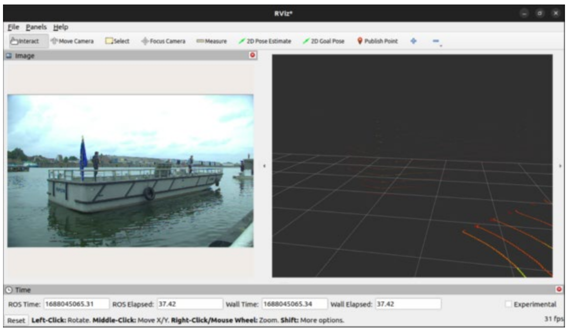 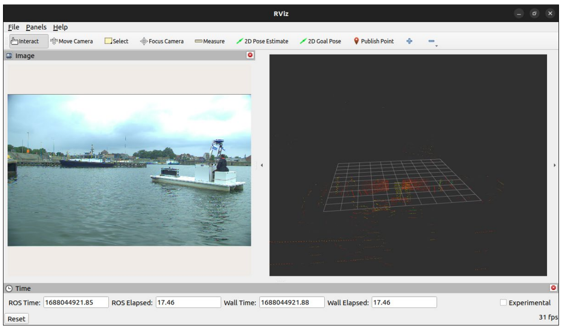

RESEARCHLAB
AUTONOMOUS SHIPPING

Investigation and applications of AI and Computer Vision technologies for autonomous ship systems

Within the framework of the Interreg NSR project AVATAR work package 6

Colophon

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Investigation and applications of AI and Computer Vision technologies for autonomous ship systems

A Vision Sensor Box for Autonomous Shipping Research

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June 2023

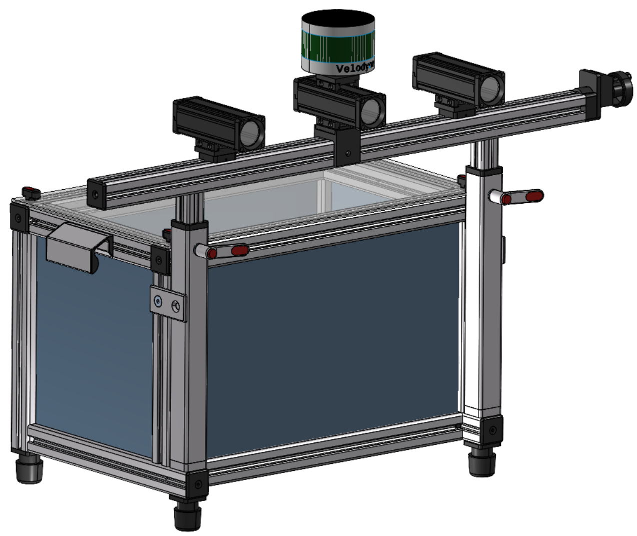

Figure 1: Sensorbox CAD Design

1 Introduction

The potential of computer vision and artificial intelligence in gaining autonomous situational awareness is well founded in the field of autonomous vehicles. Specifically in the field of inland shipping, potential has further been identified during tests on model scale vessels. The application of this technology to full-scale vessels presents some additional challenges which this work aims to alleviate. The development of computer vision algorithms and Neural Network models for full-scale applications require a wealth of training data. Whilst such datasets are comprehensive and readily available in the automotive field, the same cannot be said for the inland waterway network.

To enable data acquisition and algorithm testing on-board vessels during ongoing research it would be beneficial to have one portable sensor platform. Such a platform could simply be placed upon the vessel being used for testing, escaping the requirements of custom fitment of sensors to each individual test vessel. At the research stage, optimal sensor placement specific to each vessel is less critical.

This technical paper presents an open source vision sensor box, covering the hardware and software design through to the preliminary results gained by researchers at Delft University of Technology during the AVATAR and FAST collaborative research projects. The designs and code are available on the GitHub page of the ResearchLab Autonomous Shipping, allowing other researchers in the field of autonomy to replicate or take inspiration from this work. It is requested if any files are used in future works, that this paper be referenced.

