Project Updates: Master Record

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Contents

Introduction

This master record collates weekly project updates to produce a thorough insight into progress within a single document. Each section consists of a week's update. Within each section are the following subsections and descriptions:

- **Supervision Meetings:**
  Consists of a listing in table format of the supervision meetings that have occurred since the last update, including dates, attendees, and a brief description of discussions and actionable items.
- **Actionable Items Recap:**
  Consists of a listing in table format of the actionable items from the previous week, briefly discussing the progress made and pending tasks.
- **Additional Project Updates:**
  Consists of updates that weren't 'actionable items' from the previous week, such as brief overviews of experiments conducted, data collected, and research findings.
- **Next Week's Agenda:**
  Consists of a listing in table format of the actionable items to complete before the next weekly update, including task descriptions, rough timelines, and success metrics.
- **Comments & Concerns:**
  Consists of a brief analysis of comments or observations about other aspects of the project, such as facilities, work environment, and any outside interest in the project. Furthermore, outlines any concerns about the project.

1 01-12-2023

1.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
-	*No meeting this week.*	-	-

1.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
Exand research and make notes.	• From the few gathered papers, I have read two and have made very in-depth notes/literature reviews in my project journal. • They were bubble detection papers for extracting bubble characteristics to monitor gas seepage from the ocean floor. • The papers used Canny edge detection, which is different to my starting point with Simple Blob Detection. • Using Canny as a starting point, one of the papers described using the Snake-method to extract the exact outlines of the bubbles. • Bubble tracking was outlined in the papers: by using a Kalman filter with the previous two captured frames, then by applying the new detection of bubbles, weighted matchings can take place using the Hungarian algorithm.	• From these papers, it is clear that there is a basic/overall standardised method for detecting bubbles (using Canny). This is a different path compared to what I was originally pursuing with image thresholding and blob detection. • I will try to experiment with the edge detection methodologies that were oulined in the reports I read - this should help me gauge the complexities involved and see the performance physically. • I need to read more literature - there was one that was cited by both the papers I read, and it should go into greater depth of how Canny was employed to detect bubbles. I will be reading this next.
Research histograms	*No progress on this.*	• Since the literature I'm reading focusses on Canny edge detection, there isn't any need for thresholding and blob detection, therefore I can temporarily pause the research on histograms. • Once I get a clear view on how the *standardised* method of bubble detection works, I can then compare it with blob detection, and when I get on to that I will resume the research on an automated thresholding method with histograms.

1.3 Additional Project Updates

Additional Update	Description
Obese Project Journal	• The Project Journal document is starting to get really big (currently just under 20MB) and the project hasn't even properly started yet. • It doesn't seem like a great idea having a singular file that is growing at this rate in a Git repository (GitHub has file size limits which I may quickly reach). • I explored a few tools I could use to help solve this: • LaTeX: I can separate one document into multiple files, which can be imported into a singular file to reder a PDF. But it's not quick enough to be able to jot down progress. • Markdown: Very simple and great for jotting progress quickly. But, features are sparse, you cannot import multiple files into a singular file to render, cannot easily create references/bibliography tables, etc. • Dendron: a Markdown based note-taking app that is a Visual Studio Code extension. Packed with useful features, but a nightmare to work with - not easy to use at all. • I need to figure out a better tool.

1.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Expand research and make notes.	• Read and make notes of currently gathered papers. • Expand literature research by reading related cited work. • Think about how real-time can be achieved.	• Make notes in project journal.	Friday
Experiement with Canny edge detection for bubble detection	• Best starting point is to use the paper that the two papers I read this week cited for the technicalities of how Canny can be employed. • Once I understand the technicalities, I can then experiment with bubble detection using Python, OpenCV, and the bubble test images that I had extracted/produced.	• Log progress in the Project Journal.	Friday

1.5 Comments & Concerns

No comments or concerns at the moment.

2 02-02-2024

2.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
30-01-2024	• Discussed information on the intial report - two main/overall aims have been identified: (a) a reliable backscatter detection program, and (b) real-time compliancy ensuring efficient and reliable processing and operation. • I will be visiting India from the 18th of March to the 5th of April and will return once Easter finishes. This means I will be working remotely from India during term time between the 18th to the 22nd of March.	• I need to research on exactly how the PREEMPT-RT Linux kernel patch works to implement real-time functionality. Especially with what pre-emption means in this context, and whether interpreted programs, such as Python scripts will continue to function, since programs may have to be compiled for real-time compliancy depending on the context of pre-emption. • There is a figure in this paper which shows the Canny edge detection detecting a bubble, the bubble is filled with white on a black background. How was the bubble region calculated and filled with white? A Python script can be written as a benchmark employing the basic methodologies explored in this paper. Try to retrieve some more of the metrics and statistics outlines in the paper to achieve a better understanding.	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

Continuation 1/2			
Date	Agenda	Actionable Items	Attendees
30-01-2024	• Discussed real-time aspects, Docker/Jailhouse reserves hardware on time-basis and does not manage the scheduling and priority of tasks so jitter will still be a problem. To reduce jitter, a real-time OS needs to be looked into, however, there aren't many RTOSes with Raspberry Pi support, so a real-time kernel can be explored. • Discussed literature on using basic algorithms such as Canny and the least distance rule to detect and track underwater rising bubbles for environmental analysis. Using basic algorithms and rules such as these will form the best foundation which can act as a benchmark when comparing real-time and hardwre aspects.	• I was planning to reach out to the electronics store to enquire about the ordered components after allowing a week's time if I didn't hear anything from them, however, the components arrived surprisingly fast and I've collected them.	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

