COMBINATION OF SENSOR NETWORKS AND MOBILE ROBOTS TECHNOLOGIES FOR EFFECTIVE MONITORING (SYNERGY2009) CONFERENCE, GÖDÖLLŐ, HUNGARY

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Abstract

Both wireless intelligent sensor network and all terrain mobile robot technologies are relatively new ones. There are a lot of research work in which the two technologies were studied separately. We found that the combination using the wireless sensor network and mobile robots give us much more application opportunities and effectiveness in greenhouse and open air agricultural field monitoring. With the combination the fusion of sensors signals and the mobile router function have especially important adventures.

Keywords

wireless sensor network, mobile robots, monitoring, synergy

Introduction

Wireless sensor network and mobile robots are two new technologies in the latest 10-15 years. These are new waves of development. With these technologies we can monitor, measure and control our physical world, connected to the World Wide Web or local area networks. The SmartDust project [1] results – which was supported by Berkeley University DARPA – are appreciates by Business Week [2] to the most effective technology of the 21th century.

Using the wireless sensor network we are able to collect information from big area, for a long time. The installation is easy, the network topology is easily fit for the requirements. With these good attributes there are more and more interesting application. The first applications were ordered by the army. These applications used moving nodes. In the civil applications used mostly not moving nodes.

Publication [2] from 2008 is introduced and analyzed the developing directions and application fields. This book doesn't mention about agricultural applications. One reason can be the high price of the wireless sensor networks. The prices are reduced, there are some example in the precision agriculture. For example the Camalie Vinery project [3], where fixed sensors measure the soil moisture for the optimal watering.

One big constraint is in the agricultural applications the living organizations disturbance of the radio communication. We made measurement of this [4]. We found the communication range is 70-80% less then open air range. Another problem is to put gateway and laptop in agricultural environment for a long time.

A good solution for these problems is applying wireless sensor network and mobile robots together! The main aim for mobile robots is to discover and monitor. These functions can be extended to be a base station for wireless sensor networks.

While mobile robots are cruising in outdoor surfaces, we can easy recording the division of the surface. The precision agriculture need to know the exact surface. The seeding technologies also need the detailed surface information [5].

To collect detailed surface information is difficult because of the measuring the stochastic systems. Measuring technology is complex and uncertainty is very high. Five universities [6] made a publication about researching in this topic. The publication said the same, bad uncertainty and complex methods.

The mostly used method to measure the surface is the profilograph with laser or mechanical sensors. Using the profilograph, make an 1-4 m long artificial horizontal line, and measure n pieces of distance. To characterize the surface is used coefficient of variation.

$$s = \sqrt{\frac{\sum_i^n = (y_i - y_{átl})}{n}} \qquad (1)$$

Using profilograph is need very much human resource. One measured data cannot be represented the surface. These values don't have physical signification.

Making measurement with Pioneer P3-AT mobile robots, we can supervise that mobile platform angles are representing the surface. This rule gives us the idea, that using mobile robots and one or more wireless sensor nodes we are able to measure the changing of angles and the dynamic of changing.

Using the MEMS sensors for tilt, accelerate and angle speed measuring. There are many opportunity to place MEMS in mobile robot platform.

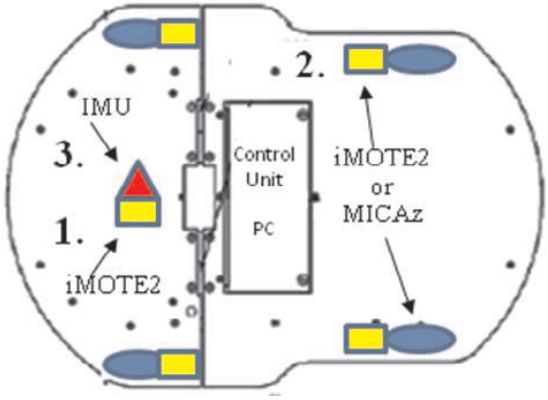

Figure 1. MEMS sensors on mobile robot platform

Using mobile robot or mobile robot swarm we can collect more information from soil, than the earlier measurement systems. This bigger data set makes more accurate and reliable statistical data.

These results are enough to precision agriculture requirements. Also this concept cannot be the only one solution, the robot has construction kinematical properties which are constrains, it limits the accurate and reliability.

Wireless sensor network

The intensive technologies in agriculture need high accuracy sensing and automation. The modern environment management using advanced monitoring.

Wireless sensor networks mainly used in industrial environment. Using wireless sensor networks in agriculture is not researched area. In agricultural environment mobile robots and wireless sensor networks must work between plants or animals. The most serious constraint factor is the wireless communication pass loss. To design and operate these systems we must know how the biological environment effects the radio frequency communication.

Using wireless sensor network we are able to collect huge quantity of information for a long time, from the real physical world.