2 Hardware

This section covers an overview of the hardware components of the sensorbox. The files and documentation for the Vision Sensorbox can be found on the RAS GitHub page.

2.1 Frame

The frame of the sensor box is constructed of aluminium profiles, panels and accessories from the Item range (item Industrietechnik GmbH). Approximate dimensions can be found below in the technical drawing.

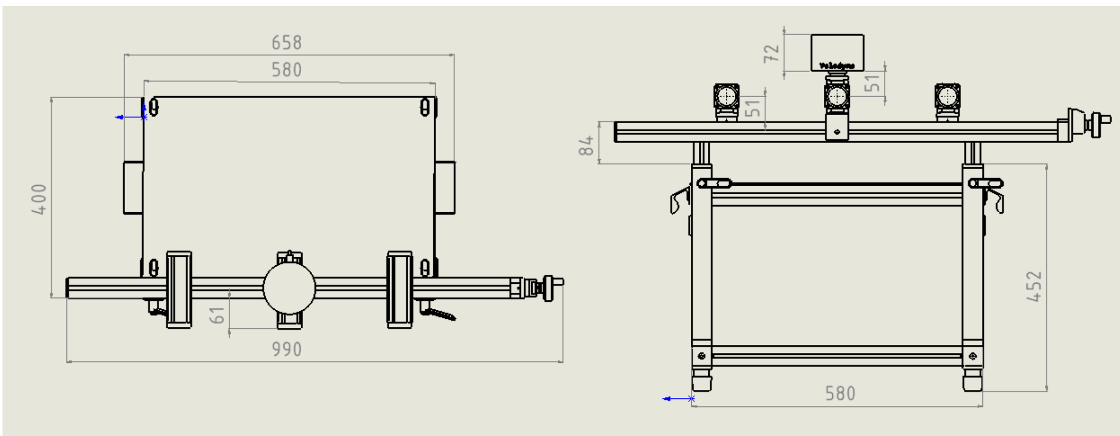

Figure 2: Frame Dimensions

2.2 Monocular Camera

The monocular camera is fixed in place on the main sensor beam. It is horizontally aligned with the LiDAR sensor and is positioned exactly in the centre of the two stereovision cameras. A Basler acA1920-40uc module is utilised in conjunction with a Basler C23-0816-2M lens to offer a wide field of view. The camera is protected by a weatherproof enclosure. All the files for 3D printing this enclosure can be found on the RAS GitHub, with a 37mm Lens Cap (Hama 00070637) also being required to complete the assembly. To prevent the camera overheating in the enclosure, the camera is mounted to a lasercut aluminium plate (3mm) which is connected to an aluminium heatsink on the outside of the enclosure via an aluminium spacer of diameter 10mm and length 15mm.

2.3 Stereovision Setup

The stereovision setup consists of two cameras, again using the Basler acA1920-40uc module with a a Basler C23-0816-2M lens. Each camera is mounted on a movable base, providing the stereovision setup with a variable baseline through adjustment of a lead screw. This capability allows the user to tune the stereovision setup to meet the application or test scenario. The minimum baseline (B) is 100mm and value on the digital readout (D) describes the displacement of each camera away from this baseline. The baseline can be thus be defined by $B = 100 + 2D$. For example, to set the baseline assuming the default baseline of 250mm, the lead screw handle should be adjusted until the the digital readout displays -75.00mm. The maximum baseline is 800mm.

2.4 LiDAR Sensor

The sensorbox is equipped with a Velodyne VLP-16 Puck. This 3D LiDAR sensor has 16 vertical layers and a full 360 degree horizontal coverage with a resolution of 0.1 - 0.4 degrees. Further details can be found in Figure 3 below.

Figure 3: Velodyne Puck Lidar

The origin of the LiDAR sensor is aligned in the horizontal frame with the monocular colour camera to simplify alignment and is positioned 89mm above the centre of the camera sensor as seen in Figure 4.

