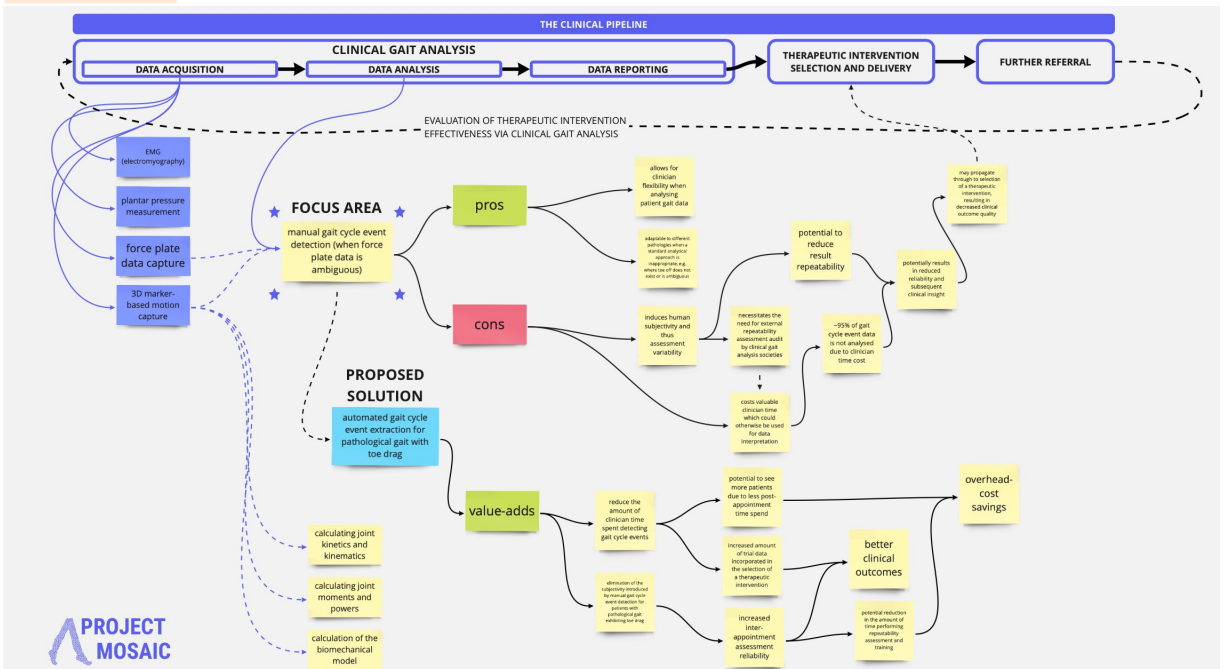


Figure 1: A systems map depicting the problem, existing solutions, and proposed solution

