Mobile Field Robotic Platform Positioning

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Abstract **– Low cost, mobile field robotic platform positioning to achieve positioning precision less than 0,1% (10 cm) over distance 100 m is described. Main applications for described system are robotized agriculture tasks. Known 0,1% precision systems are to expensive for wide use in agriculture production automation. Described positioning method use compass, gyroscope, accelerometer and distance to passive targets, read by laser rangefinder, microprocessor processing and control as well as main computer as pre-defined path set-up device and storage database for read values.**

Keywords **– Robotics, positioning, automation, agriculture, microprocessor.**

I. Introduction.

UN's Food and Agriculture Organization are giving the global food market 'critical' status, and considers what must be done to stave off a repeat of the 2007/2008 crisis[5].

The main reason is world weather conditions but in the same time labor expenses or vacant workplaces play considerable role in food price rise.

Agriculture production is far less equipped with automatics and robotics compared to industrial production.

Agricultural production typically is placed over large area. "Large area" doesn't mean "low precision" - in general today agriculture production need high precision over large area.

Mobile robotic platform positioning system for agriculture must perform task up to 24 hours per day.

The position system with acceptable precision over 1 hectare square area (100x100m) and more are under development and system basics are described below.

II. Main Positioning Methods Overview.

Main position methods and acceptance to mentioned above task are discussed below. Mainly these methods can be described as "passive" due to the fact that there are no communication between mobile robot platform and reference points, beacons, outer space satellites etc.

I.1. Global Navigation Satellite System (GPSS).

GPSS are based on radio transmission travel time from outer space satellites to land or air based receiver. At least 4 satellites must be visible to perform positioning.

Today 4 systems are in use: GPS (USA), GLONASS (Russia), Galileo (EU) and Compass (China). There are different GPS precision: military and civil (USA development). Precision can be up to several centimeters for expensive systems and <3...10 m for common systems ("Tom-Tom", mobile phone) and 6m are average precision [16]. There are special GPSS applications for agriculture on the market today (Trimble [7]), but they are to expensive for the most of the world agriculture producers.

In greenhouses GPSS have much lower precision or cannot be used at all [1]. Test results show that POLYSTAR 648 GPS receiver module (SiRFstarIII GPS chipset based) [8] cannot be applied indoors, but Broadcom BCM 4750 [9] have enough sensitivity and can be applied indoors. Besides, precision requires greater satellite visibility - not possible in greenhouses.

So possibilities of direct GPSS usage (without ground based reference points like Differential Global Positioning System) for 0,1% precision positioning over 100m distance is limited from authors point of view.

I.2. Positioning via 2D/3D scanning.

2D/3D beam scanning include laser, infrared, ultrasonic and sonic tools and corresponding positioning methods. Also known as "position-based visual servo control" [2]. Based on send-reflected sound, light or radio wave travel time measurements and have common characteristics:

- Around the platform work area must be some "walls"or special installed target to get reflection,
- determination "where I am?" requires special (and also expensive) computer software to process 2D/3D image patterns and bound them to current mobile robotic platform position. Irregular field shapes and different obstacles rise necessary computing power.
- obstacles in scanning beam line can cause wrong positioning so number of reference targets must be increased.

Laser scanner positioning.

Lasers are used in a range of applications to accurately determine level, grade, vertical alignment and distance. Spinning lasers emit a rotating 360-degree beam of light that is used as vertical, grade or horizontal reference. Laser distance scanning with following position calculation is precise but also expensive and difficult applicable regardless of the high scanning precision. Besides, continuous horizontal 360 deg laser scanner beam is dangerous for field workers or service personal eyes. High price and described disadvantages significantly slow down implementation in to agriculture area.