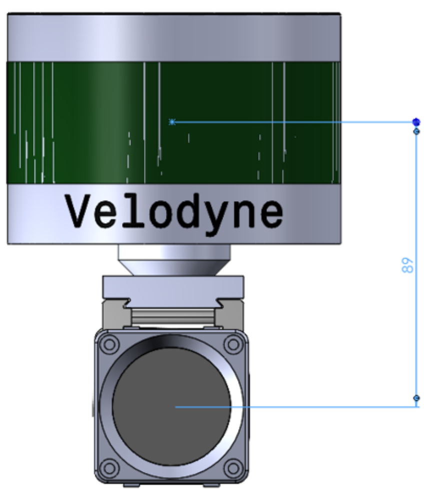

Figure 4: LiDAR Offset Height

2.5 Network

The sensorbox has its own network provided by an Asus 4G-AX56 AX1800 router. This router is both 4G and WiFi 6 equipped and allows for connection to the sensorbox from external devices as well as inter-communication between nodes within the sensorbox. The NUC has a fixed IP address at 192.168.50.100, allowing for direct VNC/SSH connection. All network and sharing protocols use the password: **VisionSystem**. The Jetson also has a fixed IP address at 192.168.50.101, with all other devices which connect to the network being automatically assigned an IP.

2.6 Power Supply

Power is supplied by a custom battery supply system comprised of Bosch ProCore 18v batteries. These batteries are designed for use on various tools in the Bosch range and in this case have been repurposed to provide power to the devices in the sensorbox. Four ProCore batteries are connected in parallel providing 18V at 16Ah when the 4Ah batteries are utilised. This capacity could be doubled to a total of 32Ah should 8Ah batteries that are also available from Bosch be utilised. A consumer based battery was chosen as they provide proven technology, with accompanying charger technology that is readily available worldwide. It is worth noting that this system could also be replicated using another brand of 18V battery than Bosch, only the battery mounts would need to be redesigned.

