AGV Localization and Navigation System using Bluetooth GPS

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***Abstract* — Localization and navigation technology is one of the key technologies for Automated Guided Vehicle (AGV). In this paper we develop an AGV navigation system utilizing commercial Bluetooth GPS. WGS-84 coordinates system is converted to space rectangular coordinate system, which is combined with orientation information, initial position and gesture of AGV can be determined. Experimental result shows that the localization accuracy can meet the demand.**

Keywords - Localization and Navigation, AGV.

I. INTRODUCTION

Localization and navigation technology is one of key technologies in AGV. AGV must accurately obtain own information of position and gesture, so as to effectively achieve specific function. Precise localization and navigation can be achieved with differential GPS system or inertial guidance system, but the cost is high. Currently, the system above is mostly applied in key fields, such as military and aerospace. Localization and navigation technology without low cost is still a bottleneck of hindering popularization and application of AGV.

In this paper, effective implementation technology of localization and navigation in AGV with civil non-differential GPS module is discussed. First, the WGS-84 coordinates system used in GPS is converted to space rectangular coordinate system, and direction information of the robot is obtained by electric compass, thus the initial position and gesture of the mobile robot is determined, and waypoint navigation is achieved. This paper analyzes the localization accuracy of used GPS module, and simulates and carries out experiment on Pioneer 3DX AGV.

II. GPS COORDINATE CONVERSION

Developed in the 70s in the U.S., GPS navigation and localization system was a kind of global three-dimensional real time satellite navigation system with high accuracy put to use in 90s. It not only has good competitive price, but also has accurate rapid real time orientation and localization. Meanwhile, it is characterized by good autonomy, strong adaptability, and high accuracy and reliability, etc.

A. Output Format of GPS

WGS-84 coordinate system is used in GPS (Global Positioning System), and spatial position is described with geodetic longitude (L), latitude (B) and height (H). In terms of GPS receivers, NMEA-0183 data output format stipulated in NMEA(National Marine Electronics Association (the U.S.)is adopted. The system utilizes the data information in localization statement GPGGA, e.g. ＄GPGGA, 072 027.00, 3 905. 102 6,N, 11 708. 623 7, E, 1, 04, 9. 9, - 19.4,M, - 3. 1,M, 3 63.

Where:

072027. 00--- Standard time in UTC_TIME24h (24 h)system. Expression: UTC time 07: 20: 27:00

3905.1027,N--- Latitude. Expression: northern latitude of 39°05.1027′.

11708.6257,E---Longitude. Expression: east longitude 117°08.6257′.

1---Localization quality, 0 =Localization failure, 1 = Non-differential localization, 2 =Difference localization.

04--- The number of satellite for localization.

9. 9--- Horizontal precision factor.

- 19. 4,--- Altitude calculated from average seawater surface in m.

- 3. 1,M---Geoid gap in m.

Empty field 1--- Data age of DGPS in s. When DPGS is not used, the field is empty.

Empty field 2--- DGPS fiducial station number. When DPGS is not used, the field is empty.

3 63--- Checksum

GPS receiver transmits localization data (NEMA-0183 statement) to computer via Bluetooth, because GPS provides geodetic longitude (L), latitude (B) and height (H) only, coordinate system conversion to space rectangular coordinate system is required. We can describe the algorithm of GPS coordinate conversion by Figure 1.

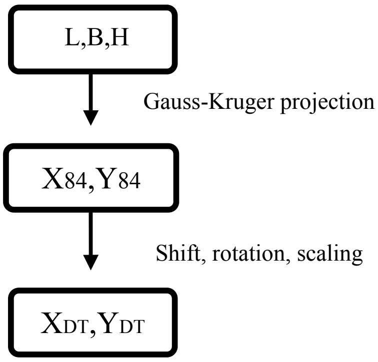

Figure 1. Block Diagram of GPS Data Coordinate Conversion Algorithm

In Figure 1, firstly receive WGS – 84 geodetic coordinates (L, B,H) with GPS, convert them to Gauss-Kruger projection coordinate (XG ,YG) by Gauss-Kruger projection, and plane rectangular coordinate (XDT ,YDT) of electronic map through shift, rotation and scaling of coordinate.

