

Journal

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Monday 29-01-2024 (project week 0)

Kristoffer

Beumer

- Started project
- Had meeting with Jonas discussing what to start with the first 2 weeks
- Read these papers:
 - A visual introduction to Gaussian Belief Propagation [1]
 - Distributing Collaborative Multi-Robot Planning With Gaussian Belief Propagation [2]
- Tried compiling examples from <https://github.com/aalpatya/gbpplanner> but faced issues with missing X11 headers, even though they were installed on my system.

Jens

Beumer

- Starting with a meeting all three (Kristoffer, Jens, Jonas)
- Read papers:
 - A visual introduction to Gaussian Belief Propagation [1]
 - Distributing Collaborative Multi-Robot Planning With Gaussian Belief Propagation [2]

- Successful compilation and run of examples from <https://github.com/aalpatya/gbpplanner>.
 - Successfully created custom environment to attempt to highlight weaknesses of the current implementation.

Tuesday 30-01-2024 (project week 1)

Kristoffer

From Home

- Created GitHub repository <https://github.com/AU-Master-Thesis/gbp-rs> as we want to rewrite the <https://github.com/aalpatya/gbpplanner> in Rust.
- Looked at different Rust simulation/visualization tools to use.
 - <https://macroquad.rs/>
 - <https://nannou.cc/>
 - <https://bevyengine.org/>
- Decided to go with **bevy** as it has a lot of community support/solutions and we thought its ECS system is really cool!.
- We read through the introduction book for bevy, to learn the core concepts behind the ECS paradigm and how applications are structured in bevy.

Jens

From Home

- Set up Rust project structure
- Looked at the visualisation tools with Kristoffer, discussing which to go with.
- Learned Bevy and ran some examples
 - Wrote some of the examples out and mix-matched some of it to learn how it all fit together.

Wednesday 31-01-2024 (project week 1)

Kristoffer

OrbitLab

- Continued to have issues compiling the code for <https://github.com/aalpatya/gbpplanner>.
- We both decided to re-flash our OS with NixOS.
- Spent some getting acquainted with the terminology and methodology of how to do things in NixOS
- Create a `flake.nix` for both our Rust port and `gbpplanner` to create a reproducible environment, where we can compile and run the code without issue.

Jens

OrbitLab

- Re-flash OS to NixOS
 - Learn NixOS and contemplated using hyprland

-

Thursday 01-02-2024 (project week 1)

Kristoffer

OrbitLab

- Continued learning about NixOS and setting up our development environment, with the tools we like to use.
- Spent some time trying to port the code from https://colab.research.google.com/drive/1-nrE95X4UC9FBLR0-cTnsIP_XhA_PZKW?usp=sharing#scrollTo=NzotHENoaY6g to our Rust implementation.

Jens

OrbitLab

- Setting up NixOS and hyprland
- Migrating gbpplanner to Rust

Friday 02-02-2024 (project week 1)

Kristoffer

From Home

- Continued our attempt to port the code from https://colab.research.google.com/drive/1-nrE95X4UC9FBLR0-cTnsIP_XhA_PZKW?usp=sharing#scrollTo=NzotHENoaY6g to our Rust codebase.
- Jens wrote the code, while we both discussed how to port the Python code to Rust.

Jens

From Home

- Rust migration

Monday 05-02-2024 (project week 1)

Kristoffer

Beumer

- Read recent survey paper from 2023 [3].
 - No mention of any paper/approach using Gaussian Belief Propagation.
 - Many newer paper use AI methodologies.
 - Neural Network based
 - Genetic Algorithms
 - Ant Colony

- artificial bee colony algorithm
- Lin-Kernighan-Helsgaun heuristic algorithm (dunno, names sounds interesting)
- Dynamic Particle Swarm Optimization (PSO) [ref: 126,128]

Jens

At Beumer

- Struggling to set up hyprland with displaylink
- Ended the struggle, and joined Kristoffer in continuing the Rust migration.

Tuesday 06-02-2024 (project week 2)

Jens

From Home

- Collaborative coding to migrate to Rust
 - Fixed a lot of compiler errors

Wednesday 07-02-2024 (project week 2)

Jens

AU 5124 139

- Attempted to continue for a while with the generic factor-graph gbp library we have been attempting to make, however, it had become too much of a headache so:
 - Started over, in a much simpler fashion
 - Supported with chatGPT
 - Supported as sparring partner, and made sure to understand things more precisely
 - Also added journal entries for all my previous weeks

Thursday 08-02-2024 (project week 2)

Kristoffer

AU 5124 139

- Continued working on the rewrite of gbpplanner in rust.
- Spent some time playning around with the C++ Eigen library, to confirm how variaous matrix operations and matrix slicing work, to correctly port them to rust.
- Reread parts of the methodology section, to better understand some of the math.

