Volumetric 3D scene reconstruction using an humanoid robot eye-in-hand depth camera

Description:
A stable and persistent 3D image of a scene enables a humanoid robot to see in 3D and take the appropriate actions. Researchers are working on a deep learning system that takes a volumetric 3D scene as an input, and outputs the actions that the robot will execute. Today's depth cameras either have a low-resolution large field of view or high-resolution small field of view. By placing a depth camera in an eye-in-hand configuration, it is possible to provide both a high-resolution and large field of view and also avoid occlusions. For this project the student will use an Intel RealSense SR300 camera mounted on the wrist/forearm of a Baxter humanoid robot. The task is to move the robot arm over the entire scene and reconstruct a volumetric 3D image of the scene and project/embed this into a voxel space. The student will work together with researchers and a PhD-candidate to solve the task. The student may consider generic SDKs such as ReconstructMe, KinectFusion, DynamicFusion or Point Cloud Library, or implement his/her own method directly using the known pose of the eye-in-hand depth camera.

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Sensorsystemer og dataanalyse for inspeksjonsoppgaver


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Net-relative localization algorithm for fish cage inspection operation

Background:
Guidance, Navigation and motion Control (GNC) of underwater vehicles in addition to control of robot manipulators for aquaculture operations are in many aspects particularly complex. Vehicles operate in very demanding environments with currents, large waves and flexible structures changing geometry in an undetermined pattern. This implies that the vehicle has to navigate and plan trajectories relative to non-fixed structures, and also interact with them during maintenance operations. Commercial off-the-shelf technology for safe and efficient GNC systems to conduct inspection, maintenance and repair routines in such environments does not currently exist.
In modern aquaculture using gravity net cages, holes in the net and other type of net failures constitute a challenge with respect to fish escapes. Based on the Norwegian reports of escape incidents for salmon farming, more than two thirds of the registered escape incidents are related to holes in the net. One important
measure established to reduce escapees is a mandatory net inspection after all operations involving manipulations of the net and weighting system. For this purpose, Remotely Operated Vehicles (ROVs) have proven to be a safe, robust and cost efficient alternative to divers. The purpose of this assignment is to determine the ROVs position and attitude relative to the net using computer vision methods in order to precisely determine what part of the cage is depicted in inspection videos.

**Assignment:**
The project consists of the following tasks:
- Survey the literature for previous solutions to relative localization.
- Make further developments to the SINTEF VIND localization system to include relevant measurements.
- Develop relevant computer vision algorithms to measure net-relative motion.
- Fuse the measurement from the computer vision algorithms with other relevant measurements to robustly estimate the net-relative motion in the entire cage volume. The algorithm should be tested in a simulated environment with several sensor configuration to find the best with respect to performance and cost.
- Perform tests with real-world data.

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**Optimal camera calibration and disparity map extraction for underwater robotic vision**

**Description:**
Camera calibration and disparity map extraction for 3D scene reconstruction is a well studied subject in Computer Vision and many approaches are proposed achieving very accurate results. However, very little has been published for underwater applications, where cameras are placed in waterproof housings (attached to unmanned vehicles), featuring a flat glass port through which the scene is viewed. Light passing from the media water through the media glass into air is distorted by a non-linear process called refraction, recorded objects in the scene might be blurred due to forward scattered light from both the source and object, as well as light scattered back from the medium (backscatter). This causes inaccuracy for the parameter estimation during the camera calibration procedure, where the intrinsic and extrinsic parameters of a camera model are estimated and therefore inaccuracy for the disparity extraction, where the distance between two corresponding points in the left and right image of a stereo pair are computed in order to estimate 3D information of the recorded scene.

This project consists of two main parts: Finding the optimal setup (regarding calibration pattern, camera, illumination, distortion models) for underwater camera calibration and disparity computation leading to maps for 3D reconstruction using different methods known in the literature.

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Fitting meshes of (known flexible objects) to noisy point-clouds

Current 3D measurements of objects result often in noisy point-clouds. The aim of this project is to find/identify known objects by fitting meshes of these objects to appropriate sub-parts of the measured point-cloud.

Evaluating underwater measurements are of particular interest within this project. Noisy 3D data from a Time of Flight camera showing fishes and 3D points obtained from stereo-camera-recordings of fishes are available and can be used as test case. There a generic fish-model-mesh has to be fitted to computed candidate positions.

The following listed preliminary tasks are likely necessary to solve the given problem and to analyze the results of the developed solution within this project.

**The pre-project the main tasks are:**
- Perform a Literature study
- Evaluate possible pre-processing steps for filtering 3D point clouds for removing as much noise as possible.
- Create ground-truth data for later performance analysis
- Evaluate which methods can be used for finding candidate locations
- Fit the known objects to the found candidate locations

**The associated master project has the following main aims:**
- Evaluate matching methods based on features in 3D point-clouds/meshes
- Identify the Objects found in 3D point clouds.
- Evaluate which pre-knowledge (in terms of smoothness, detected features) of the objects is most valuable.
- The limitations and robustness of the developed approach should be evaluated as well.

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Fish detection and tracking utilizing video recordings from large-scale aquaculture sea cages

**Description:**
Documentation of fish welfare and state estimates at large scale aquaculture farming sites is a very challenging and difficult task. In order to record behavioral, health and biomass aspects it is of importance to create a system that is able to detect and follow individual fish as well as fish groups, image fish deformation, skin damage, sea lice and deceases in high resolution detail. Utilizing 3D imaging technology which produces high quality video footage can be one way to approach this issue.

In this project imaging technology developed by SEALAB AS will be used to generate high quality video footage for fish detection and tracking purposes. If time allows approaches for welfare indicator detection and classification can be addressed.

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Occlusion aware 3D measurements of fish in large-scale aquaculture sea cages

Description:
Video footage taken at large-scale aquaculture sea cages which contain a volume of approximately 40,000 m³, and hold up to 200,000 individual fish each is characterized amongst other features by occlusion of fish. Evaluating underwater measurements are of particular interest for gaining data from fish-cages used by the aquaculture-industry but are also more challenging compared to recordings taken with lab-conditions in the air. Classical difficulties in Image Processing and Computer Vision arise for example from noise, reflections, transparency and occlusion which also may result in practical limitations of how to design the experiments in an optimal way. The aim of the study is to calculate and evaluate the 3D measurement of fish taken by a stereo (and/or plenoptic) camera underwater with respect to occlusion. Computer vision techniques will be evaluated to address the problem of occlusion leading to more robust 3D measurements of fish.

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