B. Rectangular Coordinate Formula by Gauss-Kruger Projection

The follows is rectangular coordinate formula by Gauss-Kruger projection:

$$X = S + N\lambda 2\sin\varphi\cos\varphi / 2 + N\lambda 4\sin\varphi\cos 3\varphi(5 - \tan 2\varphi + 9\eta 2 + 4\eta 4) / 24 + N\lambda 6\sin\varphi\cos 5\varphi(61 - 58\tan 2\varphi + \tan 4\varphi + 270\eta 4 - 330\eta 2\tan 2\varphi) / 720 + \cdots \quad (1)$$

$$Y = N\lambda\cos\varphi + N\lambda 3\cos 3\varphi(1 - \tan 2\varphi + \eta 2) / 6 + N\lambda 5\cos 5\varphi(5 - 18\tan 2\varphi + \tan 4\varphi + 14\eta 2 - 58\eta 2\tan 2\varphi) / 120 + \cdots \quad (2)$$

Where, S is the length of longitude from equator to one latitudeφ (IAG275 ellipsoid), N is curvature radius of prime vertical in globe ellipsoid, φ is the latitude of point to be solved in degree; λ is the longitude difference between latitude of point to be solved and central meridian in radian. η is auxiliary function, ,$\eta= e'\cos\varphi$.

$$S = 111\ 133.\ 004\ 6\varphi - 16\ 038.\ 528\sin 2\varphi + 16.\ 833\sin 4\varphi - 0.\ 022\sin 6\varphi + 0.\ 000\ 03\sin 8\varphi \quad (3)$$

$$N = a/ (1 - e2\sin 2\varphi)\ 1/ 2 \quad (4)$$

Where, a is long radius of ellipsoid, e is the first eccentricity. When the unit of λ is degree, λ shall be put in after being converted through Equation (5).

$$\lambda = \lambda°\pi / 180° \quad (5)$$

For 1980 Xi'an coordinate system, IAG275 ellipsoid is adopted, and its parameters are :

a = 6 378 140m , e = 0. 081 819 221 , e'= 0. 082 094 469.

C. Principle of Plane Coordinate Conversion

As shown in Figure 2, if coordinate (x1,y1) will be converted to coordinate (x2,y2), the coordinate azimuth of axis of coordinate system (x2,y2) in ordinate (x1,y1) is set as a (clockwise measurement of coordinate azimuth), and the coordinate of origin in coordinate of coordinate (x2,y2) in coordinate (x1,y1) is coordinate (x0,y0), and the scale coefficient from (x1,y1) to (x2,y2) system is m. Then, four conversion parameters can be solved with two sets of coordinate values in common point, and other (x1,y1) coordinates are converted to (x2, y2) coordinate systems.

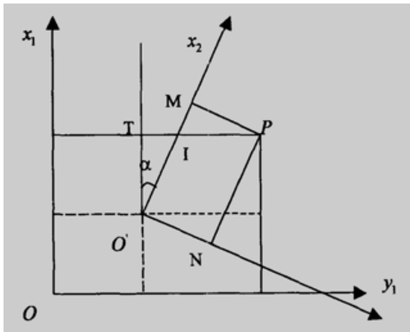

Figure 2. Schematic Diagram of Conversion of Plane Rectangular Coordinates

According to the figure above, through simple geometric conversion between right angle ΔPMI and ΔOIT right angle, basic conversion relationship from coordinate systems (x1, y1) to (x2, y2)can be obtained.

$$x2=m(y1-y0)\sin\alpha+ m(x1-x0)\cos\alpha \quad (6)$$

$$y2=m(y1-y0)\cos\alpha- m(x1-x0)\sin\alpha \quad (7)$$

In AGV, (x1, y1) coordinate system is considered as Gauss-Kruger rectangular coordinate system, and (x2, y2) as local coordinate system of the AGV. α angle is gained by electric compass, thus the position of any point in global coordinate can be converted to robotic coordinate system. Information of position and gesture of AGV at any time is able to be determined.

III. SYSTEM HARDWARE

A. AGV Hardware Platform

Pioneer 3 DX of ActivMedia Company was adopted to conduct localization and navigation study. The AGV is 44.5 cm long, 40 cm wide, and 24.5 cm high, which weighs 9 kg with load of 23 kg, maximum pan speed of 1,800 mm/sec and maximum rotation speed of 360 deg/sec. Embedded Hitachi H8S is used as the microprocessor, which is responsible for data processing and command execution of the sensor. The AGV includes the following basic equipment: sixteen sonar range units, one laser range finder, ten collision avoidance sensors, one Cannon VC - C50i camera, one wireless network card that follows 802.11b protocol and two RS - 232 serial interfaces. Other sensors and some accessories can also be mounted on it. All these parts are controlled and managed by the vehicle-mounted microcontroller and the software of AGV server-side. Pioneer Pioneer 3 - DX type AGV experimental system mainly consists of the following parts: the console, communication port, camera, laser measurement part, sonar, wheel type encoder, collision avoidance sensor, phonetic system, electronic compass and battery (as shown in Figure 3).

