

Development of a perception system for indoor environments

[Technology](#), [Computer](#)



Autonomous navigation is a well-known task in robotic research. It is associated to get the environmental information such as visual images or distance or proximity measurements from external sensors and to detect obstacles and measure the distance to objects close to the robot path[10, 35].

Most robots are equipped to distance sensors like ultrasonic, laser or infrared to be able to move through corridors and to follow walls in indoor environments.

A[A1] control algorithm based on odometric sensorial information and distance measurements supplied by sonar sensors was developed to guide a mobile robot moving along a corridor or following a wall in [3]. The[A2] Probabilistic Neural Network (PNN) structure was evaluated for wall following task using ultrasound sensors in [17].

a mobile robot control law for corridor navigation and wall-following, based on sonar and odometric sensorial information is proposed. The control law allows for stable navigation avoiding actuator saturation. The posture information of the robot travelling through the corridor is estimated by using odometric and sonar sensing.

The[A3] ultrasonic sensors were also used to measure and obtain the distance and orientation of a robot utilizing a Fuzzy Incremental Controller (FIC) for controlling a wall follower robot [10].

Trajectory tracking task is an especial task of wall following which is no obstacle like walls to detect. So, distance sensors like sonar or infrared could not help the robot to follow the trajectory.

Control[A4] algorithms based on vision sensors have also been introduced for indoor navigation. For example, a robot utilized a vanishing point of lines extracted from the corridor structure in order to identify the heading direction. But, a complex mathematical calculation is needed to capture the vanishing point [37].

A[A5] CCD color camera was used to control the position of a robot while it navigated towards a target position [15]. The images of this camera were processed and the visual features of environment were fed through a neural network to enable a mobile robot to identify its own position. The task of orientation recognition was applied in order to follow a path in environment, too.

The[A6] 3D trajectory estimation for unknown outdoor environments was investigated in [31]. This estimation was based on vision information captured by a trinocular stereo camera that is mounted on the robot. No prior map was used and the trajectory is found by tracking and detecting relative changes in the position of features extracted from images.

Most techniques used complex mathematical equations and models of the operating environment to achieve the ability to move through corridors, to follow walls, to turn corners and to enter open areas of the rooms for an indoor navigation task [7].

Researchers[A7] used vision sensors to detect trajectory and to design their steering control law using the kinematic equations of motion[13, 34]. In these works which were considered in an off-road environment, the robot used both laser range finder and stereo vision. The laser was used to scan the close front ground for analyzing its roughness, and stereo vision apperceived drivable situation of far front ground. The path planning was performed using the data acquired from these sensors.

Among three processes applied in outdoor navigation, including perception, planner, and motion control module, these works were focused on the decision of control laws of the robot, i. e. the longitudinal velocity, the lateral velocity, and the angles of sensor pan-tilts. The controller uses the information prepared by the planner. The characteristics of terrain like coefficient of longitudinal rolling resistance and the coefficient of lateral friction are known, and a description of trajectory space is presented according to the robot's dynamic analysis.

The[A8] Reinforcement Learning (RL) was applied to control a wall follower robot for learning reactive behaviors[30]. The environment is perceived in 3D using a stereo and mono vision. In this work, the images are processed to reduce the amount of relevant information and a small occupancy grid with 9 cells is created to discretize the state space. The controller utilized Q-learning technique and the action space was discrete, too.

The most considerable works which have yet been done in outdoor robot navigation have constructed a grid map to determine the traversability of

the terrains. The classical methods focus on a binary representation of the terrain from an obstacle occupancy point of view.

Another approach is to characterize the presence of an obstacle in a grid cell by giving a continuous value. This value represents the probability distribution for occupancy of the grid cell by an obstacle. The more comprehensive methods evaluate terrain characteristics, too[9, 33]. For example, traversability is defined as a non-binary mathematical function of the slope and roughness of the terrain for each cell [18].

This traversability degree has not been interfered to robot local control directly and it has just been used in the path planner. They use some systems like GPS to find their locations and measure the distance they moved through.

Kinect[A9] sensor was used to capture 3D point cloud data of outdoor environment in [28]. This data were fed to a 3D Simultaneous Localization and Mapping (SLAM) algorithm to localize the robot in the environment. This point cloud was projected into a 2D plane to make a 2D SLAM algorithm applicable, too. According to this research, the advantages of Kinect sensor are a considerably lower price, and the inclusion of color into the maps in compared to conventional laser scanners.

A[A10] system with two main parts was applied on surveillance mobile robot and enable it to have an autonomous navigation [4]. One part is a reactive navigation system. It used Kinect data to avoid obstacles. In this part, the depth map with one row and 5 columns was created using each depth image

and pixel intensity of three cells (left, front and right) are analyzed to compute the absolute minimum and maximum distances between sensor and obstacles. Eight different situations and their relevant action commands are determined. A classifying system trained possible situations of an indoor environment using Kinect data in second part of the system.

[A1]a mobile robot control law for corridor navigation and wall-following, based on sonar and odometric sensorial information is proposed. The control law allows for stable navigation avoiding actuator saturation. The posture information of the robot travelling through the corridor is estimated by using odometric and sonar sensing.