Jens

AU 5124 139

- Working with Kristoffer to continue translation to Rust.
- Decided to split the work load.

- I looked at Bevy, and learned further how to work it.
- Implemented an input-manager, such that the user can press keys on the keyboard or gamepad to interact with the simulation.
- Applied some keybinds like movement, boost to change movement speed, and toggling of a dynamic unknown object in the simulation.
 - The toggling is currently only done by setting alpha to 0/1, which should later also disable/enable the actor's hitbox.

Friday 09-02-2024 (project week 2)

Jens

From Home

- Decomposed input and objects in the Bevy ECS architecture.
- Watches episodes 1, 2, and 3 of the Bevy tutorial series.
- Decomposed the system even further to have movement handled by itself.
 - This introduced a bug where movement of objects don't stop.
- Reworked the project with a 3D scene and 3D camera.
- Created an asset loader, to handle the loading of the 3D models.
- Changed the moveable object to be a 3D model.

Kristoffer

From Home

- Found a similar paper to the [2] called Robot Web [4], that had some interesting demo videos on their [website](#).
- My intention is to read it over the weekend or next week, to see how it differs from [2].
- Continued working on the port to Rust.
 - Abstracted the robot radius into a trait `BoundingBox`, where i am right now creating a impl for a `BoundingBox2d`
 - Created an abstraction for the `CommunicationMedia`
 - Tried using Julia to verify some of the math, but had issues getting the `Distributions` package to compile on NixOS
- Still need to figure out how Messages are exchanged between robots, in a way that it is decoupled from running the simulation in a single thread with the same address space to a multiprocess system.

Saturday 10-02-2024 (project week 2)

Jens

From Home

- Fixed the movement bug from yesterday, such that velocity is reset when the movement stops.

- Extended the MovementPlugin to handle rotation as well in a similar fashion to the movement.
 - Consider decomposing the rotation into its own plugin.
- Changed the moveable object to a box instead of the roomba.

Monday 12-02-2024 (project week 2)

Kristoffer

From Home

- Continued working on porting gbpplanner factorgraph to Rust.
- Spend some time figuring out how to map Eigen operations to Rust nalgebra crate.
- Unsure about current design with every Variable have `Vec<Rc<Factor>>` and Factors having `Vec<Rc<Variable>>` makes the abstraction kinda awkward.
 - Thinking about restructuring and using a proper graph structure.
 - For this I think we can use the petgraph library.
- Also considered ways to abstract the connection with other robots/factorgraphs such that the library can be used in both simulation and real world setup.

Jens

From Home

- Finished initial camera controls.
- Set up an infinite grid to visualize the environment.

Tuesday 13-02-2024 (project week 3)

Kristoffer

AU 5124 139

- Meeting with Andriy and Jonas.
 - Showcased and discussed what we had been doing for the first two weeks.
 - Talked about some of the shortcomings we had identified with gbpplanner, and which were relevant to pursue.
 - Try and incorporate a global planner with the GBP algorithm.
 - Use a scheme to only communicate with the robots most uncertain about, to reduce number of messages being communicated in areas with a lot of robots. Avoid $O(n^2)$ complexity
 - Focus on first making a rewrite that reproduces the results of [2], before applying the software design decisions that we think would be better.
 - Focus on not only record what we do in text (in this journal), but also take pictures and video recordings of when things work and don't. Because they might be difficult to recreate later.
- Read “A Robot Web for Distributed Many-Device Localisation” [4].
 - Very similar to [2], I think some of the authors are the same.

- They exchange messages using HTTP. Where each robot host a web server that the other robots can send POST requests to.
- Similar results and findings as [2].
 - Some of their conclusions
 - “While increasing the communication radius improves the performance, 30m onwards, the difference is negligible.”
 - “Retain low ATE up to 50% message loss”
 - “Demonstrates its resilience to large initialisation errors up to (0.2m, 0.2m, 0.2rad) after which it explodes”

Jens

AU 5124 139

- Meeting with Andriy and Jonas.
- Added zoom functionality to the camera with button bindings.
- Fixed object not visible from the beginning. Due to normalization of zero-vector.
- Same problem with moving the camera, everything would vanish after a while because of normalization of zero-vector.
- Read half of “A Robot Web for Distributed Many-Device Localisation” [4].

Wednesday 14-02-2024 (project week 3)

Jens

AU 5124 139

- Set up mouse/touchpad keybindings for camera movement in simulation.

