Pose Estimation Algorithm Implication for Bicycle Using Gyroscope & Accelerometer: Design Approach

Mr. Sandeep Kumar Gupta
Computer Science Department
G. H. Raisoni College of Engineering, Nagpur
gupta4651@gmail.com

Mrs.Veena.Gulhane
Computer Science Department
G. H. Raisoni College of Engineering, Nagpur
veena.gulhane@raisoni.net

***Abstract*— The research on two-wheeled self-balancing robot has gained momentum over the last decade at research, industrial and hobby level around the world. This paper deals with the modeling of two-wheeled self-balancing robot. This paper proposes a new method by which the error of two self-balancing robot sensors can be reduced and avoids traditional Kalman filter which cannot meet real-time modulation. In this paper, Correction algorithm can come out real-time robot posture in the right way according to the characteristics of navigation sensor error from the iteration of nonlinear least-squares error model based on the method Dynamic Regulator. By computer simulation, an error through the gyro and accelerometer can be corrected. Kalman filter fused the data of gyroscope and accelerometer adaptation and errors of the sensors pose estimation can be corrected.**

The mathematical derivation of Dynamic Regulator shows that this method of reducing posture estimation error is feasible and effective, and can achieve better accurate estimates in expensively.

***Keywords*— Gyroscope, accelerometer, servomotor-controller.**

I. INTRODUCTION

Recently many investigations have been devoted to problems of controlling two-wheeled self-balancing robot, which are widely taken into applications in the field of autonomous robotics and intelligent vehicles. Robots can move on the flat and complex terrain, such as on the slope. The two- wheeled self-balancing robot models are not only of theoretical interest but also of practical interest. Many practical systems have been implemented based on two-wheeled self-balancing robot models. From the point of view of theories, the two-wheeled self- balancing robot models have attracted much attention in the field of control theory and engineering because they are nonlinear with inherent unstable dynamics. Many control techniques have been studied in the past decades for the control of benchmark under actuated systems such as the inverted pendulum, the acrobot and the rotating pendulum.

Two-wheeled self-balancing robot features intrinsic instability, lack of drive, non-holonomic constraints, which is a nonlinear system. The robot have two wheel arrangement of the axis, driven by independent motor, a body placed in the center of mass above the axis and a posture controller which drives two wheel based on body state to maintain body posture and walk upright.

Much research on its dynamic modeling and balance control has been carried out. Grasser used Newton's method to establish three dynamic models and control its posture and speed using decoupling method. TU used Lagrange method to establish its model on the level ground and the state feedback method was used to design its controller. Huang built its dynamic model on the slopes and designed a sliding mode controller without considering direction change. A dual closed-loop controller was designed with attitude control using back stepping method, while position and movement control using PID. However, these control methods mainly focus the ground level situation, and few consider the modeling and control on the slopes.

This paper proposes the solution for problem to balance a robotic two wheeled bicycle. Problem statement in the actual robot's navigation system, a variety of temporary factors, interference and measurement noise and random variation, the accuracy of the standard Kalman filter will be reduced. Therefore, the Dynamic Regulator focuses on the two self-balanced navigation.

Self frame flex-balancing robot navigation system; we need to get the acceleration of the robot posture and speed information, it is very important to build the navigation sensor output model. Dynamic Filter can make the complementary nature of the multi-sensor information, the ability to use data integration to complete the composition of the robot test Dynamic Regulator (DR) suppression interference, it also allows the system has good dynamic performance. Some researchers added one or two manipulators on the self-balancing robot to construct a mobile manipulator, which is also a research trend of this kind of robot.

Because of these shortcomings of the navigation sensors, they are always such as the output signal and noise temperature, such as is always the interference of external factors, by randomly drift, according to the characteristics of the navigation sensors, we want to minimize the error, and need to create a mathematical model, random drift is the best estimation method to deal with error compensation. The improved system will pass self-balancing test of the two robots.

Error of navigation sensors and low costs, the establishment of error models, the Dynamic Regulator to suppress noise and fuse the accelerometer and gyroscope data, this approach not only has good real-time performance, but also the algorithm simple, DR is a very practical method of selfbalancing robot navigation system.

II. LITERATURE REVIEW

The linear quadratic optimal regulator was designed to control its attitude and speed. The simulation results show that the two wheeled self-balancing robot in the slope situations can keep balance without displacement [1].

A wheeled robot model having the feature of real robot's kinematics and dynamics was built in virtual reality environment to achieve free balance, fixed-point balance, speed tracking, heading control and linear obstacle negotiating. And related procedures have been designed for real-time detection of model parameters and export of simulation data which provide a reliable basis for the experimental study [2].

Low cost MEMS accelerometer and gyro are selected to measure the posture information of the robot with a novel data fusion method. This data fusion method can overcome the shortcomings of accelerometer and gyro so that the precise posture information is obtained even with oscillation and impact. Based on the robot's dynamics model established by Lagrange's function method, two robust sliding mode controllers are designed for controlling the motions of the robot. The robot performed well with precise measurement of the posture and sliding mode controllers [3].