[A2]In particular we deal with the well-known strategy of navigating by “wall-following”. In this study, probabilistic neural network (PNN) structure was used for robot navigation tasks.

The provided files comprise three different data sets. The first one contains the raw values of the measurements of all 24 ultrasound sensors and the corresponding class label. Sensor readings are sampled at a rate of 9 samples per second.

[A3]The robot navigation is based on wall following algorithm. The robot is controlled using fuzzy incremental controller (FIC) and embedded in PIC18F4550 microcontroller. FIC guides the robot to move along a wall in a desired direction by maintaining a constant distance to the wall. Two ultrasonic sensors are installed in the left side of the robot to sense the wall distance. The wall following control of the autonomous robot has been

presented using ultrasonic sensors. The sensor data are used to measure and obtain the distance and orientation of the robot

[A4]Some control algorithms based on artificial vision have been introduced, where the robot is allowed to move by following the wall in the corridor like the one introduced by Durrant-Whyte et al.

In other research work, Zhou et al. [20] let the robot in their work to identify the heading direction through a vanishing point of lines extracted from the corridor structure. The lines look like they are scattering from one point in the image of the corridor. This 'one point' is the vanishing point. Although it looks easy to extract the lines, but capturing the vanishing point require a complex mathematical calculation.

[A5]The problem of controlling the pose of a mobile robot with respect to a target position by means of visual feedback is investigated mainly. The proposed method enables a mobile robot to identify its own position using visual features of environment. At the same time, the robot performs an orientation recognition using the same recognition method of position identification in order to follow a path in environment

We developed a visual perception navigation algorithm where the robot is able to recognize its own position and orientation through robust distinguishing operation using a single vision sensor.

[A6]This paper describes ongoing research at the University of British Columbia on the problem of real-time purely vision based 3D trajectory

estimation for outdoor and unknown environments. The system includes an inexpensive trinocular stereo camera that can be mounted anywhere on the robot. It employs existing scene information and requires no prior map, nor any modification to be made in the scene.

[A7]

Autonomous mobile robot achieves outdoor navigation by three processes, including the environment information acquired by the perception module, the control decision made by the planner module, and the motion plan performed by the motion control module[8]. Consequently, for safe and accurate outdoor navigation it is vital to harmonize the three modules performance. In this paper, the emphasis is focused on the decision of control laws of the robot, and objects include the longitudinal velocity, the lateral velocity, and the angles of sensor pan-tilts.

In an off-road environment, the robot uses laser range finder (LRF) with one degree of freedom (DOF) pan-tilt (only tilt) to scan bumpy situation of the close front ground, on which the robot is moving, and employs stereo vision with two DOF pan-tilt to perceive drivable situation of far front ground. With the data accessed from laser and vision sensors, the passable path can be planned, and the velocities of left side and right side of the robot can be controlled to track the path, consequently, the robot off-road running is completed

In this paper, a description of trajectory space[7] is presented according to the robot's dynamic analysis, which is defined as the two-dimensional space of the robot's turning angular speed and longitude velocity.

[A8]This article describes the development of a wall following behaviour using a methodology for the learning of visual and reactive behaviours with reinforcement learning. With the use of artificial vision the environment is perceived in 3D, and it is possible to avoid obstacles that are invisible to other sensors that are more common in mobile robotics.

the image is divided into a grid made up of 3 rows and 3 columns (Fig. 2(c)) for codification. Each cell will have either free or occupied label, depending on the number of edge pixels it contains. Thus defined, the state space is 29, and in order to reduce it, it is supposed that if a cell in one of the columns is occupied, all those cells above it are also occupied.

[A9]In this paper we investigate the suitability of the Xbox Kinect optical sensor for navigation and simultaneous localisation and mapping. We present a prototype which uses the Kinect to capture 3D point cloud data of the external environment. The data is used in a 3D SLAM to create 3D models of the environment and localise the robot in the environment. By projecting the 3D point cloud into a 2D plane, we then use the Kinect sensor data for a 2D SLAM algorithm. We compare the performance of Kinectbased 2D and 3D SLAM algorithm with traditional solutions and show that the use of the Kinect sensor is viable.

Our research indicates that the Kinect is a viable option for use as a sensor for mobile robotic navigation and SLAM. It offers significant advantages over conventional laser scanners, such as 3D model building, pure visual SLAM, a considerably lower price, and the inclusion of colour into the maps.

[A10] This paper presents the development of a perception system for indoor environments to allow autonomous navigation for surveillance mobile robots. The system is composed by two parts. The first part is a reactive navigation system in which a mobile robot moves avoiding obstacles in environment, using the distance sensor Kinect. The second part of this system uses an artificial neural network (ANN) to recognize different configurations of the environment, for example, path ahead, left path, right path and intersections. The ANN is trained using data captured by the Kinect sensor in indoor environments. This way, the robot becomes able to perform a topological navigation combining internal reactive behavior to avoid obstacles and the ANN to locate the robot in the environment, in a deliberative behavior