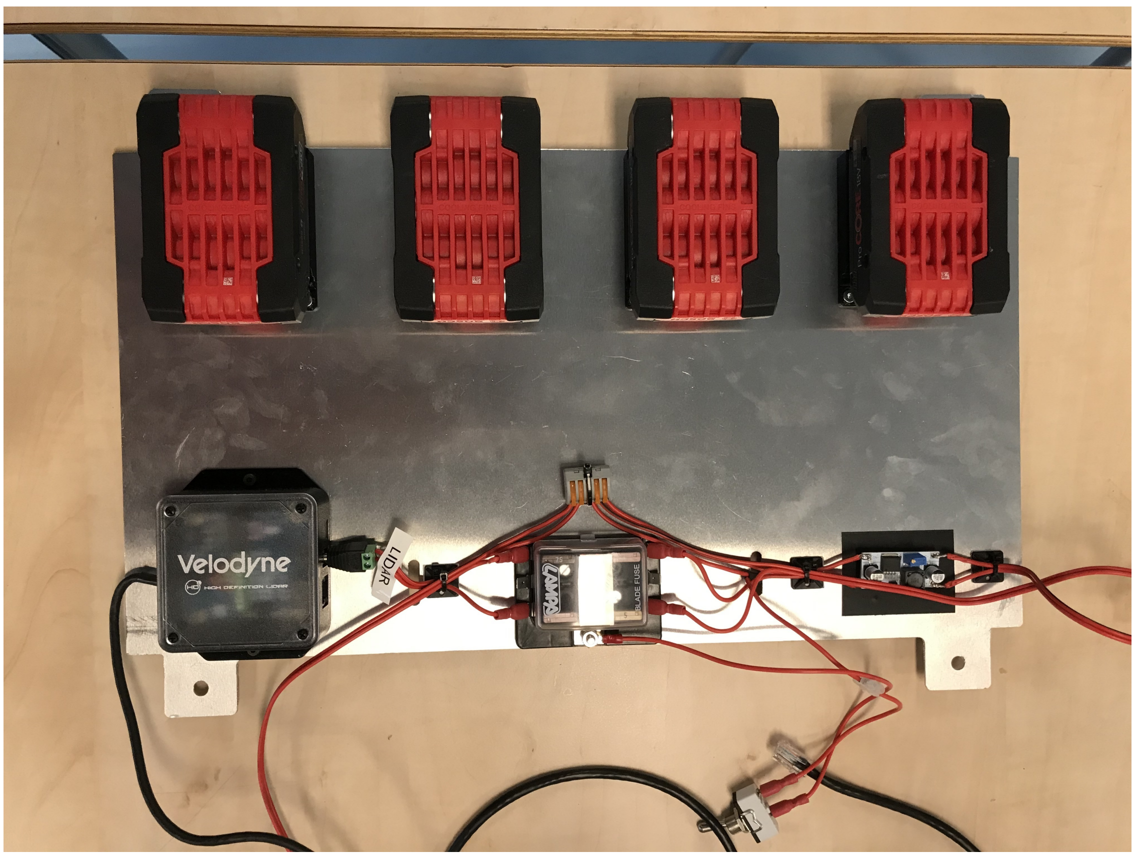

Figure 5: Power supply board

The 18V power supply is fed to an automotive fuse box prior to distribution to the devices. From the fuse box, power is then routed to the LiDAR box, Intel NUC and NVIDIA Jetson directly, whilst the supply for the router is first passed through a DC-DC converter to drop the voltage down to 12V. The selected fuse values for device protection can be found below:

- Intel NUC - 7.5A
- Jetson TX2 - 5A
- LiDAR - 3A
- Router(via DC-DC converter) - 3A

3 Software

The full ROS package for the Vision Sensorbox can be found on the RAS GitHub page here.

3.1 Publication Nodes

The publication nodes can be generated by individually running/launching each sensor separately.

```
ros2 run sensorbox monopub
```

```
ros2 run sensorbox stereopub
```

```
ros2 launch sensorbox mono_lidar_launch.py
```

Alternatively, the LiDAR and monocamera nodes can be launched with one command:

```
ros2 launch sensorbox mono_lidar_launch.py
```

Or the LiDAR, monocamera and stereovision nodes can be launched at once using:

```
ros2 launch sensorbox sensorbox_launch.py
```

3.2 Subscription Nodes

For testing purposes and for viewing the stereovision feed, the following commands can be run to generate subscribers to the monocamera and stereovision topics respectively.

```
ros2 run sensorbox monosub
```

```
ros2 run sensorbox stereosub
```

3.3 Recording and playing back datasets

Datasets are recorded and played back using the rosbag functions within ROS2. A new bag can be recorded using a command such as the example given below. Where 'filename' can be replaced with your chosen name for the dataset and the list three topics thereafter can be adapted depending on what data is required to be recorded.

```
ros2 bag record -o filename /velodyne_points /monocam_frames /stereo_frames
```

Playing back the dataset can be achieved using the command below. Remember to change 'filename' to your chosen dataset name.

```
ros2 bag play filename
```

4 Results

The following figures present some preliminary results from testing of the Vision Sensorbox in the Harbour of Vlissingen in the Netherlands and at the Rigakaai in Gent, Belgium. The datasets which have been gathered can be shared with other researchers upon request. It is the intent of the RAS to share this data later as part of a larger inland maritime dataset, so that researchers can focus on algorithm development, providing a similar service as the KITTI dataset does for autonomous cars.