Kristoffer

AU 5124 139

- Finished reading paper [4].
- Worked on porting [2] C++ code to our Rust version.

Thursday 15-02-2024 (project week 3)

Jens

AU 5124 139

- Made a system to add follow cameras to each robot tagged with `FollowCameraMe`.
- Made the follow camera work quite reliably and almost not laggy.

Kristoffer

AU 5124 139

- Ported most of `Robot`, `FactorGraph` and `Variable` class to Rust.

Friday 16-02-2024 (project week 3)

Kristoffer

From Home

- Continued port of gbpplanner to Rust.

Jens

From Home

- Meshified the environment heightmap from greyscale PNG.
 - Tested first with a perlin noise with normal vectors
 - Wasn't able to make the heightmap work with the normal vectors, due to an extra triangle being created.

Monday 19-02-2024 (project week 3)

Jens

Beumer

- Fixed the heightmap to work with normal vectors, solving the extra triangle issue.
- Started to work on how to visualise the eventual factor graph.
 - Spheres for variables, cubes for factors.
 - Spent too much time trying to make a line between the two with thickness. It works, but it is currently 2D. I wonder if it is too performance intensive just to make the 2D mesh real-time, so it might not be worth to make 3D.

Kristoffer

Beumer

- Finished transcribing the Robot class to Rust.
- Wrote some unit tests for some of the utility functions

Tuesday 20-02-2024 (project week 4)

Jens

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- A lot of fiddling to get Fusion360 working on NixOS → No success .
 - Wanted to export simple meshes for the Beumer robot. This might breach NDA?
- Change factor graph visualisation, such that lines are drawn live.
 - Destroyed then remade every Update.
 - Might be too performance intensive, but we will see later
- Wanted to delve into WGSL for a bit to learn shaders

- Thus I could make the lines thicker, but this lead me into wanting a WGS language server, which would significantly speed up my learning, but it never worked, so I gave up.
- Fixed line kinking factor with proper trigonometry, to make it exact.
 - Was initially taken from [Pervasive-Computing/flutter_app](#)
- Thought maybe I could occlude the lines using the depth in a shader, and I asked ChatGPT for help, but it was a bit too much to ask for.

Kristoffer

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- Continued porting code to Rust.
- Wrote some unit tests for the `MultiVariateNormal` struct.

Wednesday 21-02-2024 (project week 4)

Jens

AU 5124 139

- Major decomposition of `InputPlugin`, into several plugins for each input context.
- Started a `ThemePlugin`, to empower the user to be able to control the theme.
- Override some defaults of the Bevy `WindowPlugin` as part of the `DefaultPlugin`.
- Started integrating the translated gbpplanner with the Bevy simulation with Kristoffer.
 - Standardised configuration interface.
 - Developed an expressive, declarative formation configuration interface.
- Put some thought into the possible environment layouts with three levels of complexity:
 - Low: Micro-scenarios focused on single intersections/junctions.
 - Medium: Macro-scenarios imitating the complexity of a real-world case from BEUEMR.
 - High: Macro-scenario imitating a maze-like structure.

Thursday 22-02-2024 (project week 4)

Jens

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Working in pair all day.

- Continued with the formation configuration interface.
 - We were missing a way to expression waypoints for groups of robots indirectly.
- Seriously started integrating, by making decisions on what should be Bevy components/entities. And what should be left.
 - And furthermore; which concepts could be handed over and handled by the Bevy ECS.

14 weeks 5 days left to hand-in deadline

Bibliography

- [1] J. Ortiz, T. Evans, and A. J. Davison, “A visual introduction to Gaussian Belief Propagation”, *arXiv preprint arXiv:2107.02308*, 2021.
- [2] A. Patwardhan, R. Murai, and A. J. Davison, “Distributing Collaborative Multi-Robot Planning With Gaussian Belief Propagation”, *IEEE Robotics and Automation Letters*, vol. 8, no. 2, pp. 552–559, 2023, doi: [10.1109/LRA.2022.3227858](https://doi.org/10.1109/LRA.2022.3227858).
- [3] N. Abujabal, R. Fareh, S. Sinan, M. Baziyyad, and M. Bettayeb, “A comprehensive review of the latest path planning developments for multi-robot formation systems”, *Robotica*, vol. 41, pp. 1–26, 2023, doi: [10.1017/S0263574723000322](https://doi.org/10.1017/S0263574723000322).
- [4] R. Murai, J. Ortiz, S. Saeedi, P. H. Kelly, and A. J. Davison, “A robot web for distributed many-device localisation”, *IEEE Transactions on Robotics*, 2023.