

W. K. Tou, M. I. Vai and S. U. Cheang, "Elevator absolute landing position sensor using infrared interrupter and MEMS accelerometer," *2015 5th Australian Control Conference (AUCC)*, Gold Coast, QLD, 2015, pp. 366-370.

Abstract: Absolute encoder is a common solution to detect the position of elevator cabin in a reliable way, yet it require extra cabling and chain to accomplish the work. The installation and maintenance cost is the main trade-off. However, absolute position is only required by certain cases such as re-leveling. This is a situation where loading of the elevator cabin changes makes the elevator steel rope extends. The worst situation for a high-rise building may have more than 10 mm shifting in the elevator cabin platform. Such an offset between the cabin platform and floor level can stumble passenger boarding or disembarking. In this proposed design, a linear position sensor detecting the position of landing zone vane is targeted to provide position sensing resolution up to 0.01 mm with maximum of 1mm error, using traditional infrared interrupter and new MEMS accelerometer. The device can help to improve motion control of the elevator with its high resolution and high accuracy to prevent position overshooting and steady state error. Kalman filter is employed to fusion the detected position and acceleration signal and outputting a clean and reliable position reading to the elevator motion control system.

keywords: {Kalman filters;accelerometers;cables (mechanical);interrupters;lifts;micromechanical devices;motion control;sensors;Kalman filter;MEMS accelerometer;absolute encoder;acceleration signal;cabling;elevator absolute landing position sensor;elevator cabin platform;elevator cabin position;elevator motion control system;elevator steel rope;high-rise building;linear position sensor;position detection;steady state error;traditional infrared interrupter;Accelerometers;Blades;Detectors;Elevators;Interrupters;Kalman filters;Micromechanical devices;Kalman filter;MEMS Accelerometer;elevator;infrared sensor;linear position sensor;re-leveling},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7361964&isnumber=7361892>

M. A. Balug, T. Špoljarić and G. Vujisić, "Laboratory model of the elevator controlled by ARDUINO platform," *2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, Opatija, 2017, pp. 1562-1565. doi: 10.23919/MIPRO.2017.7973670

Abstract: This paper presents methods for regulating the elevator's cabin speed and position for purposes of traffic control. It contains four stations. On every station there are two position sensors and cabin call button. Cabin speed regulation is realized with microcontroller, incremental encoder and chopper, where chopper controls DC motor speed. A simple traffic control is written for ARDUINO platform.

keywords: {DC motors;choppers (circuits);lifts;microcontrollers;position control;traffic control;velocity control;ARDUINO platform;DC motor speed;chopper;elevator cabin speed;elevator control;elevator position;incremental encoder;laboratory model;microcontroller;traffic control;DC motors;Elevators;Microcontrollers;Pulse width modulation;Sensors;Traffic control;Transfer functions},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7973670&isnumber=7973374>

M. A. Mahmud, M. S. Aman, H. Jiang, A. Abdelgawad and K. Yelamarthi, "Kalman filter based indoor mobile robot navigation," *2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, Chennai, 2016, pp. 1949-1953. doi: 10.1109/ICEEOT.2016.7755029

Abstract: This paper focuses on navigation of a mobile robot in an indoor environment. Accuracy is an important issue in robot navigation. Thus, many approaches for mobile robot navigation have been proposed to improve the navigation accuracy. This paper presents work aimed to navigate a mobile robot, which uses wheeled encoder as a sensor. While using wheel encoder the robot is commanded to move along certain paths like an octagon, rectangle and its coordinates and travelled distances are monitored. The wheel encoder gives us Cartesian coordinate and orientation of the robot. The encoder accumulates error over time. Thus, a Kalman filter is proposed to minimize this error. The Kalman filter estimates the next position based on robot's action, like velocity, acceleration etc and sensor's output. The error made by both encoder and the Kalman filter is measured. Experimental results show that Kalman filter improves the accuracy.

keywords: {Kalman filters;distance measurement;indoor navigation;mobile robots;path planning;Cartesian coordinate;Kalman filter;indoor mobile robot navigation;navigation accuracy;octagon;odometry;paths;rectangle;robot orientation;sensor;wheeled encoder;Kalman filters;Mobile robots;Navigation;Robot kinematics;Robot sensing systems;Wheels;Kalman filter;Odometry;Robot Localization;Wheel encoder},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7755029&isnumber=7754737>

R. Mardiyanto, J. Anggoro and F. Budiman, "2D map creator for robot navigation by utilizing Kinect and rotary encoder," *2015 International Seminar on Intelligent Technology and Its Applications (ISITIA)*, Surabaya, 2015, pp. 81-84. doi: 10.1109/ISITIA.2015.7219957