Figure 6: Sensorbox overlooking the Harbour of Vlissingen

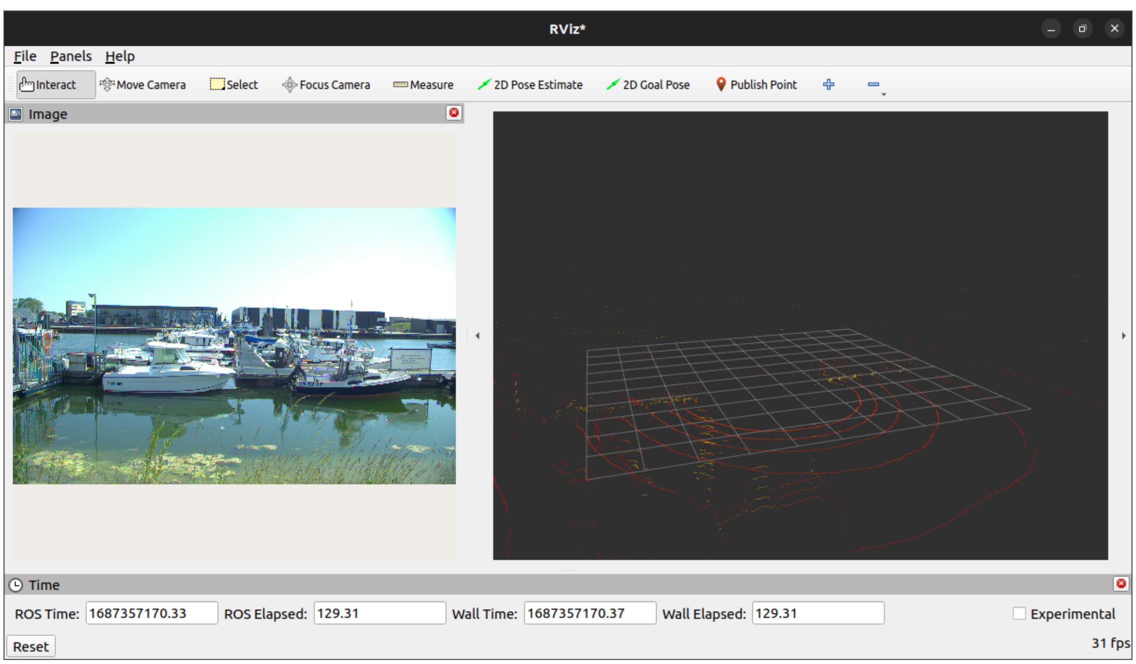

Figure 7: RVIZ display of monocular and LiDAR data from the Marina in Vlissingen.