Continuation 2/2			
Date	Agenda	Actionable Items	Attendees
30-01-2024	• Discussed the steps I took to get the development Raspberry Pi connected to the internet and accessible via SSH from my laptop. The uni network prevents cross-device communication, so I set up W-Fi for internet, and ethernet for SSH comms with my laptop. Easier said than done - this system took an entire evening to get working. • Ordered components on the day of the supervision meeting (new gen Pi, case and PSU for Pi, global shutter camera, HDMI cable, and USB drive to boot OS from). Components arrived on 01-02-2024.	• I need to start laying out an overall plan to how the initial report needs to be structured, I also need to plan out a schedule (with a Gantt chart for example) to create an outline of what needs to be completed and the timeframes. • Paul and Ben are happy with me working remotely from India, as long as my work output is the same quality as me working on-site, however, I do need to let the department know by emailing the Chair of the Board of Studies and my academic supervisor.	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

2.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
Expand research and make notes.	• My plan to read the paper that discusses the technical aspects of using Canny to detect bubbles has been read and reviewed. • I think I've collated enough information on bubble detection, however, all the paper's I have read on this are related to the environmental analysis of quantifying bubbles released from sea-floor gas seepages. Gas escaping and rising to the surface of the ocean is very different to the backscatter experienced when recording video from a constantly moving UUV, where debris also forms backscatter alongside bubbles.	• Since I struggled to find papers on detecting and eliminating underwater backscatter, I had to assume that bubbles form most of the backscatter, and if I can build a system that effectively detects bubbles, then I can easily expand it to detect other forms of backscatter. I should develop a benchmarks script that uses the fundamental and basic technologies such as Canny to detect bubbles and the least distance method to track bubbles. This benchmark can help test how effective the bubble detection idea works with detecting other forms of backscatter such as debris.
Compare differences between hypervisors: Jailhouse and Docker.	• I have outlined the differences between the two, use-cases of the two, and their effectiveness in reducing jitter to ensure better real-time complicance in the journal. The main idea was to use one of these tools to reserve hard resources in order to ensure that task latency is as little as possible. • Unfortunately, my research showed that these tools only reserve hardware on a time-basis and cannot isolate hardware completely, furthermore, it cannot manage the scheduling or priority of the tasks, so jitter will be unchanged.	• I need to research more into the PREEMPT-RT patch to understand how it works, its benefits, drawbacks, etc. • I can use the benchmark script (that I need to write) to compare performance differences between the real-time patched kernel and the normal kernel.

Continuation 1/1		
Actionable Item	Progress Report	Pending Tasks
Compare differences between hypervisors: Jailhouse and Docker.	• Best option is to implement an RTOS, however, there aren't many that are well documented and support the family of Raspberry Pi boards that I am using for this project, so the next best thing is to apply a real-time patch to the Linux kernel (PREEMPT-RT).	
Experiment with Canny edge detection for bubble detection	• I have started writing the Python script, taking extra care into the consideration of implementing logic to calculate real-time metrics of the script.	• I need to finish this off.

2.3 Additional Project Updates

Additional Update	Description
No additional updates	-

2.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
More research into PREEMPT-RT and reading into how the bubble region was determined and filled with white from the paper.	• I have collected some literature that should be explored.	• Log details in the project journal.	Monday
Write benchmark script.	• Use basic algorithms such as Canny, least distance method to detect and track bubbles. • Prioritise fast performance over bubble detection/tracking accuracy. • Use underwater GoPro footage provided by Ben.	• Make notes in project journal. • Commit code updates to repository.	Friday
Plan initial report.	• Create an overall plan of report layout.	• Log progress in the Project Journal. • Perhaps create a new document for this report.	Friday
Plan schedule.	• Make an initial draft of the schedule, outlined by a Gantt chart.	• Show Paul and Ben, refine until perfection.	Tuesday
Email CoBoS and academic supervisor reg. India visit.	• Send email.	• If the email has been sent or not.	Monday

2.5 Comments & Concerns

No comments or concerns at the moment.

3 03-11-2023

3.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
31/10/2023	• Pinpointing project scope/objectives. • Laying out rough schedule based on project objectives. • Getting started on pre-reading/literature review. • Discussing organisational tips/workflows. • Schedule for re-occurring meetings.	• Next meeting in person to see existing lighting system. After seeing the existing system, I can decide the avenue I'd like to pursue. • Carry out some rough preliminary research for the 4 potential objectives: improving real-time computing, underwater testing, backscatter depth perception, ML-based backscatter position tracking.	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

3.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks

No actionable points from the last weekly update.

3.3 Additional Project Updates

Additional Update	Description
Created project journal	• Created project-journal GitHub repository. • Consisting of Word doc outlining entire project progress.

3.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Preliminary research	• Read about each of the 4 objectives, make notes on the technical aspects that would be required for each in project journal.	• Make notes in project journal, discuss during the next supervision meeting.	Thursday
Next supervision meeting	• Next supervision meeting to take place on Thurs 9th Nov @ 2pm at the ISA (Paul Mitchell to send calendar invite). • As discussed in the last virtual supervision meeting, after seeing the lighting system it'll be easier to decide which avenue I want to research. • Since the next meeting is at the ISA I may get a tour of the facilities. I can learn about the tools I'll have at my disposal for this project.	• Not very easy to generate measurable success metrics for these items. • Decide on one of the 4 objectives. • Make notes on useful facilities for this project at the ISA in project journal.	Friday

3.5 Comments & Concerns

No comments or concerns at the moment.