Abstract: 2D map creator for robot navigation is used for robot to move around the surrounding without any collision. Typical robot navigation is relied on ultrasonic sensor as well as rotary encoder. In this paper, we present 2D map creator system for robot navigation based on Kinect device and rotary encoder. 2D map creator system allows robot for self-mapping the surrounding area while robot is moving around. The output is a 2-dimensional (2D) map representing areas that have been passed by the robot. Next, the map is used by robot to return to home automatically. Moreover, we present a technique in map creator system for robot navigation. The Kinect device and rotary encoder are placed on the robot. The depth image is utilized to distinguish between obstacle and non-obstacle object. The combination between depth image and rotary encoder produce a 2D map used for robot navigation. We use Dijkstra algorithm for calculating the shortest way between robot positions and home position. Our system has been tested under laboratory environment. The effective distance range is 60 to 600 Cm. Our rotary encoder sensor is also successfully realized and has average error 5.05%. Our 2D map creator required 1.46 second for every creating map at one location. Also, it has 2.23% of error distance on 2D map. All experiment results show that our 2D map creator is ready for performing return to home automatically.

keywords: {collision avoidance;image sensors;mobile robots;robot vision;ultrasonic devices;2D map creator system;Dijkstra algorithm;Kinect device;depth image;nonobstacle object;obstacle object;robot navigation;rotary encoder;ultrasonic sensor;Acoustics;Collision avoidance;Measurement uncertainty;Mobile robots;Navigation;Robot sensing systems;2D map;kinect;return to home;robot navigation;rotary encoder},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7219957&isnumber=7219932>

G. Wang, J. Qi, J. Xu, X. Zhang and D. Xu, "Antirollback Control for Gearless Elevator Traction Machines Adopting Offset-Free Model Predictive Control Strategy," in *IEEE Transactions on Industrial Electronics*, vol. 62, no. 10, pp. 6194-6203, Oct. 2015. doi: 10.1109/TIE.2015.2431635

Abstract: Direct-drive permanent magnet traction systems have become the trend of modern elevators. Elevator traction machines tend to use low-resolution incremental encoders as position and speed feedback devices because of their low cost. To prevent the occurrence of elevator car rollback for the gearless elevator installed with an incremental encoder with general resolution, a weight-transducerless starting torque strategy based on offset-free model predictive control is proposed. Under the condition of low-resolution incremental encoders, this control strategy can achieve a fast dynamic response and no mechanical vibration during the mechanical brake releasing. The electromagnetic torque generated by the machine can quickly balance the uncertain load torque to minimize the sliding distance of the elevator car, which contributes in achieving superior riding comfort. In order to overcome the mismatch of the predictive model caused by the uncertainty and nonlinearity of the mechanical model of the traction system, as well as intense disturbance, a model corrector is added to adjust the mismatched predictive model. The steady-state speed error can be eliminated by adding the equivalent disturbance estimator to the predictive model during the zero-servo operation at elevator startup. Finally, both simulation and experimental results are provided to verify that the proposed control strategy can achieve shorter sliding distance, smaller sliding speed, and faster dynamic response.

keywords: {automobiles;brakes;control nonlinearities;dynamic response;lifts;permanent magnet machines;predictive control;traction motor drives;uncertain systems;antirollback control;direct drive permanent magnet traction system;dynamic response;electromagnetic torque generation;elevator car;equivalent disturbance estimator;gearless elevator traction machine;incremental encoder;mechanical brake;mechanical model nonlinearity;mechanical model uncertainty;mismatched predictive model;model corrector;modern elevator;offset free model predictive control strategy;position feedback device;speed feedback device;uncertain load torque;zero-servo operation;Electromagnetics;Elevators;Load modeling;Predictive control;Predictive models;Steady-state;Torque;Anti-rollback;Antirollback;Gearless elevator;gearless elevator;off-set free model predictive control;offset-free model predictive control (MPC);permanent magnet traction machine;permanent-magnet traction machine;riding comfort;weight transducerless},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7105881&isnumber=7247793>

D. J. Lee, Y. M. Yun, Y. S. Hwang and J. M. Lee, "2D grid map building using ICP algorithm and line extraction," *2014 14th International Conference on Control, Automation and Systems (ICCAS 2014)*, Seoul, 2014, pp. 852-855.

