Automated rearfoot angle tracking on video images

Project plan

Bachelor's degree in Applied Computer Science
field of AI development

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1 INTRODUCTION

This document serves as a project plan for the internship assignment titled *automated rearfoot angle tracking on video images*. The internship is being completed by Matej Buršík, a bachelor's degree student in Applied Computer Science specializing in Artificial Intelligence development.

The purpose of the project plan is to provide a structured outline of the internship goals, the technical approach to the assignment, and the timeline for its completion. The assignment focuses on the development of a proof-of-concept workflow utilizing computer vision and artificial intelligence, with the potential extension to create a test application based of the workflow.

The internship is conducted at Materialise Motion, a company with expertise in biomechanical technology solutions with focus on software development and 3D printing technologies. Throughout the thirteen-week internship period, the assignment should be completed with a handover of the project and documentation at the end.

1.1 Company background

Materialise Motion is a division of Materialise, a company known for its pioneering work in 3D printing and digital manufacturing. Materialise Motion specializes in creating innovative solutions for footwear and orthotics, with a strong focus on custom shoe inserts. The main office of Materialise is located in Leuven but the Materialise Motion office is located in Paal. Materialise has 2437 employees across all of this divisions.

Materialise Motion expertise lies in combining advanced biomechanics with cutting-edge 3D printing technology. One of their standout products is the Phits 3D-printed orthotics, which are tailored to each individual's unique movement patterns. Using dynamic pressure plate analysis, Materialise Motion captures data on how a person walks or runs. This data is then used to design and produce lightweight, durable, and highly customized shoe inserts that provide optimal support and comfort. (*Phits Custom 3D-Printed Orthotics* | *Patients Information*, n.d.)

Materialise Motion is working on revolutionizing the field of orthotics by offering a sustainable and highly customized alternative to traditional methods, often even outperforming them.

The assignment for this internship is done within the research and development department of Materialise Motion.

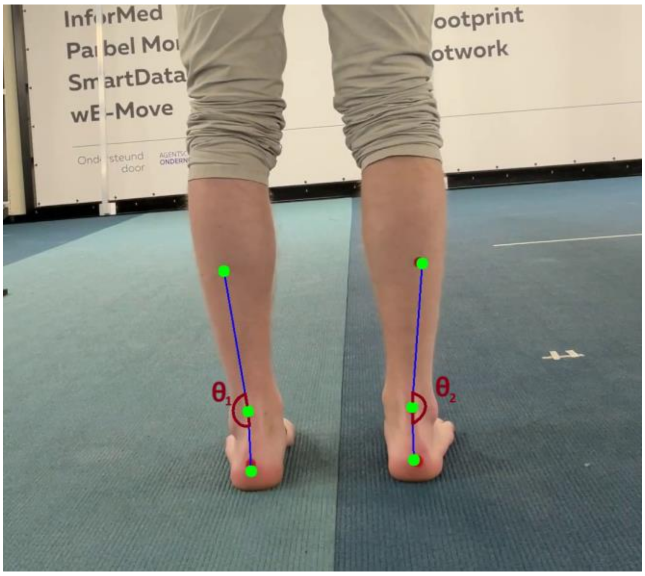
2 PROJECT ASSIGNMENT

The overall assignment can be separated into two parts. The main portion and an extension. The main part of the assignment is to research and develop a proof-of-concept workflow to extract the rearfoot angle for each leg from a video or an image. There are two additional requirements which are that the solution needs to use commercially viable tools and that it is computationally light since it is expected to run on handheld devices in the future. There are two options for the extension part of this project. Either create a simple test application implementing this workflow, or to make the workflow function without any additional markers being placed on the patient. It is expected that the main portion is finished. If there is spare time during the internship, then some work on the optional tasks would be appreciated.

2.1 What is this rearfoot angle?

The rearfoot angle refers to the angular relationship between the calcaneus (heel bone) and the lower leg. It is often used in biomechanical assessments to evaluate foot alignment and function. This angle can indicate whether the rearfoot is in a neutral, varus (inward tilt), or valgus (outward tilt) position. (*Biomechanical Assessment of Foot and Ankle*, 2010) Understanding the rearfoot angle can be used for designing custom shoe inserts that address specific foot alignment issues and enhance comfort and performance.

For the purpose of this assignment, there are three points defined on the leg between which the rearfoot angle can be measured. These points are middle of the heel, middle of the ankle, and middle of the calf. Please refer to the image below for more clarity.



2.2 Why this assignment?

At the moment, there are not many ways of measuring this angle efficiently and automatically, especially not while the patient is in motion. The aim of this proof-of-concept workflow and potential application implementation would be to allow clinicians to easily make this measurement enhancing their ability to create custom shoe inserts for patients. By making the measurement automated, we eliminate the possibility of human error and reduce the time of measuring and analysing the rearfoot angle. Since the eventual application would be on a handheld device, it removes the need for specialized equipment to perform the measurement.