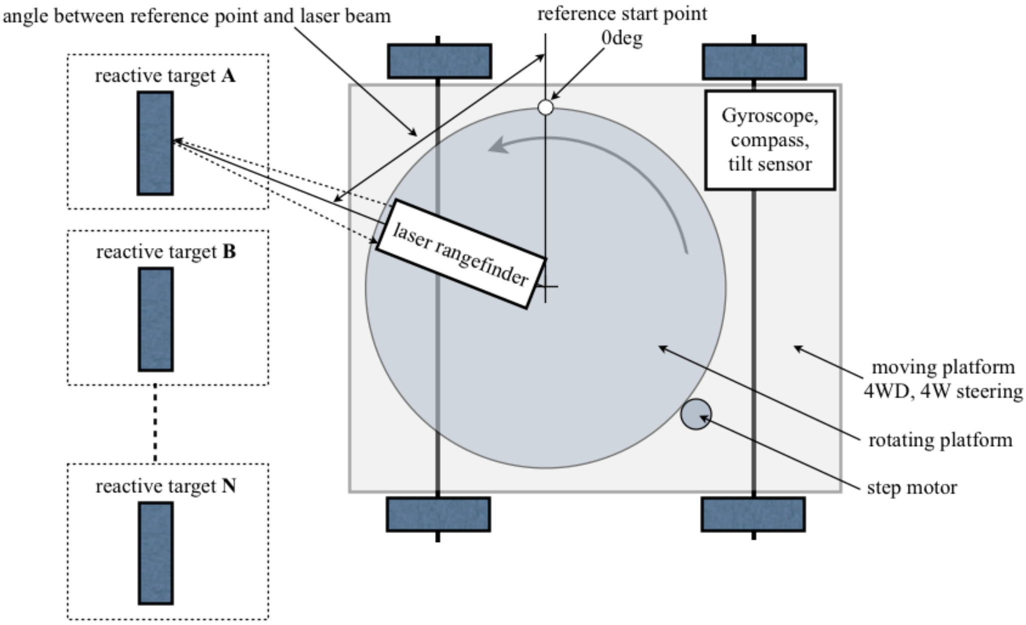

Fig.1. Mobile agricultural robotic platform positining components.

Infrared positioning

Infrared (IR) sensors are used as proximity or distance detectors for distances up to several meters in general, but some positioning systems like Festo NorthStar [10] or Hagisonic StarGazer [11] are in use. NorthStar and StarGazer infrared positioning here are based on reference spot detection. Reference points are fixed on ceiling.

This determine that infrared position also can have very limited application for agriculture tasks.

Ultrasonic and sonic positioning.

Ultrasonic position require large size reference targets (up to 3x3m) and distance is limited to ~15m. Lower precision compared to laser or infrared systems. Not very suitable for agriculture field. Ultrasonic rangefinders mainly are used as up to 5 m distance rangefinders.

I.3. Positioning by WiFi hotspots.

WiFi hotspots are easy available in urban area. Position is based on WiFi signal level decrease with distance [3] and special purpose integrated circuits [12] are designed for this task. Antenna design and position against the ground can significantly influence precision due to important influence on transmitted signal power. Positioning precision is >5m.

WiFi hotspots (widely available in cities) in rural area must be installed specially. Such special installations cause additional questions, additional problems and increase overall system price.

As described above, mobile field or agricultural robotic platform positioning or position determination is a complicated task, regardless of chosen method or several methods. Determination “where I am?” cannot be determined in easy way.

III. Proposed Positioning.

III.1. Positioning components.

Proposed position determination system (Fig.1.) consists of:

- laser rangefinder (100m reading distance), horizontally and vertically positioned by step motors and servomotor via gears or gearboxes,
- X, Y axis MEMS (Micro Electro-Mechanical System) gyroscope,
- Z axis MEMS gyroscope,
- X, Y, Z axis MEMS accelerometer (up to 3g acceleration),
- ultrasonic obstacle and distance sensor (10 – 500 cm range),
- odometer to read traveled distance,
- tilt compensated magnetoresistive compass module to detect platform “heading” against earth magnetic field,
- 3-4-5 or more passive targets (Fig.2.),
- on-board computing microprocessor,
- step and servomotor drivers,
- WiFi (IEEE 802.11) communication (<150m range [13]) between moving platform and reference computer,
- Reference computer operate UNIX approved [14] Apple iOS4.3 or OS X 10.5 - 10.7 operating system.

All mentioned equipment are widely in use today and are competitive priced.

Known video image capture techniques (require approx. even light conditions) and following video frame pattern recognition can be applied for positioning assistance and potentially is planned during future research. But one must keep in mind - application significantly increase of the overall system price.

III.2. Operation.

Pre-defined movement path is uploaded from reference computer to mobile platform via WiFi or serial (USB, I2C) connection. Movement over path and position on the path is controlled and corrections are made by processing compass, gyroscope, accelerometer and tilt sensor readings.

The accelerometer (Acc) measures the gravitational acceleration (G) in three dimensions X, Y, Z.

AccValue = (AccRd - Acc0) / AccSensitivity (1),

where AccValue - G measured by the sensor,
AccRd - analog reading,
Acc0 - value when Acc is horizontal,
AccSensitivity - accelerometer sensitivity.

The gyroscope (gyro) measures rotation degrees per second (deg/sec) in three dimensions X, Y, Z.