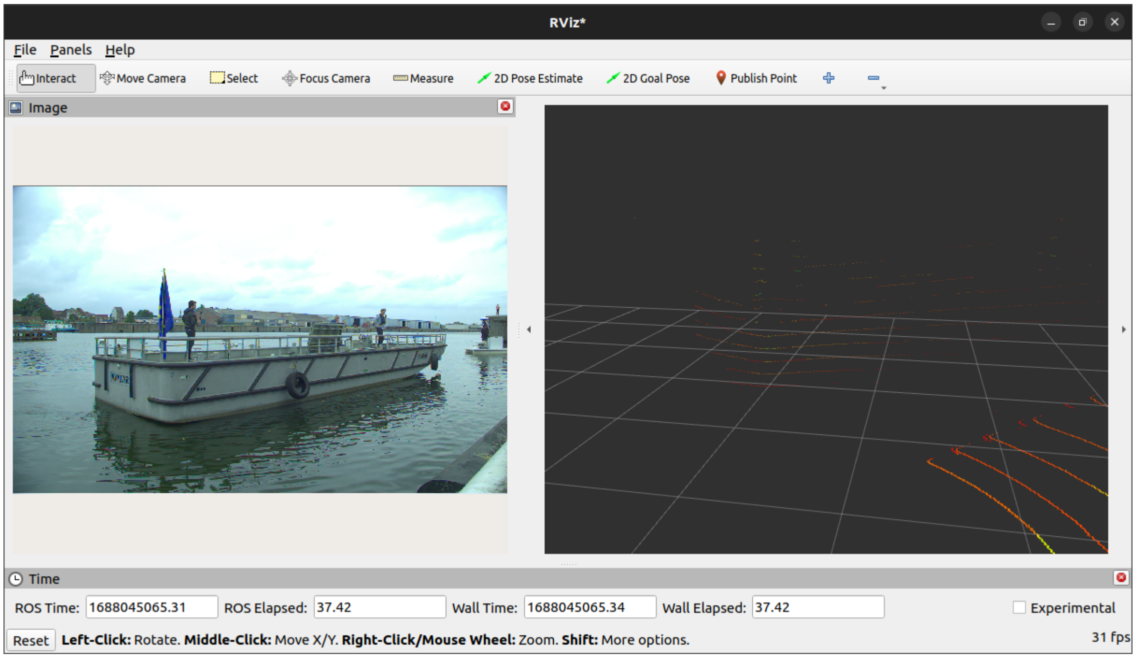

Figure 8: RVIZ display of monocular and LiDAR data of the AVATAR vessel in Gent.

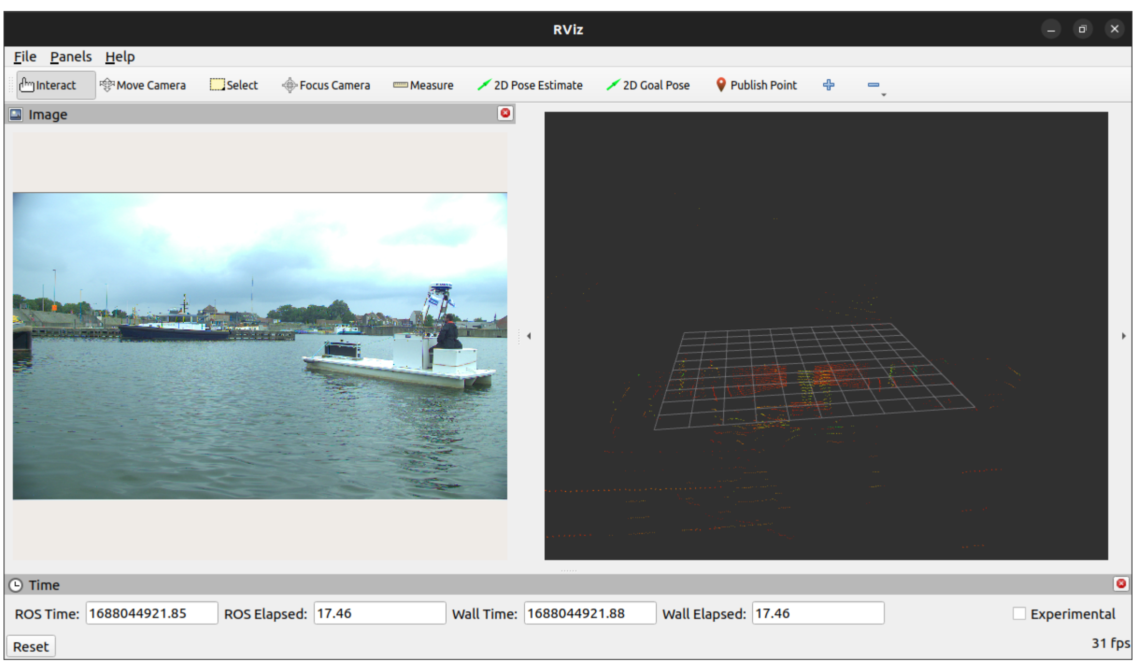

Figure 9: RVIZ display of monocular and LiDAR data of the Maverick (KU Leuven) vessel from onboard the AVATAR vessel in Gent.

5 Conclusion

This technical paper provides an overview of the Vision Sensorbox that has been developed in the ResearchLab Autonomous Shipping at TU Delft. The platform described in this work provides the capacity to gather vision and LiDAR data onboard full scale partner vessels. Such data sets will be utilised for the development of computer vision and AI algorithms for situational awareness in the field of autonomous inland shipping. The sensorbox also provides a platform to deploy these algorithms for realtime experimentation in the near future. The design of this sensorbox and its supplementary code is being offered open-source to the wider scientific community to catalyse research in this field. It is hoped that other researchers can find inspiration from this and even replicate the platform should they wish.

Acknowledgements

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Figure 10: The RAS Vision Sensorbox