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Version history

Version	Date	Person	Note
V0.1	04-03-18	Jesse Bouwman	
V0.2	14-03-18	Jonathan ten Hove	Review
V0.3	15-03-18	Jesse Bouwman	Minor changes

1. Preface

Before Willy can drive autonomic inside, Willy must be aware of his environment. Because GPS is not available indoors, another solution must be available. Autonomic driving will be supported by the current sensors on Willy such as the ultrasonic sensors and this research focusses on a separate technology that makes Willy more aware of his position.

2. Goal of indoor navigation

The goal of indoor navigation is that Willy can drive autonomously within a building where GPS is not available and be more aware of its surroundings. Willy needs a system which can recognize where it is located indoors. With this system Willy can drive indoors, follow a route or drive in a way that the coverage of the area is as high as possible for a detailed map and cleaning.

3. Compatibility requirements

The indoor navigation system needs to work with the other systems. Willy uses ultrasonic sensors to avoid obstacles. The ultrasonic sensors need to have priority above the navigation so Willy can never hit an obstacle. If the navigation needs to get somewhere behind an obstacle it needs to find an alternative route.

Another requirement is that when Willy is outside, GPS takes over the function of positioning. However the systems that work inside could help the ultrasonic sensors with avoiding obstacles.

Challenge of implementing indoor navigation

There are some challenges with implementing indoor navigation. In the first place we need the sensors. At the time of writing Willy has a Kinect as well as a SICK TIM-551 LiDAR available. However both are not implemented as of this moment.

Another challenge is that the system of Willy is already quite complicated because of the different modules. The benefit of the ROS-platform is that a new module could easily be installed. The communication goes via ROS where other modules are connected. However there is no way at this moment to connect new modules hardware-based. There are no open connections left for additional hardware.

4. Research

5. Different solutions

5.1. Kinect

A Kinect version 1 sensor has previously been used on Willy. It was used to recognize objects and people. Unfortunately the sensor is currently not implemented in Willy.

The Kinect could be used again and has a few very important features. A research of the previous group showed us that there is a newer version with better features. A problem with the newer version is that the Kinect V2 is not documented yet. This means that if we want to use the newer version we need to write it all ourselves. When using Kinect V1, almost everything we need is available. Another reason is that the newer version is a lot more expensive.

Feature	**Kinect 1**	**Kinect 2**
Color Camera	640 x 480 @30 fps	1920 x 1080 @30 fps
Depth Camera	320 x 240	512 x 424
Max Depth Distance	~4.5 M	8 M
Min Depth Distance	40 cm in near mode	50 cm
Depth Horizontal Field of View	57 degrees	70 degrees
Depth Vertical Field of View	43 degrees	60 degrees
Tilt Motor	yes	no
Skeleton Joints Defined	20 joints	25 joints
Full Skeletons Tracked	2	6
USB Standard	2.0	3.0

Table 1: Features of Kinect 1 & 2 (Willy, 2017)

Furthermore the first version of the Kinect is widely used with the ROS platform. Together with SLAM(Simultaneous Localization And Mapping) it can be used to make a 3D map of the environment.