4 08-03-2024

4.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
05-03-2024	• Initial report feedback review for first draft with Ben.	• Write second draft taking into account of the feedback.	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

4.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
• Complete initial report.	• I have completed and submitted the report.	• -

4.3 Additional Project Updates

Additional Update	Description
I have a project timeline Gantt chart set up to track project progress	Accessible from the project GitHub page (`https://github.com/Sidharth-Shanmugam-MEng-Project-2023-24`), and is called 'project-timeline' (`https://github.com/Sidharth-Shanmugam-MEng-Project-2023-24/project-timeline`)

4.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Script to record footage from RPi and Pi GS camera.	• During this week, I've been able to record in un-encoded raw format. I need to find a way to parse this data to view the footage. • If I can't get this working, then I already have a failsafe in place - logic to record with MJPEG encoding with zero lossy compression.	• Code pushed to its GitHub repository.	Tuesday
Record test footage	• With the script to record footage completed, I can then use the facilities at the ISA to record test footage.	• Footage recorded.	Thursday
Research real-time metrics and implement in backscatter cancellation software	• Need to research ways to accurately record real-time metrics in Python. • Need to research which metrics are important for this project and must implement in software.	• Code pushed to its GitHub repository (tagged V1)	Friday

4.5 Comments & Concerns

No comments or concerns at the moment.

5 08-12-2023

5.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
07-12-2023	• *Please refer to Project Journal for more details on each agenda item, due to formatting constraints, I couldn't put them in here - sorry.* • Discussed research finding. • Discussed hypervisor aspects. • Discussed real-time aspects. • Ordering components.	• Compare differences between hypervisors: Jailhouse and Docker. • Finish off reading literature on the technicalities of Canny for bubble detection.	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

5.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
Expand research and make notes.	• There's one paper that discusses the technical aspects of using Canny to detect bubbles, this will be read next.	• I need to read more literature - there was one that was cited by both the papers I read, and it should go into greater depth of how Canny was employed to detect bubbles. I will be reading this next.
Experiement with Canny edge detection for bubble detection	*No progress on this.*	• Unfortunately, I could not find time to play around with this. • I can try to get started next time, but currently prioritising the modules that are running in this semester.

5.3 Additional Project Updates

Additional Update	Description
Obese Project Journal	• No progress on this yet as I still can't find a solution that will work well. • Will make do with MS Word, maybe will look into implementing LaTeXfor next semester.

5.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Expand research and make notes.	• Read and make notes of currently gathered papers. • Expand literature research by reading related cited work. • Think about how real-time can be achieved.	• Make notes in project journal.	Friday
Compare differences between hypervisors: Jailhouse and Docker.	• I will be using one of them to increase program priority to eliminate Jitter as much as possible.	• Log progress in the Project Journal.	Friday
Experiement with Canny edge detection for bubble detection	• *Not a priority, try to make a start if possible.* • Best starting point is to use the paper that the two papers I read this week cited for the technicalities of how Canny can be employed. • Once I understand the technicalities, I can then experiment with bubble detection using Python, OpenCV, and the bubble test images that I had extracted/produced.	• Log progress in the Project Journal.	Friday

5.5 Comments & Concerns

No comments or concerns at the moment.

6 09-02-2024

6.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
Multiple points across the week with Ben and Paul separately.	• Started to run into a lot of software-related issues: originally installed Ubuntu Server OS for it's lightweight nature (space-wise and processing-wise since it doesn't come with a lot of features built in, which is perfect for reduced power consumption and fast processing time). However, the kernel does not support the Raspberry Pi products of cameras. For that, I'd need Raspberry Pi OS (there is a 'lite' version which is also very lightweight which is what I used), unfortunately, I had to rework a lot of the set-up steps due to various process incompatibilities (mainly networking-related and Pi Camera hardware-related) with RPi OS and Ubuntu OS.	• Once everything is set up, I need to write a script to record bubble footage using the Pi and Pi global shutter camera from the underwater testing facility so that I can fine-tune my benchmarking script.	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

Continuation 1/3			
Date	Agenda	Actionable Items	Attendees
	• I researched more into the theory of real-time Linux kernels with PREEMPT-RT, I realised that this kernel patch only implements real-time functionalities in the kernel logic to replace time-bound spinlocks with real-time mutexes. This 'apparently' results in a monumental reduction in general OS latency. Normal userspace tasks such as Python scripts that the user can run are usually non-real-time, however, should be more 'snappy' due to not needing to wait for kernel logic to finish before preemption.	• It is possible to write kernel-based software to harness real-time features, but it is difficult, therefore I will stick with Python and userspace code, I will compare the effects of RT with the non-RT kernel with the benchmark script.	

Continuation 2/3			
Date	Agenda	Actionable Items	Attendees
	• I have completed a basic Python script that uses the Canny edge detection algorithm to detect backscatter from the GoPro underwater footage that Ben provided. OpenCV Contour detection is used for filling the closed loop edges from the Canny output so that I can overlay black holes on a white background to drive the DLP projector to eliminate backscatter. I have added logic to track real-time metrics such as the time it takes to process each frame, etc. The test footage isn't very good since it has a lot of artifacting, this drastically reduces the Canny's performance and increases the frame processing time.	• I need to focus on perfecting Canny before working on the Contour detection logic. For this, I'd need better test footage, which is what I will be making the recording script for. After that I can look into other types of Contour detection algorithms, perhaps research into segmentation algorithms.	

Continuation 3/3			
Date	Agenda	Actionable Items	Attendees
	• I need to start work on the initial report. I have logged a lot of information in my project journal so it shouldn't be too difficult to summarise in a report.	• I will need to create a basic plan on document structure. List out section and summarise the information that will need to go in it. Bring this basic plan to the next supervision meeting and we can refine it further. Will also need to consider the tasks and timelines, can make a simple plan of the overall tasks and we can discuss breaking this down into smaller chunks and giving each an timeline. Paul mentioned to take into account of situations when things don't go to plan by adding sufficient buffers.	