doi: 10.1109/ICCAS.2014.6987899

Abstract: This paper suggests using the ICP(Iterative Closet Point) algorithm to create a 2D map and using line extraction to calibrate line error. The data used in two-dimensional map is only obtained by sensor of mobile robot. The robot can build a 2D map by using data currently through value of encoder, but this method is difficult to calibrate because of difference of distance from value of sensor. Through this, it is occurred wrapping and distortion of map. In order to calibrate position error about this part, distance is calibrated by ICP algorithm and line extraction.

keywords: {calibration;feature extraction;image sensors;iterative methods;mobile robots;robot vision;2D grid map building;ICP algorithm;iterative closet point algorithm;line extraction;map distortion;mobile robot sensor;position error calibration;two-dimensional map;Equations;Films;Laser modes;Robot kinematics;ICP (Iterative Closet Point) algorithm;Laser scanner;Line extraction;Map building},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6987899&isnumber=6987542>

B. Han, I. W. Jeong, Y. H. Seo and H. S. Yang, "Hybrid Scheme of Localization and Map Building with a LRF and a LPS for a Mobile Robot Navigation," *2011 International Conference on Information Science and Applications*, Jeju Island, 2011, pp. 1-6.

doi: 10.1109/ICISA.2011.5772353

Abstract: Localization and map building in an indoor environment are important problems for a mobile robot. There are two approaches to these problems: a metric approach and a topological approach. The metric approach uses various range sensors to determine the distance between an obstacle and the robot for the precise localization of a robot; the topological approach gives the robot its state on the basis of landmarks. Because both approaches have some advantages and disadvantages, researchers in the field of mobile robotics have combined the two approaches so that the robot can explore the environment autonomously. This so called hybrid approach still requires certain types of additional odometric information for rapid convergence of positioning the robot as well as information on landmark recognition. To build a more accurate map and to localize precise the position and orientation of the robot, we use a local positioning sensor to compensate for the accumulation of wheel encoder errors and landmark recognition errors. In this paper, we propose a new way of fusing a laser range finder, a local positioning sensor, and wheel encoders. The experimental results confirm that the robot can construct its own environment and localize itself accurately and consistently.

keywords: {collision avoidance;distance measurement;laser ranging;mobile robots;position control;LPS;LRF;indoor environment;landmark recognition error;laser range finder;local positioning sensor;map building;mobile robot navigation;mobile robotics;odometric information;positioning convergence;robot localization;robot orientation;robot position;wheel encoder error;Buildings;Mobile robots;Robot kinematics;Robot sensing systems;Wheels},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5772353&isnumber=5772305>

J. Qi, S. Zhang, Y. Yu, Y. Li and Y. Xu, "Experimental analysis of ground speed measuring systems for the intelligent agricultural machinery," *2010 Seventh International Conference on Fuzzy Systems and Knowledge Discovery*, Yantai, 2010, pp. 668-671.

doi: 10.1109/FSKD.2010.5569415

Abstract: Measuring machine's speed precisely is quite critical for intelligent agricultural machinery. With Advanced RISC Machines (ARM) as the speed measurement terminal, speed measurement precision was tested and studied when the sensor was served by the encoder, inductance near-switch, doppler-radar and Global Positioning System (GPS) in the Autumn-ploughed farmland. In a 40m-long testing distance, the measurement precision of the above sensors was tested when the tractor driving at 4.0km/h, 5.0km/h and 6.0km/h. After the measured speed data were contrasted to the theoretical data, the result proves that the coefficient of variation (CV) of GPS is the highest; the data from the radar is most close to the theoretical data with the error of 2.03%; the biggest error of the inductance near-switch is 2.82%; the biggest error of the encoder is 2.85%. The performance price ratio of the inductance near-switch is the highest among the four, and it can meet the requirement of intelligent agricultural machinery.

keywords: {Global Positioning System;agricultural machinery;microprocessor chips;reduced instruction set computing;velocity measurement;ARM microprocessor;advanced RISC machine;doppler radar;global positioning system;ground speed measurement;inductance near switch;intelligent agricultural machinery;variation coefficient;Agricultural machinery;Extraterrestrial measurements;Global Positioning System;Inductance;Inductance measurement;Radar measurements;ARM microprocessor;ground speed;intelligent agricultural machinery;speed sensor},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5569415&isnumber=5569069>

H. Qasem, O. Gorgis and L. Reindl, "Design and calibration of an inertial sensor system for precise vehicle navigation," *2008 5th Workshop on Positioning, Navigation and Communication*, Hannover, 2008, pp. 229-231.
doi: 10.1109/WPNC.2008.4510379