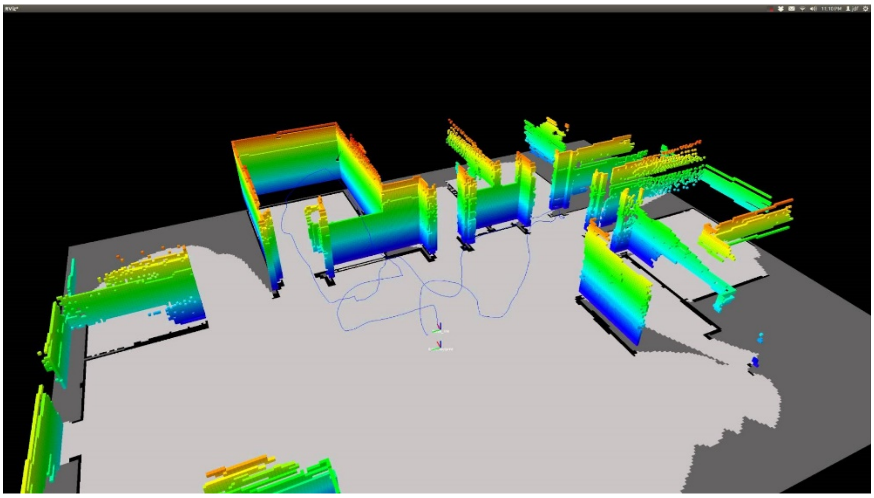

Figure 1: SLAM with Kinect v1

5.2. LiDAR

The LiDAR is a Light Detecting And Ranging sensor. It uses a laser to scan the environment. The one which is available for Willy is a SICK-TIM 551 LIDAR. (Sick , 2018)

This specific LiDAR has a field of view of 270 degrees and scans at a rate of 15Hz. The operation range is between 0.05m up to 10m.

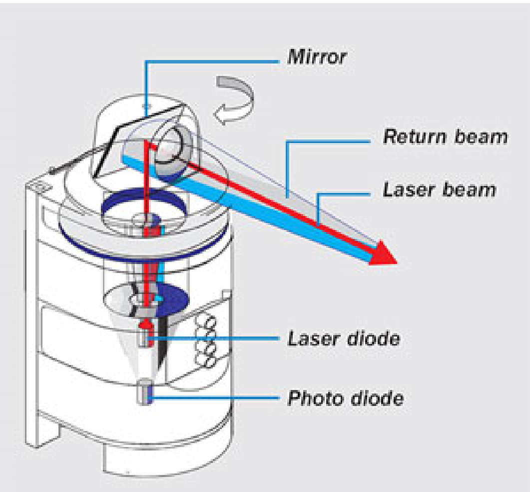

Figure 2: How a LiDAR works

Together with plotting software, for example RViz, Willy could make a map which then can be used for indoor navigation. A minor problem with a LiDAR like the SICK TIM-551 is that it can only create a 2D point cloud. It will not detect a table when the LiDAR is placed lower for example.

Another task for the LiDAR could be for safety. Because of the LiDAR being very fast at a 15Hz scanning rate, the SICK TIM-551 can be used for recognition of possible dangerous obstacles.