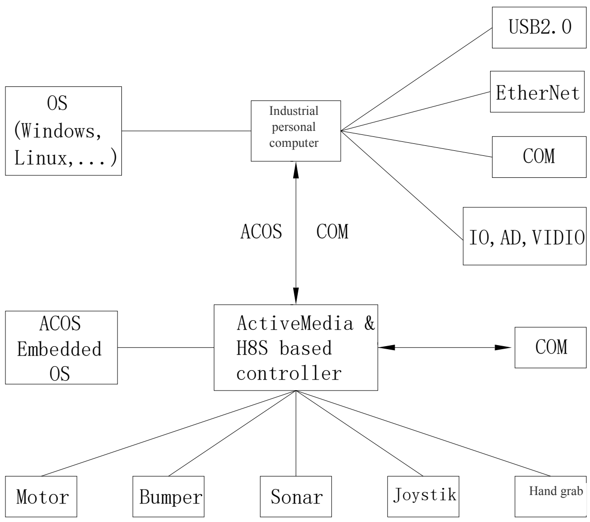

Figure 3.. Pioneer 3 - Dx AGV System Composition

B. GPS Module and Data Acquisition

The system selects and uses Gaorui Mini Foenix Bluetooth GPS module, and MTK ultrahigh efficiency MT3 solution is used in the module. The localization accuracy can reach 3 m, and the module is connected through Bluetooth serial ports. The receiving sensitivity is -162 dBm. It can track 32 satellite signals at the same time and follow the NMEA - 0183 data output format. The location information cycle is 10 ms, and the data refresh frequency is 1 Hz.

NMEA - 0183 sends data in the form of character string. The receiver can send multi-type character strings, which only needs several fields in "$GPGGA" character string in experiment. Therefore, received data need to be parsed to obtain the required information. The length of the character string is variable for different decimal point digits, so the location of the information in character string cannot the basis of locating in separation of required information, but the location of comma separator in the character string.

1) Data Detection

In order to ensure the effectiveness of the collected GPS data, the data detection must be conducted. Receiver will send many types of character strings. Therefore, whether it is "$GPGGA" character string shall be first judged; Then, the integrity of "$GPGGA" character string shall be judged. If character number of the character string which begins with "$GPGGA" is greater than or equal to 66, it can be determined that the received data is valid.

2) Data Extraction

Data extraction refers to separation of data information in valid character string after data detection and acquisition of exact UTC time, latitude and longitude information. The received information is stored in the form of character string, and data can be extracted by segment.

IV. GPS SINGLE POINT LOCALIZATION ACCURACY ANALYSIS

The receiving performance of GPS receiver was tested by Visual GPSXP software. Figure 4 is the single point test distribution diagram prepared on one point selected in the experiment field. Statistics (as shown in Table 3-1) was conducted by 550 times of sampling of measurement data on the point. Statistical results showed that the average of longitude is 113.339395340, standard deviation of longitude is 0.286 m, the average of latitude is 23.1580582240, the standard deviation of latitude is 0.165 m, the average of Altitude is 29.47 m and standard deviation of Altitude is 0.166 m, and the data drift amount was small. Error range is within 2 m. The experiment results showed that the GPS used in the experiment could meet the demand of the experiment.

Table 3-1. GPS Single Point Test Values

	Sampling numbers	Average value	Variance
Longitude	550	113.33935°	0.286m
Latitude	550	23.15805°	0.165m
Height	550	29.47m	0.166m

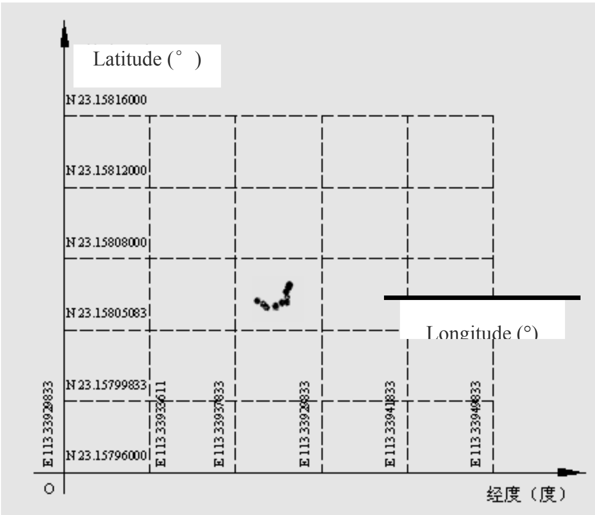

Figure 4.. GPS Single Point Test Data Distribution Diagram.

V. SIMULATION STUDY

Four target points are set in simulation experiment. As shown in Figure 5, the AGV reaches each point according to the expected path, who needs to avoid the obstacles in walking process. The simulation experiment is conducted by MobileSim software, and the simulation results are shown in Figure 6.