Abstract: This paper presents a developed inertial navigation multi sensor node, along with an efficient calibration technique to improve the accuracy of the measurement acquired from a set of inertial sensors and magnetic encoder. The implemented node consists of a high resolution magnetic compass sensor, a distance sensor works as magnetic encoder, an accelerometer and a gyroscope to detect the linear and angular acceleration. The node is installed on an autonomous mobile vehicle as part of an inertial system to find the real-time position and direction of the vehicle. RF wireless transceivers and a microcontroller are installed to process and to send the measured data wireless to a central processing unit for more processing and evaluation. The whole hardware and software design of the system is presented. Accuracy and calibrations issues are also discussed. Errors caused by bias, scale factors and nonlinearities in the sensor readings which cause accumulations in navigation errors with time are considered.

keywords: {accelerometers;automobiles;calibration;gyroscopes;navigation;transceivers;wireless sensor networks;RF wireless transceivers;accelerometer;angular acceleration;autonomous mobile vehicle;data wireless;distance sensor works;gyroscope;hardware design;high resolution magnetic compass sensor;inertial navigation multisensor node;inertial sensor system calibration;inertial sensor system design;inertial system;linear acceleration;magnetic encoder;microcontroller;precise vehicle navigation;software design;Acceleration;Accelerometers;Calibration;Gyroscopes;Inertial navigation;Magnetic sensors;Mobile robots;Remotely operated vehicles;Sensor systems;Wireless sensor networks;Indoor precise navigation;Inertial sensors Wireless sensor node;Sensor fusion},
URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4510379&isnumber=4510344>

O. Real-Moreno *et al.*, "Accuracy improvement in 3D laser scanner based on dynamic triangulation for autonomous navigation system," *2017 IEEE 26th International Symposium on Industrial Electronics (ISIE)*, Edinburgh, 2017, pp. 1602-1608.
doi: 10.1109/ISIE.2017.8001486

Abstract: Autonomous navigation has been an important task in recent years to keep track of vehicles location, to provide safety and accuracy on its trajectory and to see their surroundings and predict if it is possible to travel across them. In this paper, a method to improve accuracy on laser vision systems based on dynamic triangulation for mobile robots is proposed. This laser vision system consists on a positioning laser, a scanning aperture and a fixed distance between them. The positioning laser points a laser beam over a surface and it is detected by the scanning aperture. The proposed method to improve accuracy on laser vision systems relies on the scanning aperture; current designs calculate the detection angle counting the pulses of a pulse train across a motor rotation. The disadvantage of this method is that the angular velocity of the motor may vary, resulting in an incorrect calculation of the angle of detection. In the proposed method, a new signal provided by an encoder is used to reduce the error generated by variations in angular velocity.

keywords: {angular velocity measurement;measurement by laser beam;mobile robots;navigation;optical scanners;3D laser scanner;angle calculation;angular velocity;autonomous navigation system;detection angle calculation;dynamic triangulation;encoder;laser beam;laser vision system;mobile robot;motor rotation;positioning laser;scanning aperture;Apertures;Laser beams;Machine vision;Mirrors;Mobile robots;Sensors;Surface emitting lasers;autonomous navigation;laser;scanner;scanning aperture;triangulation},
URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8001486&isnumber=8000791>

M. Mashali, R. Alqasemi, S. Sarkar and R. Dubey, "Design, implementation and evaluation of a motion control scheme for mobile platforms with high uncertainties," *5th IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics*, Sao Paulo, 2014, pp. 1091-1097.
doi: 10.1109/BIOROB.2014.6913926

Abstract: In this work, we present a motion control scheme for a robotic mobile platform using low-cost vision sensor to update encoder values. We track the pose of a power wheelchair using wheel encoders along with a Microsoft Kinect camera. Two methods of pose estimation are implemented and tested. These methods are a) encoder-based odometry and b)ICP(Iterative Closest Point)-based updated odometry. We evaluate the performance of each method using precise wheelchair pose ground truth data acquired via a state-of-the-art VICON® system with eight motion capture cameras. Offline data processing is performed to refine the ICP parameters and estimate the covariance matrices of the Kalman filter. The offline data processing results demonstrate that our ICP-based updated odometry has very accurate pose tracking. By implementing our control scheme, the position error is improved by a factor of 15 and the localization orientation error is improved by a factor of 13. In online implementation, there was 4 times improvement for both position and orientation angle estimation. To demonstrate the robustness of our approach, we apply it for online obstacle avoidance. A wheelchair-mounted robotic arm (WMRA) is also included in this platform and will be used for future work on combined mobility and manipulation control with sensor assistance.