GyroRate = (GyroRd - Gyro0) / GyroSensitivity (2),

where GyroRate - rate measured by the sensor,
GyroRd - reading,
Gyro0 - value when gyroscopes are positioned horizontally ,
GyroSensitivity - gyroscope sensitivity.

GyroRate are measured in degrees per second and this must be taken in to account for microprocessor programming.

Prototype experimental platform gyroscope and accelerometer readings show fluctuation between 4 digits range of 10-bit ADC. Experiment was based on microprocessor Atmega328 ADC [15], LPR530AL [16] (X, Y axis gyroscope), LY530ALH (Z axe gyroscope) and ADXL335 [17] (X, Y, Z axis) accelerometer.

109 824 measurements was recorded for each parameter (gyroscopes and accelerometer outputs) during 90 minutes of testing.

Applied to angle measurements this can cause significant error over time. Kalman filter [18] or Complementary filter [19] computing algorithms can be applied to reduce circuit fluctuations.

High frequency signal filter on ADC input or threshold level application allow directly use gyroscope average readings - excluding accelerometer and filtering. In the same time such solution increase minimum of detected angle speed. Research is planned to determine the best solution for described instability reduction.

Besides mentioned, to answer to the question “where I am?” additional tools are in use. On defined time intervals or before and after obstacle detection precise position detection take place by means of laser rangefinder readings and triangulation calculations.

On horizontal axis step motor drive rotating laser range finder via simple gear transmission with reduction 40:1.

1,8 deg angle motor step correspond to 0,045 deg rotating sensor platform angle. Special means to exclude gear back-drive are necessary.

Vertically laser rangefinder is controlled by tilt sensor and driven by servomotor to keep laser beam horizontally during platform movement.

Laser rangefinder rotation step frequency is 0,5-1,5Hz and mainly is determined to achieve correct laser rangefinder readings. Corresponding step motor step frequency is 10 – 30 Hz. Smooth operation is achieved by half- step motor control.

On horizontal plane angle value between each reference and following target (for example, angle between reference A and target A, Fig.2) is equal to step motor step count multiplied 0,045 deg. Distance between moving platform and target is read by laser rangefinder.

Rangefinder value are compared to pervious value on the same rotating platform angle and to database stored predefined traveling path values. Necessary path corrections are made after each sensor platform revolution.

On vertical plane servomotor is used to compensate mobile platform tilt against target and is controlled by 3-axis tilt sensor.

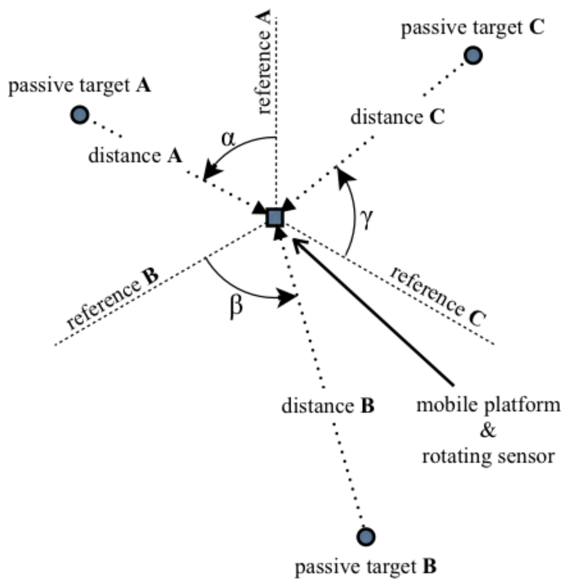

Fig.2. Mobile platform and beacon location

0,045 deg laser rangefinder position step correspond to 78,45 mm arc length (Fig.3) on 100m distance and precision is less than 0,08%.

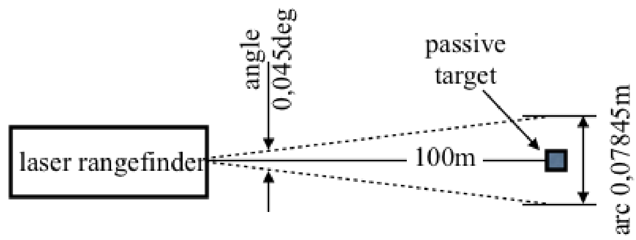

Fig.3. Laser rangefinder arc length corresponding to rotation platform angle.

Database contain stored preset traveling path values. Path values like speed, turn angle, acceleration, direction etc. are calculated by path geometrical drawings or set manually via touchscreen input or any other way. Manual control also is provided via touchscreen. Robotic platform movement path is set by database data reading next from current position.