Stakeholder Map

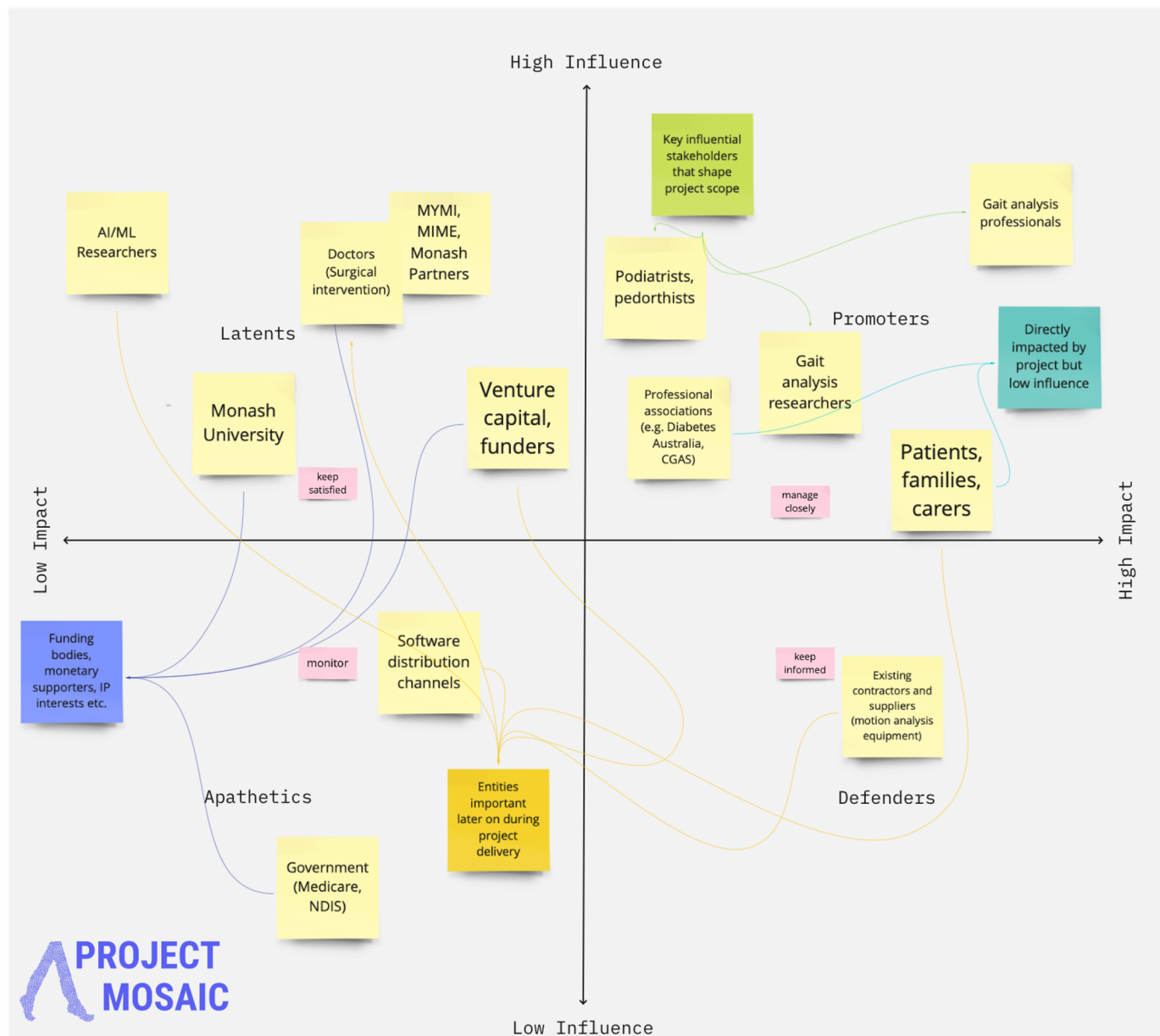


Figure 2: A stakeholder map depicting relevant project stakeholders and their impact-influence

Outcomes of Quantitative Research

Gait cycle event detection is a necessary step during the clinical gait analysis process for patients with pathological gait [8]. When patient gait is normal or near-normal, foot strike and lift-off data gathered from force plates is used to extract gait cycle events, however, for patients exhibiting toe drag, force plate data can be confounded or unreliable due to gait cycle event ambiguity [3,4].

Extracting gait cycle events from patients with pathological gait exhibiting toe drag thus requires manual clinician input, representing a wastage of time that could otherwise be used for more valuable tasks. This amounts to 150 hours of engineering time per year if the lab only sees one patient per day [3]. The Oxford Gait lab sees approximately one patient a day requiring manual gait event detection (Conversation, December 2021), and the Kingston Centre Monash Health Gait Lab sees 4 of these patients a week (Conversation, November 2021). In a Clinician interview (December 2021), this time spent manually detecting gait cycle events has been termed a “monkey task”, and represents valuable time that could be otherwise spent analysing more data, or conducting other value-adding activities [3,4].

Currently, only 1/6 of captured gait cycle event data for each patient is used to generate a gait analysis report which subsequently informs a therapeutic intervention (Conversation, December 2021) [3]. Each trial consists of over 6 steps, however only 1 or 2 steps are analysed. As each patient requires 3 to 4 hours of clinician time for data acquisition, increasing the amount of gait cycle event data utilisation would increase the value of captured data, whilst also potentially informing a more accurate therapeutic solution.

In addition, gait analysis laboratories spend a “a lot of effort” ensuring measurement repeatability and reliability, in addition to ensuring compliance with measurement standards set forth by national clinical gait analysis societies (Conversation, December 2021). This time investment represents an operational overhead that has the potential to be significantly reduced.

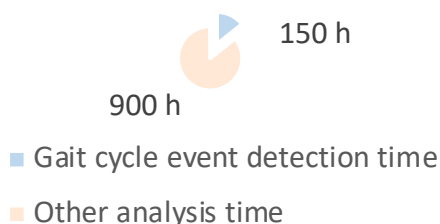


Figure 3: The constituent durations of the data analysis process

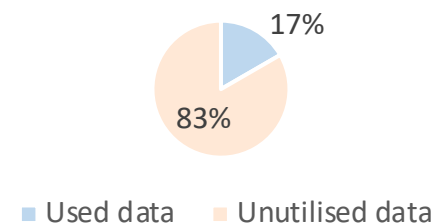


Figure 4: The amount of unutilised and utilised data

Outcomes of Qualitative Research

Clinical gait analysis laboratories assess a variety of patient pathologies, however, stroke, multiple sclerosis and cerebral palsy patients represent the predominant cohort of patients who exhibit foot drop and toe drag [9].