6.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
More research into PREEMPT-RT and reading into how the bubble region was determined and filled with white from the paper.	• All progress complete for this item, and logged into the proejct journal. • The paper doesn't go into much detail on how the bubble region was segmented after applying Canny.	-
Write benchmark script.	• A simple script with bubble detection with Canny and segmentation with contour detection is complete, albeit very inaccurate.	• I will need to record better test footage to work with for fine-tuning the script before I can improve the bubble segmentation logic and implement bubble tracking and position predictions.
Plan initial report & plan schedule.	• No progress on this.	• Due to running to a lot of software and hardware issues, I ended up with this task in backlog. The software and hardwre problems have been mostly resolved, so I can make an effort on this next week.
Email CoBoS and academic supervisor reg. India visit.	• Done	• The department has acknowledged and approved this visit.

6.3 Additional Project Updates

Additional Update	Description
No additional updates	-

6.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Script to record footage from RPi and Pi GS camera.	• Write script, test that it works before deployment.	• Make notes in project journal if needed. • Commit code updates to GitHub repository.	Wednesday
Improve bubble segmentation performance in benchmark script	• With the better testing footage, fine-tune the Canny parameters and research into bubble segmentation.	• Log progress in the Project Journal. • Commit code updates to GitHub repository.	Friday
Plan initial report & schedule	• Summarise report sections and outline roughly what content needs to go in each.	• Log progress in the Project Journal.	Tuesday

6.5 Comments & Concerns

No comments or concerns at the moment.

7 10-11-2023

7.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
09-11-2023	• Discussed real-time software research findings. • Tour of the ISA, desk assignment. • Meetings to happen bi-weekly in person until next semester. Will be in touch with Paul & Ben with any project updates. • Discussion about hypervisors with Ben. Using Docker to package script and assign CPU/hardware, potentially solving OS scheduling issues. • I've shown interest in the 'improving real-time computing' aspects of the project. May have some aspects of underwater testing using facilities. • Rewriting software in C to reduce the overheads introduced by Python. • Paul & Ben mentioned to start simple with the software logic - with simple thresholding - then fine tuning to improve accuracy. • Ben mentioed to read older literature (e.g. 2010-era) on digital image processing - since there wont be any added complexities such as computational intelligence/ML/AI. • Work can be done to research the performance of different algorithms to detect and eliminate backscatter.	• Ben will send me some underwater footage to help me test any code without needing to implement in hardware and physically test. • I will ask Ben to send me the existing Python code so that I can get it set up on my Raspberry Pi. • With some underwater footage, I can modify the existing Python code to stream the video from file instead of from a camera, I can try to experiment with hypervisors (Docker) to see differences in performance. If there is an improvement, I will implement Docker in my final code. • I will try to research digital image processing from *older* literature. • I will try experiment with running C programs on Raspberry Pi.	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

7.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
• Next meeting in person to see existing lighting system. After seeing the existing system, I can decide the avenue I'd like to pursue.	• I have shown interest to delve into the 'improving real-time computing' avenue. • I have seen the existing lighting system, and have received a tour of the ISA.	• *No pending tasks.*
• Carry out some rough preliminary research for the 4 potential objectives: improving real-time computing, underwater testing, backscatter depth perception, ML-based backscatter position tracking.	• Initial research into 'improving real-time computing' has been conducted with some reading into real-time software (documented in the Project Journal). • I have not conducted any research on the other 3 objectives since those avenues would probably not be pursued. • Underwater testing aspects may need to be researched, however, not any time soon.	• *No pending tasks.*

7.3 Additional Project Updates

Additional Update	Description
No additional updates.	-

7.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Experiment with hypervisors	• Get existing Python code and some underwater GoPro footage from Ben. • Modify the existing Python code to stream the video from file instead of from a camera. • Package the software with Docker, measure performance differences.	• Modified code should be working and containerised with Docker. • Make notes in project journal, discuss during the next supervision meeting.	Friday
Gather some digital image processing literature	• Since this is quite early on and I have other modules to focus on this semester, I won't be going into too much depth with the literature. • So this actionable item would be to simply gather a list of potential pieces of literature that I could read in depth at a later date. • I should be making some brief notes on the contents.	• Log the brief notes in the Project Journal, citing the sources of the literature.	Friday
Experiment with RPi and C programming	• Make simple scripts in C and run on Raspberry Pi. • Set up a simple-yet-efficient workflow that can speed up development time in preparation for when I start writing the project software.	• Log progress in the Project Journal, maybe even store code in a 'spike' repository on Github.	Friday

7.5 Comments & Concerns

No comments or concerns at the moment.

8 12-04-2024

8.1 Supervision Meetings

8.1.1 09-04-2024

Attendees: Sidharth Shanmugam, Paul Mitchell

Agenda:

- Pi Camera recording script has now been completed:
  - Instead of recording the direct output from the sensor, I am recording from the Pi's Image Signal Processor (ISP) hardware module that converts the 'Bayer' data into a human-readable format such as BGR888 (which also is natively supported by the OpenCV library) without any noticeable performance sacrifices.
  - By using the ISP module, the output resolution can be scaled to minimise disk write speed bottlenecks. As an extra precaution, I have written logic to record directly to a RAM buffer, which is then offloaded for format conversion when recording has stopped. I have also implemented logic to fix the recording framerates and have set it to default at 30 FPS, the sensor supports up to 60 FPS.
  - The output recorded file is a stream of binary data in BGR888 format, for easy playback such as on VLC, I have written logic to convert this file into an .MKV using a lossless encoder (FFV1).
  - Although not mentioned to Paul yet (sorry, forgot to mention this during the supervision meeting), I have been having trouble trying to focus the Pi Camera lens, it's almost like the lens is not compatible with the Global Shutter camera, perhaps the camera has a slightly different construction compared to the Raspberry Pi High Quality Camera. Ben is aware and has experienced the same issue, he has ordered a new lens.
- Backscatter simulation software:
  - Following our last meeting where the delays in underwater testing were discussed, Ben suggested I write a program that simulates the movement of bubbles to test my system. I have now completed writing this software - the program simulates bubbles rising from the bottom to the top of the screen.
  - I have added randomised axis velocities (horizontal and vertical axes) to ensure the bubbles don't follow a linear path as this will help verify the performance and accuracy of my backscatter tracking implementation (which will be developed in the near future). As bubbles rise underwater, they get bigger due to the pressure difference, I have added logic to grow the bubbles as they rise - this will be useful to track performance and accuracy of the system as bubbles change appearances.
  - Instead of exporting the simulation as a video, I have decided to export images of each frame. This behaviour matches how the Pi Camera will be interfaced with in the system - inside of a 'while'-loop, each iteration denotes a frame, the software will retrieve the Pi Camera's frame output array, essentially allowing for direct control of the system's recording frame rate.
  - I have also added logic to export a CSV dataset of every bubble's centre coordinates and radius in every single frame of the simulation. This will provide a synthetic ground truth which I can directly use to quantify my system.
- Initial report feedback:
  - I really appreciated the feedback, there was a lot of important suggestions that I can use for my fimal report to enhance my grade (I'm really hoping to achieve an overall grade of