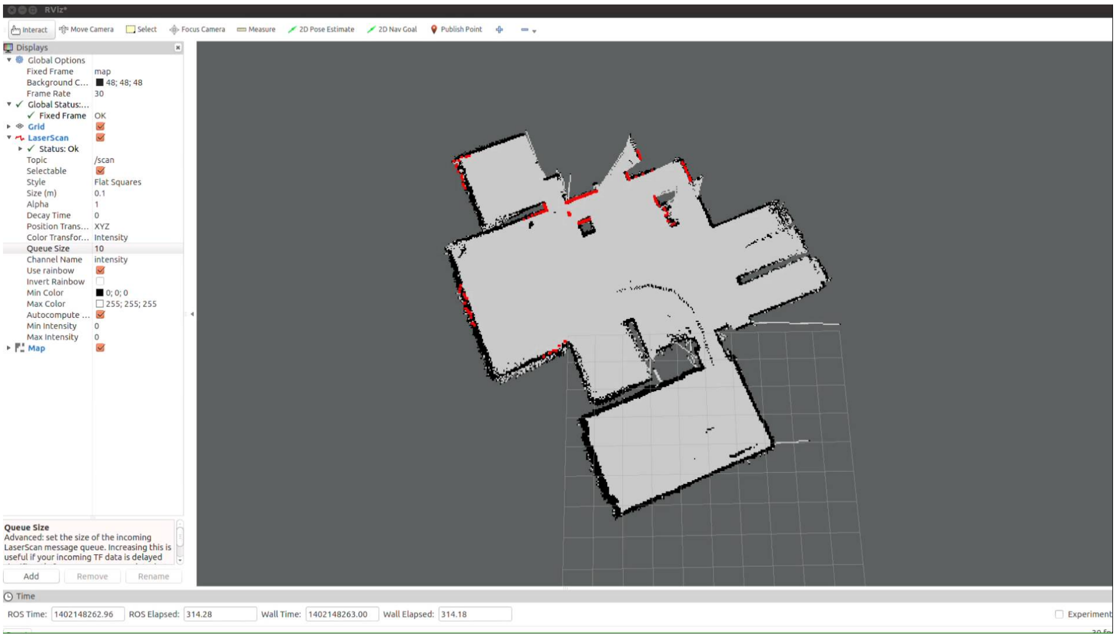

Figure 3: Plotting with RViz

5.3. Beacons

Beacons are small devices who emits signals. These signals can be detected by the robot to know where it is located based on signal strength. The beacons could use Bluetooth, Wi-Fi, radio signals and there even is a version which is using only light. With triangulation the distance to the beacons can be measured and the location will be determined.

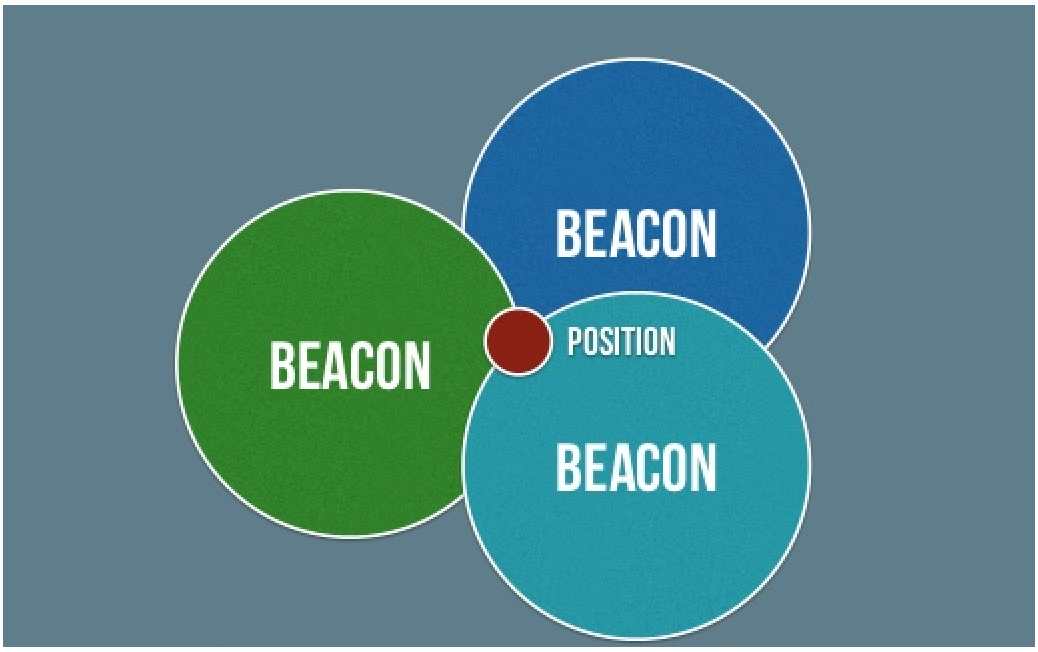

Figure 4: Triangulation for location measuring

5.4. Ultrasonic Sensors

Ultrasonic sensors are sensors that send and receive sound waves to measure the distance to an object. It calculates the time between sending and receiving a wave.