keywords: {Kalman filters;cameras;collision avoidance;covariance matrices;distance measurement;image sensors;iterative methods;mobile robots;motion control;pose estimation;robot vision;uncertain systems;wheelchairs;ICP parameter estimation;ICP-based updated odometry;Kalman filter;Microsoft Kinect camera;VICON system;WMRA;covariance matrices;encoder-based odometry;iterative closest point-based updated odometry;low-cost vision sensor;manipulation control;mobility control;motion capture cameras;motion control scheme;offline data processing;online obstacle avoidance;pose estimation;power wheelchair;robotic mobile platform;sensor assistance;wheel encoders;wheelchair-mounted robotic arm;Covariance matrices;Estimation;Iterative closest point algorithm;Motion control;Robot sensing systems;Wheelchairs;Wheels},
URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6913926&isnumber=6913735>

E. Munoz Diaz, O. Heirich, M. Khider and P. Robertson, "Optimal sampling frequency and bias error modeling for foot-mounted IMUs," *International Conference on Indoor Positioning and Indoor Navigation*, Montbeliard-Belfort, 2013, pp. 1-9.
doi: 10.1109/IPIN.2013.6817922

Abstract: The use of foot-mounted inertial measurement units (IMUs) has shown promising results in providing accurate human odometry as a component of accurate indoor pedestrian navigation. The specifications of these sensors, such as the sampling frequency have to meet requirements related to human motion. We investigate the lowest usable sampling frequency: To do so, we evaluate the frequency distribution of different human motion like crawling, jumping or walking in different scenarios such as escalators, lifts, on carpet or grass, and with different footwear. These measurements indicate that certain movement patterns, as for instance going downstairs, upstairs, running or jumping contain more high frequency components. When using only a low sampling rate this high frequency information is lost. Hence, it is important to identify the lowest usable sampling frequency and sample with it if possible. We have made a set of walks to illustrate the resulting odometries at different frequencies, after applying an Unscented Kalman Filter (UKF)

using Zero Velocity Updates. The odometry error is highly dependent on the drift of the individual accelerometers and gyroscopes. In order to obtain better odometry it is necessary to perform a detailed analysis of the sensor noise processes. We resorted to computing the Allan variance for three different IMU chipsets of various quality specification. From this we have derived a bias model for the UKF and evaluated the benefit of applying this model to a set of real data from walk.

keywords: {Kalman filters;accelerometers;distance measurement;footwear;gyroscopes;inertial navigation;nonlinear filters;pedestrians;signal sampling;UKF;accelerometers;bias error modeling;foot-mounted IMU chipsets;foot-mounted inertial measurement;frequency distribution;gyroscopes;high frequency components;human odometry;indoor pedestrian navigation;odometry error;optimal sampling frequency;sampling frequency;sensor noise process;unscented Kalman filter;zero velocity updates;Acceleration;Bandwidth;Elevators;Footwear;Legged locomotion;Noise;Sensors},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6817922&isnumber=6817839>

S. T. Wu, J. Y. Chen and S. H. Wu, "A Rotary Encoder With an Eccentrically Mounted Ring Magnet," in *IEEE Transactions on Instrumentation and Measurement*, vol. 63, no. 8, pp. 1907-1915, Aug. 2014.

doi: 10.1109/TIM.2014.2302243

Abstract: A novel design of a magnetic rotational sensor is presented in this paper. It contains a ring magnet simply magnetized through its central axis, which is deliberately displaced a distance from the axis of rotation. Hall effect sensors fixed at a distance to the magnet will detect a near sinusoidal variation in the magnetic-flux density as the magnet rotates a cycle, even though the flux is symmetrically distributed about the central axis of ring magnet. Finite-element analyses and physical measurement on an experimental device confirm the smoothness of the flux-density curve, based on which a harmonic fitting algorithm is used to estimate the rotational angle. Relation between measurement accuracy and eccentricity of the magnet is established by extensive testings on the experimental device. It is found that, using two differential pairs of Hall effect sensors, a fifth-order harmonic fitting yields a measurement error of less than 0.14 degrees for a certain amount of eccentricity.