80%+ :-)).

- I will need to re-evaluate my objectives for the project as I won't have enough time to achieve all of them - I'm making great progress with the first objective of reliable backscatter cancellation system, with that done, I can start to make progress with the real-time research objective. The final objective regarding tracking and pre-emptive cancellation may need to be scrapped.

Actionable Items:

Milestone V1:

- I already have a system that implements the features for V1: (a) simple Canny-based segmentation, (b) real-time metric tracking, I just need to update this to complete the third objective to optimise for test footage of bubbles recorded from testing tank. Since we don't have the tank ready yet, I will optimise this for my bubble backscatter simulation output instead.

8.2 Actionable Items Recap

8.2.1 Script to record from Pi Camera

Progress Report:

- *Done!*

Pending Tasks:

- *None.*

8.2.2 Backscatter simulation program

Progress Report:

- *Done!*

Pending Tasks:

- *None.*

8.2.3 Recording underwater footage from the ISA tank

Progress Report:

- The housing is now sealed up correctly, the Pi is accessible via SSH through Ethernet, and my Pi Camera recording script works perfectly. The live preview feed is extremely useful especially when trying to apply fine adjustments to the camera (focus/aperture).

Pending Tasks:

- There are still some health and safety/other administrative issues that must be resolved before using the ISA tank. Once this has been completely checked-off, I should have access to record footage.

8.3 Additional Project Updates

8.3.1 Laptop Issues

- In the last update on Friday, I mentioned that the laptop had been given to a repair centre to fix the flexgate issue and it would be back by that Sunday.
- It took them an entire week for them to get to open up the laptop housing, and another few days of diagnosis just for them to get back and say that the entire display unit needs to be replaced :-(.
- I ended up collecting my laptop back without any repairs done to it, I am managing with external monitors and of course my iPad which I'm using to mirror my laptop screen using Sidecar.
- I have spoken to a few repair centres near York, one in York and one in Bradford that are offering a service to repair the cable itself - apparently they cut the cable where it's damaged, and solder in a small section of a similar donor cable. This will add a few millimeters of flex cable length to ensure this issue will not happen again in the future.
- Hopefully the issue will be fixed by Monday. I'm so glad I added in the two weeks of buffer time in the Gantt schedule for this as this issue has caused so many delays.

8.4 Next Week's Agenda

8.4.1 Monday - Reach milestone V1

Actionable Items:

- All that needs completion is logic to implement logic to track real time metrics. This needs to be ported over to the codebase from my prototyping code.

Success Metrics:

- Code pushed to the git repository.

8.4.2 Wednesday - Implement PREEMPT-RT kernel and quantify (Milestone V2)

Actionable Items:

- Implement the PREEMPT-RT kernel along-side the standard kernel.
- Quantify the performance differences with the V1 software.

Success Metrics:

- Analysis logged in the project journal

8.4.3 Friday - Snake-based segmentation & tracking (Milestone V2)

Actionable Items:

- The V1 system uses Canny to detect edges, with the detected edges passed to OpenCV's findContours() method to extract closed loop edges. The cancellation logic then uses a minimum enclosing circle (MEC) implementation which calculates a circumcircle which completely covers the minimum area of the detected contour. The MEC implementation must be replaced with the snake method.
- The 'least distance rule' and Kalman filter approach must be researched for the backscatter tracking implementation in the system.
- I will be putting the parallax part of 'Project holes and mitigate parallax' task on pause until the final housing is completed and the ISA tank is functional.

Success Metrics:

- Code pushed to the git repository.

8.5 Comments & Concerns

No comments or concerns at the moment.

9 15-03-2024

9.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
12-03-2024	• Progress update on Pi camera recording script.	-	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

9.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
Script to record footage from RPi and Pi GS camera.	• The RPi implementation of MJPEG isn't zero lossy. • I have a better understanding of how the raw data is captured, this should help with parsing and playback. • Recording in raw format will be challenging due to insufficient boot drive write speeds.	• I need to fine-tune the recording logic to use RAM for buffering instead of writing directly to the boot drive. • I need to write a view script that parses the raw data to play back the video recording.
Record test footage.	• Unfortunately, the seal for making the housing watertight didn't set in time, so recording has been postponed.	• Once the seal has cured, Ben will record the footage for me using the script. • I need to send him instructions on how to use the program.
Research real-time metrics and implement in backscatter cancellation software.	• No progress on this due to the backlog of other tasks.	• I will shift this for next week.