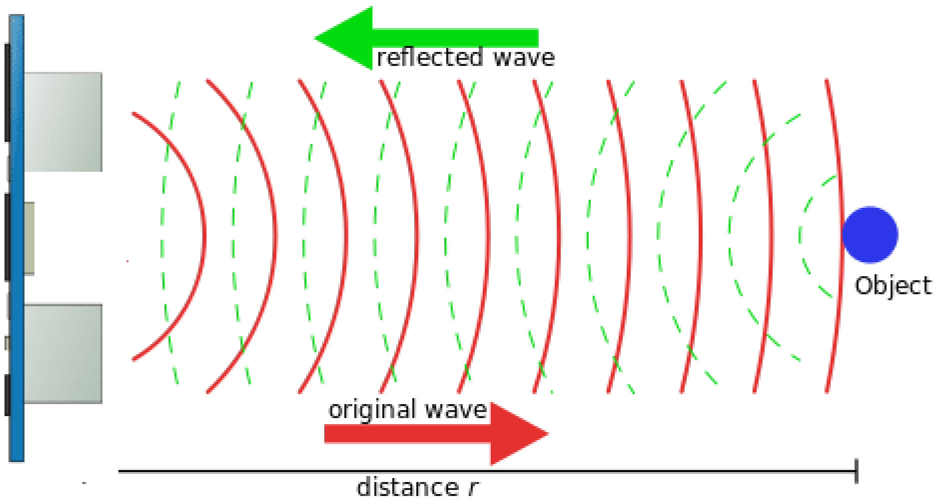

Figure 5: Working of ultrasonic sensors

There is however a problem when using ultrasonic sensors for mapping the area. Because the waves of sound are almost randomly cone shaped, the robot can't calculate distances as precise as for example LiDAR.

[Afbeeldingsresultaat voor ultrasonic sensor mapping]

Figure 6: Cone shaped sensor wave

In this example we see that these sensors could be used for warning before collision, because the cone only helps improve the coverage of the area. However for measuring distance and localization they cannot be used. But more effective for obstacle avoidance and preventing collisions.

6. Advantages by each solution

6.1. Kinect

- 3D point cloud
- High-resolution
- People recognition
- ROS integrated and widely documented
- Integrated camera

6.2. LiDAR

- 2D point cloud
- Fast (15Hz scanning frequency)
- 270 degrees Field of View
- Range (0.05-10m)

6.3. Beacons

- Cheap (around €30 for three modules)
- Reliable navigation
- High accuracy
- Ultrasonic sensors
- Cheap (< €5 per sensor)
- Easy to set up === Disadvantages by each solution

6.4. Kinect

- Difficult to set up
- Needs further research for implementation
- Small field of view
- Loose its recognition very fast
- Latency
- LiDAR
- Only one height is measured so it could not detect all obstacles (2D)
- Difficult to set up
- The version we have has 270 degrees Field of View while 360 degrees might be easier to work with
- Beacons
- Not usable without preparation inside the room
- Does not work without a very high amount of beacons
- Ultrasonic sensors
- Easy to fool. When the wave cone hit an object closer to the robot, the wrong distance is measured.
- Due to the cone shape, measurements are not reliable for mapping and localization
- More susceptible to interference

7. Conclusion

For the indoor navigation of Willy, a combination of options can be used. Because of the documentation which is available for the Kinect V1 and the fact that these are cheap, we will do a further investigating of using the Kinect on Willy.

As a second addition Willy can use the SICK TIM-551 LiDAR for safety as well as for navigation and localization purposes. We will do a further investigation in the use of this LiDAR.

The Beacons are not a preferred option because preparation of each room Willy needs to drive is necessary. Beacons make Willy less flexible.

The last suggestion for navigation, the ultrasonic sensors, will not be used for navigation. The sensors are betters used for obstacle detection and as a last safety measure for the robot.

7.1. Bibliography

Configuration Robot Localization. (n.d.). Retrieved from http://docs.ros.org/indigo/api/robot_localization/html/configuring_robot_localization.html Sick . (2018, 01 19). *Sick-TIM 551*. Retrieved from Sick sensor intelligence: https://www.sick.com/us/en/detection-and-ranging-solutions/2d-lidar-sensors/tim5xx/tim551-2050001/p/p343045Willy, P. 2. (2017). *Research Obstacle Detection V1.2*. Zwolle.