This feature would eventually be part of an application that Materialise Motion already provides to clinicians to create custom shoe insert, increasing their quiver of tools. It would also create to possibility to increase the customer base from orthopaedics and custom orthotics into other medical sectors like physical therapy, and sport medicine. This could potentially be achieved by selling the feature as a separate module, making it cheaper for the customer who do not need all the features.

2.3 How will it work?

For the main version of the workflow, the clinician puts 6 markers on the patient's legs. Then they will record the patient walking. The video will get processed by the program. The program should be able to track the markers and calculate the rearfoot angle for each leg without the need of manual preprocessing of the data.

2.4 Past solutions

At the moment, radiographic evaluation is considered as a golden standard for assessing foot alignment such as rearfoot angle. (Biomechanical Assessment of Foot and Ankle, 2010) The issue with this method is that it requires expensive specialized equipment and exposes the patient to ionizing radiation. There are methods being developed that use non-ionizing radiation, but they still require expensive specialized equipment. (Trujillo-Hernández et al., 2024) Lastly, simple methods like visual assessment or using an orthopaedic goniometer are frequently considered unreliable, not objective, and need to be validated by other methods to proof a diagnosis. (Biomechanical Assessment of Foot and Ankle, 2010)

In context of Materialise Motion, one of the incentives to investigate this assignment was their customers mentioned needing to use multiple tools from different sources to work effectively and accurately. Also, this assignment was already attempted before, but the result was not commercially viable for Materialise Motion because of the licensing that the pretrained model which was used was operating under. Thanks to this situation, I was provided with a substantial amount of data which was created for that attempt.

3 PROJECT TIMELINE

The entire internship spans thirteen weeks, starting 24th of February and ending 23rd of May. During these thirteen weeks, the plan is to research, develop, and test two different approaches to solving the assignment, taking approximately five weeks pre approach. If there is time left (which there should be three weeks left) it would be interesting to develop a test application for the better workflow. At first glance this looks like a very rough timeline and that's because it is. The inherit issue with setting up a strict timeline for a research and development assignment is that there are quite a few unknows. This is because of the whole explorative approach to solving a problem.

3.1 First five weeks (24/2 – 28/3)

In the first five weeks of the project, the primary focus is on researching pretrained models that can be utilized for the use case of the assignment. Pretrained models are machine learning models that have already been trained on large datasets and can be fine-tuned for specific tasks, saving both time and computational resources. There are several requirements for the model to be considered as a viable option for the use case. Some of the feature that the company is looking for are relatively low hardware requirement to run, license allowing commercial use, and reliable prediction accuracy.

After selecting the desired pretrained model, the next step is to establish a functioning workflow. A workflow in this context refers to a structured sequence of steps that streamline the process of training, testing, and deploying the pretrained models. It this case, it involves setting up the necessary dependencies, configuring the software environment, and integrating the pretrained model into a pseudo-application. A pseudo-application is a prototype version of an application, created primarily for testing, demonstration, or proof-of-concept purposes. It mimics key functionalities of a full-fledged application but lacks full integration, scalability, or robustness.

Once a proper workflow is established, testing and evaluation starts to take place. The goal is to assess the effectiveness of both the workflow and the model's performance. This phase helps identify any potential limitations, improvements, and refinements for further stages of development. Evaluating helps to determine the most suitable approach for model development based on factors like efficiency, compatibility, and ease of integration.

3.2 Second five weeks (31/3 – 2/5)

In the second five weeks of the project, the focus shifts toward researching the best method for creating a custom model tailored to the specific use case. Unlike pretrained models, a custom model is trained from scratch or fine-tuned extensively to meet unique requirements. This involves exploring various deep learning frameworks such as PyTorch, TensorFlow, and FastAI, each offering different advantages in terms of flexibility, ease of use, and performance.

Once the appropriate framework is selected, the next step is to develop a workflow for the custom model. This workflow includes preparing training data, defining model architecture, setting up an optimization process, and configuring the training environment, on top of also deploying this custom model into a pseudo-application.

Similarly to the previous five weeks, following the workflow setup is the testing and evaluation. They are conducted to assess both the functionality of the workflow and the model's performance.

3.3 Last three weeks (5/5 – 23/5)

In the final three weeks of the project, time is allocated as buffer weeks to account for any unforeseen challenges or delays encountered during earlier stages. In research and development, unexpected issues such as technical bugs, or other problems that can arise, requiring additional time for troubleshooting and approach adjustments.

If no major setbacks occur, the focus shifts toward developing a test application that integrates the better workflow created throughout the project. A test application serves as a practical demonstration of the implemented models and workflows, allowing for real-world validation of their performance. Unlike a pseudo-application, which is primarily for experimentation and proof-of-concept testing, a test application is more structured and interactive. This step involves integrating the model into an interface, handling inputs and outputs effectively, and ensuring that the system runs efficiently under expected conditions.

By the end of this phase, the goal is to have a functional test application that not only demonstrates the feasibility of the chosen approach but also provides a foundation for further development and deployment of the application.