9.3 Additional Project Updates

Additional Update	Description
No additional updates.	-

9.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Script to record footage from RPi and Pi GS camera.	• Complete recording script. • Complete playback script.	• Code pushed to its GitHub repository.	Friday
Record test footage	• With the script to record footage completed, use ISA facilities to record test footage of bubbles.	• Footage recorded.	Friday
Research real-time metrics and implement in backscatter cancellation software	• Need to research ways to accurately record real-time metrics in Python. • Need to research which metrics are important for this project and must implement in software.	• Code pushed to its GitHub repository (tagged V1)	Friday

9.5 Comments & Concerns

No comments or concerns at the moment.

10 16-02-2024

10.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
13-02-2024	• Showcase of simple bubble detection script and Pi Camera recording script. • Discussed deployment of Pi Cam recording script to gather better test footage using ISA tank. • Discussed rough plan of initial report.	• The Pi Cam recording script should record in raw format without any compression to eliminate artefacting. • Better test footage is required to continue work on the simple bubble detection script. • I mentioned that I will be prioritising the initial report this week due to nearing deadline, working on hardware/software is a time sinkhole.	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

10.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
• Script to record footage from RPi and Pi GS camera.	• Script is complete, Pi Cam interfacing was successful, and I've managed to tune the lens for better focus.	• From the last supervision meeting, I need to change the code to record in raw format.
• Improve bubble segmentation performance in benchmark script.	• No progress has been made on this directly, I still need to record test footage.	• *Still pending.*
• Plan initial report & schedule.	• Rough plan has been summarised in the project journal. • An initial draft has been started.	• *Still pending.*

10.3 Additional Project Updates

Additional Update	Description
No additional updates.	-

10.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Draft of initial report.	• Full focus will be shifted towards the initial report. • I will need to finalise an initial draft for review by Ben and Paul. • Needs to be prioritised due to the nearing deadline.	• Initial draft in initial-report GitHub repository.	Friday

10.5 Comments & Concerns

No comments or concerns at the moment.

11 17-11-2023

11.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
15-11-2023	• Findings on Python performance issues research. • Discussed objectives for detecting backscatter. • Discussed objectives for predicting backscatter motion. • Discussed timing complexities for synchronising find backscatter-project holes-predict next location cycle. • Future work could be to stitch images of the seabed together to produce 'panorama'.	• Research simple blob detection algorithm. • Research object tracking algorithms, starting with linear moving on to more advanced algorithms later.	• Sidharth Shanmugam • Benjamin Henson

11.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
• Experiment with hypervisors	• Underwater GoPro footage with backscatter has been received. • Existing code has been retrieved, had to extract the files from the Pi's SD card. • Will be shifting this task for later so that I can produce software beforehand.	• *No pending tasks.*
• Gather some digital image processing literature	• I have gathered two textbooks for digital image processing. • Didn't get a chance to read through them yet, but will be doing so for next week.	• Log the different algorithms and complexities for each.
• Experiment with RPi and C programming	• I've researched that C programming would be quite difficult for this task. • Instead of C I could use C++. • A lot of the online resources suggested prototyping in Python, then translating to C++ for production.	• Set up C++ workflow to develop and deploy to Raspberry Pi.

11.3 Additional Project Updates

Additional Update	Description
No additional updates.	-

11.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Start researching on blob detection algorithms	• Use the literature for this.	• Make notes in project journal.	Friday
Gather literature for object tracking/predicting movement	• Starting with linear interpolation.	• Make notes in project journal.	Friday
Experiment with blob detection algorithms	• Extract individual frames from the underwater GoPro footage. • Or create own backscatter assets (black/grey background with white dots). • Using Python and OpenCV, experiment with blob detection algorithms.	• Log progress in the Project Journal, maybe even store code in a 'spike' repository on Github.	Friday

11.5 Comments & Concerns

No comments or concerns at the moment.

12 19-04-2024

12.1 Supervision Meetings

12.1.1 09-04-2024

We didn't have a specific meeting on Tuesday's as we usually do this week due to the ISA's morning closure. However, since I work from the ISA daily, we were able to meet up informally at multiple points throughout the week to discuss progress.

Agenda:

- Multiprocessing was a massive failure!
  - V1 software is complete!
  - I realised that the current version is completely sequential, which is very inefficient since on a multicore system, such as the 4-core Raspberry Pi 4 and 5, only one core will be utilised. Python is not multithread compatible out of the box due to the Global Interpreter Lock (GIL), which is a mechanism to synchronise threads. However, the 'multiprocessing' package allows for the creation of processes which are functions that is run bypassing the GIL.
  - I have re-written the software to implement each stage (i.e., greyscale conversion, histogram equalisation, etc) of the image processing pipeline as a process which runs on different cores. Since thread safety is crucial when moving data between different threads, queues must be utilised when sending data.
  - The performance data that I measured with the multiprocessing version was very surprising when compared to the single-core version: processing each frame took an average of 2x longer with multiprocessing, I went from an average frame processing time of 17ms to 33ms!
  - I think the biggest reason for this slow-down is due to the queues being an inter-process communication (IPC) service, there is a lot of overhead involved with IPCs, including serialisation, deserialisation and context switching between threads.
  - Another crucial problem with multiprocessing is the induced frame delay: capturing is a fast process that feeds into the much slower processing stage - so for example, when the 25th frame is being processed, the 100th frame is being captured, resulting in a 75-frame delay.
  - Unfortunately, due to the much reduced performance I will not be researching multiprocessing any further. Although a lot of time had been spent on this (3.5 days) without any meaningful performance benefit when compared to the single core program, I have learnt a lot:
    * Multiprocessing processes have much more overhead to startup as an entirely new OS process is being created as each one is run.
    * IPC services have a lot of overhead, as I mentioned before. Also, there is a lot of I/O bound tasks which can severely bottleneck multiprocessing.
    * Pipelining and multiprocessing only works for an FPGA, where each pipeline stage is hardcoded in fabric and isn't software threads that is being scheduled to each CPU-core by an OS.
    * (Ben mentioned this:) Never second-guess the compiler/OS when it comes to optimisations as it can optimise the code much better for runtime.