In 2020, 27,428 Australians were diagnosed with stroke for the first time. Additionally, more than 445,087 Australians live with the effects of stroke [10], more than 25,600 Australians live with multiple sclerosis as of 2017 [11], and approximately 34,000 Australians have cerebral palsy. Each of these pathologies may influence a person's mobility and stability, and in 2018, contributed to a combined national healthcare burden of approximately 5 disability-adjusted life years (DALY) per 1,000 population, or approximately 135,000 DALY in total [12].

Patients with these pathologies are commonly referred to clinical gait analysis laboratories by clinicians (orthopaedic surgeons, physical therapists, physiotherapists, podiatrists, pedorthists, etc.) in order to inform a therapeutic intervention with quantitative clinical data. Evidence suggests that gait analysis alters treatment plans for post-stroke patients and surgical decision-making for children with cerebral palsy [13,14], and that preoperative gait analysis improves surgical outcomes for cerebral palsy patients [15].

In Australia, about 42 organisations and research institutions participate in gait and biomechanical analysis activities [16], representing a sizeable userbase for the implementation of an automated solution for the detection of gait cycle events in patients exhibiting foot drag. Interviewed clinicians have expressed that these patients remain a challenge, and that manual event detection is still conducted with a similar approach to 15 years ago [clinician interview]. There is thus a demonstrable need for an automated gait cycle event detection system for patients with pathological gait exhibiting toe drag.

Business Model, Market Analysis

Patients with pathological gait exhibiting toe drag represent a significant cohort for gait analysis clinics that see a higher proportion of stroke patients. Manually detecting gait cycle events for this cohort represents a clinician time-sink, whilst also reducing the amount of data that can be feasibly analysed and subsequently incorporated into clinical reporting and therapeutic decision-making.

Across Australia, clinicians from gait analysis laboratories commonly express that manual gait cycle event detection represents an opportunity for automation, representing not only a clinician time saving, but also a quality-of-life improvement.

According to the Monash Health Kingston Centre Clinical Gait Analysis Service (Conversation, November 2021), they hold the largest database of patient gait data in Australia, representing a sizeable unutilised opportunity for the development of a machine learning tool without requiring the large developmental cost usually associated with externally acquiring a suitable dataset. Ergo, by using the existing Monash Health dataset thus mitigating the large capital expenditure required for development of a machine learning tool, a low-development cost, high-return subscription model could be deployed to maximise return on capital expenditure.

In addition, due to the utilisation of the Monash Health gait dataset in the development of a machine learning model, Monash Health would maintain majority or total ownership of any such outputs generated from its' dataset.

An automated tool for the detection of gait cycle events for patients with pathological gait exhibiting toe drag would annotate the .C3D files output by the existing software in use by clinical gait analysis laboratories (e.g. VICON Nexus, Polygon). Minimal clinician training would thus be required to utilise such a tool, as such a solution would integrate seamlessly into existing workflows.

AI tools in clinical gait analysis have been researched within an academic context, however no commercial solutions currently exist. By developing a machine learning model using the largest dataset of clinical gait analysis data in Australia, a potential solution would have the capability to have enhanced specificity, sensitivity, reliability, and repeatability in comparison against existing algorithm-driven solutions and manual gait cycle event detection by human operators.

Our Team



Avinash Tatsat



Patrick Gu



Nikolaos Darras

Avinash Tatsat:

I am in my final year of studying Chemical Engineering and Pharmaceutical science. I have a very keen interest in engineering with therapeutic or biotechnological applications and pursuing this interest has led me to develop a strong practical foundation in research and development. Alongside this, I have experience managing teams and finances through my role as Treasurer of the Monash Parkville Student Union. When I have time, I love going camping/hiking (absolutely adore Wilson's Prom) and seeing live music!

Nikolaos Darras:

An expert in Motion Analysis, acquiring and interpreting research data and results, running analyses and tests using specified and agreed techniques and models, and sharing information and knowledge by conducting presentations at conferences and seminars around the world.

Patrick Gu:

I'm heading into my fourth year of ECSE Engineering and Biomedical Science, and am excited to bring my technical background into a project at the intersection of engineering and healthcare. Additionally, I have extensive experience with working in and managing teams as the 2021 MYMI Compliance Director, in addition to my stakeholder management experience from working within management consulting projects. I love running and swimming, and am also an avid classical pianist.

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