3.4 Project handover (19/5 – 23/5)

The final phase of the project is the handover process, where all relevant files and documentation are provided to Materialise Motion. It will take place during the last week of the internship. This step ensures that the work completed during the internship is well-documented, reproducible, and useable for future use cases.

As part of the handover, all files mentioned in the documentation section are included. This consists of the reporting document, the project plan, reflection document, and the realisation document which is an internship thesis. In addition to documentation, all actual project files are handed over. These include source code, trained models, datasets, configuration files, and any scripts used for preprocessing, training, testing, and evaluation. Ensuring that these files are well-organized and properly annotated makes it easier for others to continue the work if the company decides to continue this project.

3.4.1 Risks

When continuing development on this project, several risks should be carefully considered to ensure its long-term viability and effective implementation.

Artificial Intelligence is a rapidly developing industry, with new models and techniques frequently surpassing existing approaches. While this project employs advanced methods at the time of development, newer solutions may soon provide improved efficiency, accuracy, and performance.

Since the workflow aims to automate biomechanical assessments, it may be subject to medical regulations and ethical concerns. Ensuring compliance with industry standards and guidelines for AI-assisted medical diagnostics is crucial. Transparency in data usage, accuracy validation, and algorithmic decision-making will be important for regulatory approval. Additionally, ethical concerns such as bias in AI predictions should be systematically addressed to maintain credibility and trust.

Since the automated rearfoot angle tracking workflow is expected to become part of an already existing Materialise Motion’s clinical software, seamless integration and compatibility is important.

4 DOCUMENTATION & COMMUNICATION

In this section, the focus is to explain the documents that are linked to this internship assignment and the communication between different parties associated to the internship assignment. There are four main documents that are necessary for the internship: reporting document, project plan, reflection document and the realisation document; and there are three main parties: Materialise Motion (the company), Thomas More (the university), and Matej Buršík (the intern). In this case, the internship supervisor was Laurien Stroobants representing the university and the internship mentor was Sam Van Rossom representing the company.

4.1 Reporting document

The reporting schedule for this internship was set to a weekly format. In this format, the intern provides a day-by-day update in a document, every week outlining their assignment progress and workplace experience. It is sent to the internship supervisor and mentor every Friday.

4.2 Project plan

Currently, you are reading the project plan for this internship. The purpose of this project plan is to provide a structured outline of the internship goals, the technical approach to the assignment, and the timeline for its completion.

4.3 Realisation document

The realisation document is essentially a bachelor thesis covering the process of solving the internship assignment. It is written in a style of 5W1H which stand for Who, What, When, Where, Why, and How. This style is a writing approach that helps writers develop clear, structured, and well supported content by addressing the six fundamental questions. It is an effective tool for structuring a thesis, ensuring clarity, depth, and coherence.

4.4 Reflection document

There are two main parts the reflection document consists of. First part was the reflection on the internship project which covers to what degree was the assignment completed. Second part was the personal reflection which covers how the intern has grown during the internship, what problems they faced, and what did they learn.

4.5 Communication

At the start of the internship, there was a kick-off meeting where all three parties were present. The topic of the meeting was to clear up the internship assignment, go over some important dates, and to explain a rough timeline of the internship.

As mentioned in the Reporting document section, there is a weekly communication which connects all parties in form of a weekly report which was send out at the end of the week. Furthermore, this document was discussed on weekly, every Monday, at an Update meeting with the internship mentor. The discussion points usually revolve around last week’s report and what is the plan for the current week.

Another weekly meeting were the Research meetings, during which employees linked to research presented their updates and discussed further plans. These meetings more less resembled weekly standup meetings.

There were also two situations when the intern returns back to Thomas More campus to present general updates about the internship with focus on the documentation. The first presentation mostly covered topics like introduction to the internship assignment, and the first version of the project plan. The second presentation covered topics like progress on project plans, quick overview of the first versions of the realization document, updated timeline, and the intermediate internship evaluation.

After the end of the internship, there was a final presentation for the employees of Materialise Motion. This presentation covered basically everything that the intern has done during the internship. This would include how he approached the project, what he tried, what were the results, what are his conclusions, and a final demo of the application.

Lastly, there is Jury presentation, several weeks after the end of the internship, during which the intern presented their accomplishments during the internship as a part of their bachelor portfolio.

5 References

phits Custom 3D-Printed Orthotics | Patients Information. (n.d.). https://www.materialise.com/en/healthcare/patients/phits-custom-3d-printed-insoles

Biomechanical Assessment of Foot and Ankle. (2010). Physiopedia. https://www.physio-pedia.com/Biomechanical_Assessment_of_Foot_and_Ankle

Trujillo-Hernández, G., Flores-Fuentes, W., Ramírez-Hernández, L. R., Sergiyenko, O., Castro-Toscano, M. J., Mercado-Herrera, A., & Murrieta-Rico, F. N. *Patents of Systems and Methods Using Non-Ionizing Radiation for Measuring Rearfoot Deformations.* (2024). https://doi.org/10.3390/inventions9060122