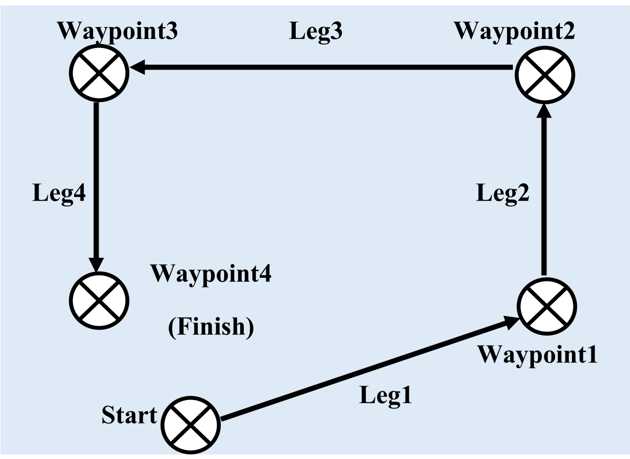

Figure). Target Point Setting

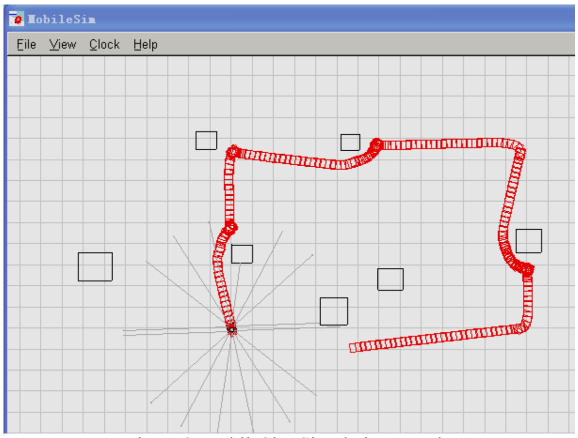

Figure6. MobileSim Simulation Result.

The black squares in the figure represent obstacles. The AGV starts from starting point to target point 1, and moves ahead to target point 2, then reaches target point 2 after bypassing obstacles, finally reaches target point 4.

VI. CONCLUSIONS

Experimental result showed that achieving waypoint navigation of AGV with bluetooth GPS is a kind of efficient solution with low cost. Further study work include pre-processing of GPS data to reduce the impact of noise and drift on accurate localization, and realization of multi-sensor information fusion with other sensors, e.g. photoelectric encoders, electric compasses, laser distance sensors and ultrasonic sensors.

REFERENCES

[1] Yang Zijun, Liao Fengying, Wei Qing. “The application of GPS in navigation and localization system of mobile robots” [J]. Ship electronic engineering, 2005, 25 (6) : 5-7.

[2] Ouyang Zhengzhu, He Kezhong. “The application of GPS in intelligent mobile robots” [J]. Microcomputer information, 2001, 17 (11) : 56-58.

[3] Meng Xiangli, Cao Zuoliang. “Multi-sensor localization information fusion in mobile robots based on GPS “[J]. Journal of TIANJIN UNIVERSITY OF TECHNOLOGY, 2006.12(6):47-49.

[4] Chen Zewang, Yuan Xin. “A kind of practical GPSP electronic map coordinate conversion algorithm” [J]. Journal of Nanchang Institute of Aeronautical Technology (natural science version),2003, 17 (1) : 72-76.

[5] http://www.MobileRobots.com.

[6] Wen Luo,Junfeng Xue,Haiqing Bo. Solid carbide tool grinding crack reason analysis and process improvement [J]. Journal of technology tools, 2006,40（6）：37-40.

[7] Chu Yonghai, Tian Fujuan, Ma Jing. “Local coordinate conversion and application.” Journal of HUBEI WATER RESOURCES TECHNICAL COLLEGE. 2006.2(1):42-47

[8] Pazderski.D;Dutkiewicz.P “Low-cost GPS receivers in navigation of mobile robots” [A]. Robot Motion and Control, 2002. RoMoCo '02. Proceedings of the Third International Workshop on .2002 119 – 122

[9] Thomas Braun. Parallel image processing [M]. Li Junshan, eds. Xi 'an: xi 'an jiaotong university press，2003：29-31.

[10] NVIDIA.CUDA C Programming Guide version 4.2[EB/OL].

[11] http://developer.download.nvidia.com/compute/DevZone/docs/html/C/doc/CUDA_C_Programming_Guide.pdf，2012.7.
[12] Guo Jia; Essay on Image Segmentation; Chinese New Technology and New Products; 01 issue in 2011
[13] Zhang Hao. A Novel Image Registration Method Based on Edge Fitting, photoelectron, laser, first issue in 2009.

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