  - Although this was a failure, I can still write about it in my final report as I have a set of meaningful data and graphs.

- ISA tank is ready for use.
  - The tank is ready for use, I will be using it on Monday.
  - While we were discussing this, Ben and I tested the prototype setup to ensure the projector and camera are both properly focused and whether the script/software all works.

Actionable Items:

- Install PREEMPT-RT kernel and quantify:
  - Since I now have the V1 software in place, I can build the real-time kernel and test with it.

12.2 Actionable Items Recap

12.2.1 Reach milestone V1

Progress Report:

- *Done!*

Pending Tasks:

- *None.*

12.2.2 Implement PREEMPT-RT kernel and quantify

Progress Report:

- Since I got very much side-tracked with the multiprocessing research, I couldn't spend much time on this.
- However, I have managed to figure out how to do it - I'll need a Linux host system to build the kernel, I can do this on the Pi itself without a host system, however, it'll take forever to compile.
- I have installed and set up a Ubuntu OS VM again, I had to uninstall the VM from earlier in the project due to internal drive space constraints, however, that shouldn't be an issue anymore.

Pending Tasks:

- Build and compile the kernel.
- Copy in new kernel and quantify.

12.2.3 Snake-based segmentation & tracking

Progress Report:

- *No progress due to mulitprocessing side-tracking.*

Pending Tasks:

- The V1 system uses Canny to detect edges, with the detected edges passed to OpenCV's findContours() method to extract closed loop edges. The cancellation logic then uses a minimum enclosing circle (MEC) implementation which calculates a circumcircle which completely covers the minimum area of the detected contour. The MEC implementation must be replaced with the snake method.
- The 'least distance rule' and Kalman filter approach must be researched for the backscatter tracking implementation in the system.
- I will be putting the parallax part of 'Project holes and mitigate parallax' task on pause until the final housing is completed and the ISA tank is functional.

12.3 Additional Project Updates

None at the moment.

12.4 Next Week's Agenda

12.4.1 Monday - Record underwater footage

Actionable Items:

- I've got the code in-place for this, just need to record.

Success Metrics:

- Downloading a video file of the recording to use as test footage.

12.4.2 Monday - Implement PREEMPT-RT kernel and quantify

Actionable Items:

- Build and compile the kernel.
- Copy in new kernel and quantify.

Success Metrics:

- Analysis logged in the project journal

12.4.3 Friday - Snake-based segmentation & tracking (Milestone V2)

Actionable Items:

- The V1 system uses Canny to detect edges, with the detected edges passed to OpenCV's findContours() method to extract closed loop edges. The cancellation logic then uses a minimum enclosing circle (MEC) implementation which calculates a circumcircle which completely covers the minimum area of the detected contour. The MEC implementation must be replaced with the snake method.
- The 'least distance rule' and Kalman filter approach must be researched for the backscatter tracking implementation in the system.
- I will be putting the parallax part of 'Project holes and mitigate parallax' task on pause until the final housing is completed and the ISA tank is functional.

Success Metrics:

- Code pushed to the git repository.

12.5 Comments & Concerns

No comments or concerns at the moment.

13 24-11-2023

13.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
24-11-2023	• Overview of the gathered literature for research and review. • Overview of the Python script with OpenCV simple blob detection.	• Expand research and make notes. • Think about real-time aspects along side the research. • Work on automating the fine-tuning of thresholds in the Python script with histograms.	• Sidharth Shanmugam • Benjamin Henson • Paul Mitchell

13.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
• Start researching on blob detection algorithms	• I have listed a few academic papers related to underwater bubble detection, mostly from IEEE. • The two textbooks that I'd checked out of the library don't relate much to the project, I will keep them just in case for supplementary information. • I've struggled to find textbooks that goes into detail on these aspects.	• I plan to read the papers, making notes in the Project Journals on each. • I will read any referenced papers/textbooks that are related to the project.
• Gather literature for object tracking/predicting movement	• I have gathered some papers on underwater object tracking.	• I will be making notes, and expanding my literature collection by exploring the referenced papers. • I am prioritising research on blob detection at the moment.
• Experiment with blob detection algorithms	• I have made some prototype code to help with my blob detection research in Python using OpenCV. • Using various filters, I have been successful in detecting most of the bubbles in the test image inputs. • All progress on this has been logged in the Project Journal.	• Fine tune blob detection parameters and test with non-bubble backscatter. • Maybe even apply some of the algorithms discussed in the research papers.

13.3 Additional Project Updates

Additional Update	Description
No additional updates.	-

13.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Expand research and make notes.	• Read and make notes of currently gathered papers. • Expand literature research by reading related cited work. • Think about how real-time can be achieved.	• Make notes in project journal.	Friday
Research histograms	• Research methods to automate the fine-tuning of the currently hard-coded values for the thresholding.	• Log progress in the Project Journal.	Friday

13.5 Comments & Concerns

No comments or concerns at the moment.

14 26-04-2024

14.1 Supervision Meetings

Like last week, we didn't have any normally scheduled supervisions this week as Paul was out of the office. However, I did meet with Ben to talk on many occasions across the week.

Agenda:

- PREEMPT-RT kernel worsens system performance.
  - Just like the research and experimentation with multiprocessing, implementing a real-time kernel with PREEMPT-RT proved a failure, even though, in theory, it should've improved at least the system stability by maintaining a constant frame processing time.
  - The results showed a 1ms rise in the average frame processing time, which is roughly a 16% increase. Not only this, but the stability is also worse, as the standard deviation in processing time for each frame increased by almost 60%.
- Tank recording.
  - Recording was successful and the results were also great as the system worked quite well to detect just the backscatter in the foreground without any confusion about the background texturing - this is quite important as the system must work only for backscatter and not any region of interest that needs recording.
- Final report.
  - I have started planning this report, I wanted to give Paul a quick overview of how I have planned to structure this report, however, he was quite busy so this conversation did not proceed.
  - I have reached out to Simon Bale to clarify if we can reuse parts of the initial report in the final report - since, in my opinion, it makes more sense to use the initial report as a foundation, which the final report builds on. I am awaiting Simon's final response on this matter before I start writing content.