keywords: {Hall effect transducers;angular measurement;curve fitting;finite element analysis;magnetic field measurement;magnetic flux;magnetic sensors;magnetisation;measurement errors;Hall effect sensor;eccentrically mounted ring magnet;finite element analyses;flux density curve;harmonic fitting algorithm;magnet eccentricity;magnetic flux density variation detection;magnetic rotational sensor;magnetization;measurement accuracy;measurement error;rotary encoder;rotational angle estimation;symmetric magnet flux distribution;Barium;Harmonic analysis;Magnetic analysis;Magnetic devices;Magnetic flux;Magnetostatics;Rotation measurement;Angle measurement;hall effect sensors;magnetic encoders;rotational position sensors;rotational position sensors.},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6736110&isnumber=6851964>

K. Patel and L. Vachhani, "A novel visual odometry correction using sensor fusion technique on multiple cameras," *2013 IEEE International Symposium on Intelligent Control (ISIC)*, Hyderabad, 2013, pp. 352-357.

doi: 10.1109/ISIC.2013.6658621

Abstract: Visual odometry estimates the position and orientation of the mobile robot using vision information. A good estimate is always the key for a robotic task implementation. The proposed technique is based on finding the translation component of the robot's movement with low level feature extraction using multiple cameras. The change in successive images from a camera gives an estimate of displacement of the robot while it is moving. This change is found by extracting features using the edge detection and correlation on small portion of two successive images. The proposed faster and computationally less expensive method of feature extraction is not very accurate as compared to existing feature extraction. But, proposed system with multiple cameras does not alter the speed of operation and improves accuracy using simple sensor fusion technique. Proposed method is also merged with odometry using encoder technique and results show further improvement in accuracy. Experiments reported in this paper validate that odometry calculation with multiple cameras using simple direct sensor fusion technique reduces error by atleast 60%. The results demonstrate that the visual odometry is possible with low level feature extraction.

keywords: {cameras;distance measurement;edge detection;feature extraction;mobile robots;position control;position measurement;robot vision;sensor fusion;edge detection;encoder technique;low level feature extraction;mobile robot;multiple cameras;odometry calculation;orientation estimation;position estimation;robot displacement estimation;robot movement;robotic task implementation;simple direct sensor fusion technique;successive images;translation component finding;vision information;visual odometry correction;Cameras;Feature extraction;Image edge detection;Robot vision systems;Visualization},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6658621&isnumber=6658610>

Y. Li, J. J. Wang, S. Xiao and X. Luo, "Dead reckoning navigation with Constant Velocity Update (CUPT)," *2012 12th International Conference on Control Automation Robotics & Vision (ICARCV)*, Guangzhou, 2012, pp. 160-165.

doi: 10.1109/ICARCV.2012.6485151

Abstract: This paper introduces a new algorithm for dead reckoning navigation named Constant Velocity Update (CUPT), which is an extension of popular Zero Velocity Update (ZUPT). With a low-cost IMU (Inertial Measurement Unit) attached to a user's shoe, the proposed algorithm can efficiently reduce IMU errors by detecting not only the stance phases during walking, but also the cases at constant velocity, such as in an elevator or on an escalator. The concept, design and test of a CUPT prototype are detailed in this paper. Test results show that it can effectively detect constant velocity, and its horizontal positioning errors are below 0.45% of the total distance travelled, and vertical errors below 0.25%. This performance reached the highest accuracy in available literature.

keywords: {accelerometers;footwear;gyroscopes;inertial navigation;position measurement;velocity measurement;CUPT;IMU error reduction;ZUPT;accelerometer;constant velocity detection;constant velocity update;dead reckoning navigation;elevator;escalator;gyroscope;horizontal positioning error;inertial measurement unit;low-cost IMU;stance phase;travel distance;user shoe;vertical error;walking;zero velocity update;Acceleration;Accelerometers;Elevators;Legged locomotion;Navigation;Sensors;Trajectory;CUPT;EKF;ZUPT;dead reckoning},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6485151&isnumber=6485123>

K. D. Kim, Y. G. Kim, J. An, Z. G. Xu and S. G. Lee, "Enhanced localization for team robot navigation using compass sensor and USN," *ICCAS 2010*, Gyeonggi-do, 2010, pp. 91-95.

doi: 10.1109/ICCAS.2010.5669967

Abstract: This paper presents an enhanced localization for team robot navigation in an unknown environment. Localization information from encoder is subject to noise resulting from friction between road surface and wheels, or the error in motor itself, in the environment. In addition, the measured error is accumulative as a robot navigates. The mobility in disaster situations is more serious because of the

unstable environment. In order to solve these problems, we proposed a localization and navigation system which is comprised of an 802.15.4a protocol based communication module to measure the distance between team robots and a compass sensor to get the heading angle of every robot. The proposed method is based on a modified Kalman Filter which is adapted in our system to improve the quality of 802.15.4a protocol and compass sensor for reducing the error in measurement process. From the experimental results, we will verify better performance of the proposed system for more practical localization and navigation in the disaster sites through the team robot cooperation.