Two-wheeled self-balancing robot is a mechanically unstable, non-homonymic constraint robot. This paper has established a dynamics and kinematics more effective for self-balancing robot's balance model, has designed fuzzy controller based on the T -S fuzzy model with the parallel distribution compensator (PDC) the structure [4].

III. TWO-WHEELED SELF-BALANCED ROBOT MODEL SELECTING

The self-balanced robot navigation required an excellent performance of precision, reliability and autonomy. Inertial navigation system could provide comprehensive information of navigation independently. The Global Positioning System posited widely, what always attracted people was the high precision and low cost, but the signal is easy to keep out. The error would accumulated ceaselessly with the time went by.

The system could complement each other; it was widely used in the present integrated navigation system. Integrated system navigation system made the full use of two, and overcame the shortcomings.

This system model and the statistic characteristics of noise had been known, and the system noise was the Gaussian White home measured noise had not been known. This paper used the integrated navigation system as the research object, the integrated navigation system was used as the main navigation system, using speed and position information Global Positioning System provided as the observed quantity. To establish the mathematical models, the ADC to be used with Micro Controller Units to obtain the information of sensor, such as gyroscope and accelerometer.

Gyroscope output continuous voltage signal, after 12 bit A / D conversion, provided by the gyro random drift only greater power, is because centrifugal not only the temperature to reach a stable over time, gradually, average output in the form, and ultimately tend to the dynamic stability. Repeat experimental results show that the different characteristics of the gyroscope of time, Based observations show that the drift error is mainly due to the influence of temperature in the work process of the gyroscope, According to the ambient temperature deviation is reduced to a positive or negative.

The same method to analyze the accelerometer output value; through two figures we know that the error characteristics of accelerometers and gyroscopes are basically similar, but different parameters.

III. DYNAMIC REGULATION ALGORITHM

Aiming at two-wheeled self-balanced robot SINS/GPS integrated navigation system, state space model, Traditional

Kalman filter algorithm is optimal in theory. But it is difficult to meet the actual system Kalman filtering Gaussian white noise and other conditions, easily lead to instability of the differences and filters. Dynamic Regulator algorithm with forgetting factor, to improve the robustness of the system, to improve the accuracy of the system.

A. Discrete-time linear equation of the model

Consider the following model, which is expressed by the discrete-time linear equation:

$$X(k+1) = \Phi(k+1,k)X(k) + T(k+1,k)W(k) \quad (1)$$

$$Y(k+1) = C(k+1)X(k+1) + V(k) \quad (2)$$

In this equation V(k) is the measurement noise vector, C(k) is observation matrix, Y(k) is observation vector, W(k) is system noise vector, X(k) is error state vector, F(k,k +1) is state transition matrix, T(k +1,k) is noise state transition matrix.

The formula of Dynamic Filtering is:

$$\hat{X}(k\,|\,k) = \hat{X}(k\,|\,k-1) + K(k)[Z(k) - C(k)\hat{X}(k\,|\,k-1)] \quad (3)$$

$$\hat{X}(k\,|\,k-1) = \Phi(k,k-1)\hat{X}(k-1\,|\,k-1) \quad (4)$$

$$K(k) = P(k\,|\,k-1)C^T(K)[C(K)P(k\,|\,k-1)C^T(K) + R(k)] \quad (5)$$

$$P(k\,|\,k-1) = \Phi(k,k-1)P(k-1\,|\,k-1)\Phi^T(k,k-1) + T(k,k-1)Q(k-1)T^T(k,k-1) \quad (6)$$

$$P(k\,|\,k) = [1-K(k)C(k)]P(k\,|\,k-1)[1-K(k)C(k)]^T + K(k)R(k)^T K(k) \quad (7)$$

In order to develop the control system, we need a dynamic model of the system that will link the system's behavior (described by the state space variables) to its inputs (defined in introduction).This model is characterized by the system's parameters (i.e. size, mass and moment of inertia of the vehicle.

B. The inertial sensor data fusion based on Dynamic Filtering

Dynamic Filter estimates the state of the process and measurement noise and feedback. The feedback control provides an efficient recursive solution to solve the minimum mean square by the feedback correction of optimal estimation of nonlinear optimal estimation of the final state vector. The main idea of inertial sensor data fusion is the use of gyroscopes and accelerometers different error characteristics, Information collected in order to correct their mistakes. Optimal estimation of the two robot pose obtained by the Dynamic Regulator and gyro bias calibration, automatic tracking deviation.

The red line is the data of gyro, blue line is the data of accelerometer and yellow line is the data of Kalman filter.

IV. CONCLUSION

The design of algorithm for the regulation of sensor data to keep the two-wheeled robot standing for a long time. It is clear that the Dynamic Regulator will more suitable to control the self-balanced robot. Integrated navigation system in the unknown measurement noise, the essence of traditional Kalman filter method is very difficult to meet the problem. This paper presents a real-time.

Dynamic Regulator methods will use inertial sensors, data fitting, nonlinear least squares method and the error model of experimental error characteristics. Estimated attitude will solve the problem of random drift error compensation. Get a low-cost, high-precision self-balancing robot posture sensor system.

This paper will use the integrated navigation system as the research object, the integrated navigation system will be used as the main navigation system, using speed and position information Global Positioning System provided as the observed quantity.

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