Actionable Items:

- Quantify real-time performance of the system with underwater recording.
  - At the moment, I've only quantified the real-time performances using my synthetic bubble simulation, however, with the underwater footage now recorded, it would make sense to quantify that to gauge the true system performance.

14.2 Actionable Items Recap

14.2.1 Recording underwater footage

Progress Report:

- *Done!*

Pending Tasks:

- *None.*

14.2.2 Implement PREEMPT-RT kernel and quantify

Progress Report:

- *Done!*

Pending Tasks:

- *None.*

14.2.3 Snake-based segmentation & tracking

Progress Report:

- *No progress due to PREEMPT-RT backlog.*

Pending Tasks:

- The V1 system uses Canny to detect edges, with the detected edges passed to OpenCV's findContours() method to extract closed-loop edges. The cancellation logic then uses a minimum enclosing circle (MEC) implementation which calculates a circumcircle that completely covers the minimum area of the detected contour. The MEC implementation must be replaced with the snake method.
- The 'least distance rule' and Kalman filter approach must be researched for the backscatter tracking implementation in the system.

14.3 Additional Project Updates

14.3.1 Skipping the predictive system objective.

- Unfortunately, due to very tight project time constraints, I will not have enough time to work on this research objective. It's a shame that I have to skip this, as I was very interested in researching how AI can accelerate unconventional use cases such as this.
- I will be focusing more on quantifying the real-time aspects and researching optimisations for more accurate backscatter segmentation and cancellation.

14.4 Next Week's Agenda

14.4.1 Wednesday - Parallax and offset calibration.

Actionable Items:

- While recording the test footage in the ISA tank, I noticed a large offset between where the camera was recording and where the projector was projecting. There is some overlap between the two, where the system can effectively work, so I will need to plan and implement some logic in code that can automatically find the overlap region and crop the feed/projection.
- I also noticed some image distortion which also needs resolving. This can be done quite simply by projecting a chessboard, capturing it at various angles, and passing it into an OpenCV function that can calculate a distortion matrix which can be used to undistort the captured image frame.
- The auto-cropping feature is very complicated to implement, so this task may be entirely postponed or skipped as it is unlikely we will be doing any more experiments in water due to the project's time constraints.

Success Metrics:

- Code pushed to the Git repository.
- Image cropping visually verified.
- Image undistortion visually verified.

14.4.2 Wednesday - Snake-based segmentation & tracking (Milestone V2)

Actionable Items:

- The V1 system uses Canny to detect edges, with the detected edges passed to OpenCV's findContours() method to extract closed-loop edges. The cancellation logic then uses a minimum enclosing circle (MEC) implementation which calculates a circumcircle that completely covers the minimum area of the detected contour. The MEC implementation must be replaced with the snake method.
- The 'least distance rule' and Kalman filter approach must be researched for the backscatter tracking implementation in the system.
- I will likely need to implement and test the tracking implementation using my synthetic bubble simulation as the tank footage of bubbles isn't very trackable.

Success Metrics:

- Code pushed to the git repository.

14.4.3 Friday - Complete the 'Introduction' section of my report.

Actionable Items:

- Hopefully by Monday, I will receive confirmation from Simon regarding the final report. Once I have received this, I will be able to start writing the report. I will aim to complete the 'Introduction' section and maybe even make a start on the next section which covers the background information.

Success Metrics:

- LaTeX code pushed to the git repository with a compiled PDF.

14.5 Comments & Concerns

No comments or concerns at the moment.

15 27-10-2023

15.1 Supervision Meetings

Date	Agenda	Actionable Items	Attendees
31/10/2023 (upcoming)	• Pinpointing project scope/objectives. • Laying out rough schedule based on project objectives. • Getting started on pre-reading/literature review. • Discussing organisational tips/workflows. • Schedule for re-occurring meetings. • (more to be added if I can think of anything else important)	• N/A	• Sidharth Shanmugam • Paul Mitchell • Benjamin Henson

15.2 Actionable Items Recap

Actionable Item	Progress Report	Pending Tasks
• Actionable item 1	• Progress report 1 • Progress report 2 • Progress report 3	• Pending task 1 • Pending task 2 • Pending task 3
• Actionable item 2	• Progress report 1 • Progress report 2 • Progress report 3	• Pending task 1 • Pending task 2 • Pending task 3

Since this is the first weekly report and supervision meetings haven't previously taken place, there are no actionable items to reflect on. Therefore, a boilerplate table is provided above to outline the structure for future weeks.

15.3 Additional Project Updates

Additional Update	Description
Created weekly updates automation	• Created weekly-updates GitHub repository. • Branch contains templates which I update each week. • Jenkins CI/CD to pull the templates, compile LaTeX to generate PDFs. • PDFs then downloaded and emailed accordingly.

Since this is the first weekly report and work on this project hasn't commenced yet, there are no additional updates to reflect on.

15.4 Next Week's Agenda

Actionable Item	Description	Success Metrics	Target
Actionable item 1	• Description point 1 • Description point 2 • Description point 3	• Success metrics 1 • Success metrics 2 • Success metrics 3	Thursday
Actionable item 2	• Description point 1 • Description point 2 • Description point 3	• Success metrics 1 • Success metrics 2 • Success metrics 3	Wednesday

The future week's agenda will be discussed in the upcoming supervision meeting. Above is a boilerplate table to outline the structure for future weeks.

15.5 Comments & Concerns

No comments or concerns at the moment.