Moving robotic platform coordinates are relative to passive targets. This cause additional computations to compare with GPSS values if GPS module is applied. GPS module is necessary to drive automatic mobile platform from “home” to work-field and vice versa if necessary.

Important point is laser rangefinder power supply and data exchange between rotating laser rangefinder platform due to 360 deg laser range finder rotation.

Power transfer via collector rings and following data transfer over power line [4] can be applied but in mentioned mobile platform work environment can cause to frequently servicing. Special electromagnetic connection is designed for power supply and serial data transfer (similar to wireless power supply).

III.3. Positioning reliability.

Environment conditions – temperature, light, wind, dust, rain etc. – affect positioning precision, reliability and positioning ability at all.

Reliable circuit and mechanical design also affect mobile robotic platform stability and reliability, but significantly less in this case.

The simplest way to increase positioning reliability is to increase count of passive targets or to increase target size. Ad-hoc placement target size is limited by acceptable transportation and carrying size, as well as wind (target field installation) must be taken into account.

Hexagonal (Fig.4) or quasi-hexagonal (distance between beacons are only approximately equal) passive target grid is optimal solution increased work area or use several robotic platform co-working in the same large area. Distance between opposite targets cannot exceed 100m, mainly set by wireless data exchange - not possible on distances larger than 150m.

More complex system contain on target installed laser beam detector and radio-wave transmitter. Transmitter send target code to mobile platform receiver after detecting target crossing by laser beam. Received signal allow to read laser rangefinder measured value. Here the main problem is laser beam detector design: detecting angle must be 360^0 and detecting height at least 200 - 250mm to “catch” the beam. Mentioned solution is omitted at current development stage of mobile robotic platform position system development.

Several robotic platform co-working is essential from productivity point of view.

Higher on-board computing power significantly simplify platform co-working path calculation complexity and reduce information data exchange between platform and reference computer - reduced to database stored values upload from reference computer and newly collected data storing to database.

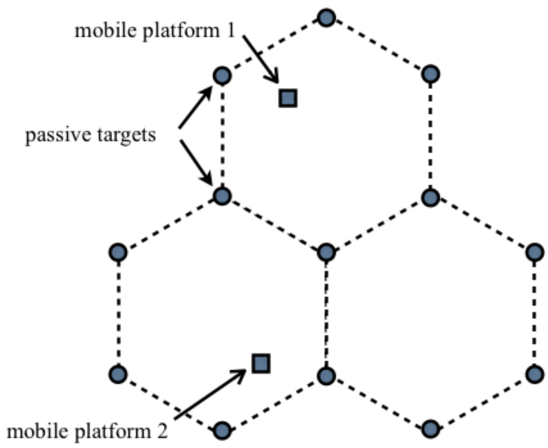

Fig. 4. Hexagonal grid.

III.4. Energy efficiency.

Energy efficiency is important for agriculture processes automation and robotics application due to large work/application area.

Energy efficiency is the next most parameter after positioning reliability.

Frequent platform charge significantly reduce productivity due to travel time to charger and back. Traveling to charger and back waste energy, so platform charging possibility also must be included in passive targets. Rechargeable batteries and charge from solar panel, small wind turbines, heat pumps or other alternative energy sources must be applied for passive target energy storage feeding. Alternative energy sources is worth to use outside in field where mains in general is not available. Inside greenhouse mains power is more easy and cheaper solution for recharging (if applicable). Choice mainly is determined by passive target status: ad-hoc placed or stationary.

Alternative solution is to apply special charging platform traveling to each work platform when charging is necessary, if several mobile platforms are in use in one field. Here productivity and economical factors are important.

Possibility to distribute energy between working platforms by charging each other must be developed. Pervious suggestions open close to energy Smart Grid [20] research field.

Optimal robotic platform movement path for each task allow significantly reduce power consumption. Detailed description isn’t current article task.

Special energy saving step motor boost circuit is developed and applied regardless of low step frequency (10-30Hz).

Real traveling data collection and registering in to database allow increase energy efficiency for routine tasks via more precise path planning or correction.

IV. CONCLUSIONS.

Described above method must be perceive as a simple mobile field robotic platform positioning concept to achieve 0,1% precision over 100m distance.

Positioning inaccuracy is sum of MEMS devices readings inaccuracies, non even step motor steps, obstacles on laser rangefinder laser beam path or bad weather conditions as well as small number of targets. Obvious, applying target grid will reduce described above inaccuracies.

Future research and development include full-scale prototype build, open air (real conditions) field tests, simultaneous several platform co-working under hexagonal grid positioning.

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