keywords: {Kalman filters;multi-robot systems;position control;802.15.4a protocol;Kalman filter;USN;compass sensor;friction;localization system;navigation system;team robot navigation;Compass;Kalman filters;Mobile robots;Navigation;Noise;Robot sensing systems;Compass Sensor;Kalman filter;Multi-Robot;USN},
URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5669967&isnumber=5669634>

W. Chonnaparamutt and H. Kawasaki, "Fuzzy systems for slippage control of a pruning robot," *2009 IEEE International Conference on Fuzzy Systems*, Jeju Island, 2009, pp. 1270-1275.
doi: 10.1109/FUZZY.2009.5277092

Abstract: For a mobile robot using an encoder to measure the travel distance, a critical cause inducing the error is the slip of the wheel. The slippage not only causes the distance error, but also increases the overall energy consumption and decreases the locomotion performance. To cope with these effects without spending extra sensors or high processing load, the slippage control system composed of two fuzzy modules, namely the trajectory estimator and velocity controller, has been developed based on experimental data collected from encoders and a motion capture system. The control system applied the cross-coupling control technique by employing the estimated velocity from the estimator as a part of an input for the velocity controller of four wheels. This way, the simple yet effective slippage control system is feasible. Promising results verify the potential of the system. Thus, this initial research provides the framework to develop the competent slippage control system for our pruning robot.

keywords: {fuzzy control;mobile robots;motion control;position control;velocity control;cross- coupling control technique;distance error;fuzzy systems;mobile robot;motion capture system;pruning robot;slippage control system;trajectory estimator;velocity controller;wheel slip;Control systems;Energy consumption;Fuzzy control;Fuzzy systems;Mobile robots;Motion control;Motion estimation;Sensor systems;Velocity control;Wheels},
URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5277092&isnumber=5276875>

J. Chu, Hongqing Wang, Wenjing Chen and R. Li, "Application of a novel polarization sensor to mobile robot navigation," *2009 International Conference on Mechatronics and Automation*, Changchun, 2009, pp. 3763-3768.
doi: 10.1109/ICMA.2009.5245970

Abstract: Orientation and position information are indispensable in mobile robot navigation. In this paper, a novel polarization sensor for getting orientation information is introduced. It exports an absolute azimuth angle. To take it effect in mobile robot navigation, a fuzzy logic controller is designed. It can direct the robot walking along the designed trajectory according to the information from the polarization sensor. Assisted by the wheel encoders, some navigation experiments are implemented outdoors. The result indicates that the error of the polarization sensor is independent of the travel distance and it can play an important role in automatic navigation system in a further way.

keywords: {control system synthesis;fuzzy control;mobile robots;path planning;position control;robot kinematics;sensors;absolute azimuth angle;automatic navigation system;fuzzy logic controller;mobile robot navigation;orientation information;polarization sensor error;position information;robot walking;wheel encoder;Azimuth;Fuzzy logic;Legged locomotion;Mobile robots;Navigation;Polarization;Robot sensing systems;Robotics and automation;Sensor systems;Wheels;fuzzy control;mobile robot;navigation;polarization sensor},
URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5245970&isnumber=5244759>

J. S. Hu, Y. J. Chang and Y. L. Hsu, "Calibration and on-line data selection of multiple optical flow sensors for mobile robot localization," *2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Nice, 2008, pp. 987-992.
doi: 10.1109/IROS.2008.4650803

Abstract: This paper proposes a calibration method as well as a computational algorithm to integrate the data of multiple optical flow sensors for 2-dimensional trajectory measurement. Optical flow sensors offer a different kind of odometer as compared with the wheel encoder. Using multiple sensors, it is possible to reduce the effect of measurement uncertainties. Since all sensors are mounted on a rigid body, their measurement data must obey a certain relation. This relation is utilized in this paper and mathematical formulations are developed to realize the computation. It is shown that the calibration procedure can be cast as an optimization problem given measurement data. Further, the rigid-body relation is formulated as a null-space constraint using the calibrated parameters. During operation, unreliable sensor measurements can be removed by accessing the error distance to the null space. Experimental results are presented to support the proposed methods.

keywords: {calibration;flow sensors;mobile robots;optical sensors;position control;2D trajectory measurement;calibration method;mobile robot localization;multiple optical flow sensor;multiple sensors>null-space constraint;rigid-body relation;Adaptive optics;Computer vision;Image motion analysis;Optical imaging;Optical reflection;Optical sensors;Sensors},
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J. j. Yu, S. s. Park, W. K. Hyun and h. y. Choi, "A correction system of odometry error for simultaneous map building based on sensor fusion," *2008 International Conference on Smart Manufacturing Application*, Gyeonggi-do, 2008, pp. 393-396.
doi: 10.1109/ICSMA.2008.4505560

Abstract: This paper represents a SLAM(simultaneous localization and map building) system with odometry and indoor GPS sensor. This paper presents an accurate localization method by relative and absolute sensor fusion for map building system of mobile robot, we developed a sensor based absolute position tracking algorithm and grid based map building algorithm using this algorithm. A wall following decision engine like a fuzzy algorithm was proposed for map building navigation. Generally, while the robot is navigating the environment for map building position is estimated by odometry. However the position estimation using encoder data is not accurate owing to slipping and odometry linearization error. To solve this problem we proposed a sensor fusion method using encoder and indoor GPS. We proved this system's validity through field test.

keywords: {Global Positioning System;SLAM (robots);distance measurement;mobile robots;sensor fusion;absolute position tracking algorithm;correction system;decision engine;encoder data;fuzzy algorithm;indoor GPS sensor;mobile robot;odometry error;position

estimation;sensor fusion;simultaneous localization;simultaneous map building;Equations;Error correction;Global Positioning System;Mobile robots;Navigation;Optical transmitters;Robot sensing systems;Sensor fusion;Sensor systems;Wheels;SLAM;indoor GPS},

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M. Heiss, "Error-detecting unit-distance code," in *IEEE Transactions on Instrumentation and Measurement*, vol. 39, no. 5, pp. 730-734, Oct 1990.

doi: 10.1109/19.58616

Abstract: A particular kind of unit-distance code is proposed. Unit-distance codes are applied especially to absolute encoders (linear or rotary). The various positions of the encoder are represented by the various code words of the code. In contrast to conventional unit-distance codes, this code offers the possibility of detecting all single-bit errors except the two single-bit errors that cause a code word which represents the adjacent position. Unit-distance codes are characterized by a Hamming distance of 1. Thus, Hamming distance is not a unit of measurement for the code's error-detection ability. Therefore, a Hamming distance is defined especially for unit-distance codes excluding the adjacent code words from the calculation of distances. An application shows the utility of the code in the field of instrumentation and measurement

keywords: {analogue-digital conversion;error detection codes;Gray code;Hamming distance;absolute encoders;error detecting code;flash A/D convertor;instrumentation;measurement;path distance;single-bit errors;unit-distance code;Binary codes;Hamming distance;Helium;Instrumentation and measurement;Measurement units;Microelectronics;Optical sensors;Reflective binary codes},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=58616&isnumber=2129>

P. Goel, S. I. Roumeliotis and G. S. Sukhatme, "Robust localization using relative and absolute position estimates," *Proceedings 1999 IEEE/RSJ International Conference on Intelligent Robots and Systems. Human and Environment Friendly Robots with High Intelligence and Emotional Quotients (Cat. No.99CH36289)*, Kyongju, 1999, pp. 1134-1140 vol.2.

doi: 10.1109/IROS.1999.812832

Abstract: A low cost strategy based on well calibrated odometry is presented for localizing mobile robots. The paper describes a two-step process for correction of 'systematic errors' in encoder measurements followed by fusion of the calibrated odometry with a gyroscope and GPS resulting in a robust localization scheme. A Kalman filter operating on data from the sensors is used for estimating position and orientation of the robot. Experimental results are presented that show an improvement of at least one order of magnitude in accuracy compared to the un-calibrated, un-filtered case. Our method is systematic, simple and yields very good results. We show that this strategy proves useful when the robot is using GPS to localize itself as well as when GPS becomes unavailable for some time. As a result robot can move in and out of enclosed spaces, such as buildings, while keeping track of its position on the fly

keywords: {Global Positioning System;Kalman filters;distance measurement;mobile robots;parameter estimation;sensor fusion;GPS;absolute position estimates;calibrated odometry;enclosed spaces;encoder measurements;gyroscope;relative position estimates;robust localization;systematic errors;Error correction;Global Positioning System;Gyroscopes;Intelligent robots;Mobile robots;Navigation;Orbital robotics;Robot localization;Robot sensing systems;Robustness},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=812832&isnumber=17546>