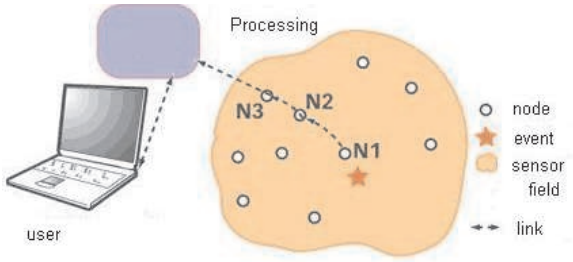

Figure 2. Collecting data from real physical world

Figure 2 is showing how to collect information from agricultural environment. When en event happend the node sends the measured value or information to the proecessing center. Using low power, short range communication, the multi-hop protocol find an optimal route for the information (N1-N2-N3). The processing center is a database for all kind of measured value, from all sensors to the total measuring time. The user can monitoring the whole time, all sensors values.

One of the biggest advantage of the mesuring system: wireless (communication and power). Other hand in this comfortable property, this is serious constraint in communication and battery lifetime.

Mobile robots

We use Pioneer P3-AT mobile robots. They designed to use indoor and outdoor environment. These type is the most used robot in own category. With all-time four wheel drive and good design, these robots have good off-road capabilities. The driving motors controlled by PWM controller and encoder. In the top of robot platform we can connect many input device: sonar, laser scanner, normal or stereo camera, GPS, robot arm, etc. For intelligent working, include inner and outer communication, the robots have a PC and a microcontroller. In the platform we can place more MEMS sensors (mote).

Figure 3. Mobile robot on the field

Some size of robots which are important to measure the surface:

Weight: 11,8 kg (with 3 batteries)
Axial distance: 275 mm
Wheel diameter: 225 mm
Wheel width: 80 mm
Width (by wheels): 400 mm

MEMS sensors are mass products, so their prices get smaller. This is also a good reason to use them. The stereo camera and laser scanner are good for validate the method. For special requirements more sensors can give good result, but today price level it is too expensive.

Synergy of wireless sensor network and mobile robots

Wireless sensor networks are easy to use, flexible measuring systems. There are many type of sensor, for industrial and agricultural measuring. For example: temperature, light, humidity (soil, air, plant), acceleration, inertial sensors, pressure, A/D converter, microphone, etc.

Wireless sensor network has some disadvantages: short range communication, limited battery lifetime. Short range communication is extended by multi-hop routing protocol. Battery life time can be extended by various technology of energy harvesting (solar, wind power, vibration energy).

Wireless sensor network are very flexible to using them mobile environment, sensors are not able to move.

Mobile robots are a good platform for wireless sensor network. These robots are developed to move indoor and outdoor surfaces. All-time 4 wheel drive and robust design give them very good off-road capabilities. Local WLAN connection makes a high speed flexible data connection. The built-in PC have a big computing capacity including a data base server for wireless sensor network measured values, storing pictures and movies created by remote controlled cameras attached to the robot.

WLAN has a limitation from the access point. This distance is bigger than wireless sensor network range. To extend this constraint GPRS and EDGE technologies give us unlimited communication.

Using mobile robots high tech, high speed devices (PC, motor, GSM) battery lifetime is quit short. Energy harvesting is a good opportunity but not enough for continuous working. External charging, battery changing or pause for energy harvesting can extend the battery lifetime.

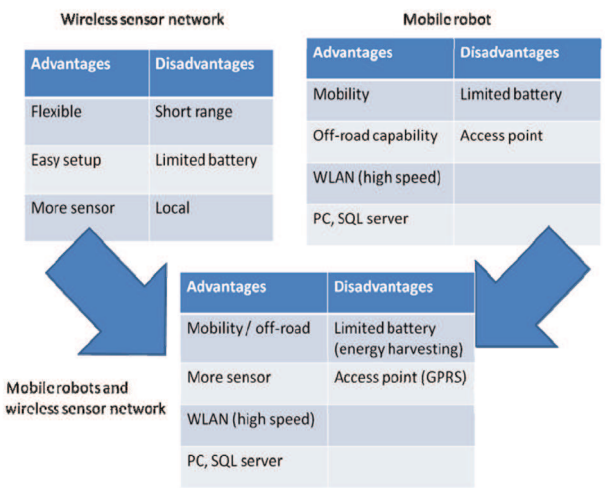

Figure 4. Synergy

Figure 4 showing the advantage of using wireless sensor network with mobile robots. Mobility, flexibility, high capacity communication, computation and monitoring are the common advantages. Limited battery lifetime is the most problem to use this complex system.

In our sample application (monitoring soil surface) the measurement takes just a few minutes, battery lifetime doesn't affect the method.

Sample application

Measuring the soil surface is a good combination of mobile robots and wireless sensor network. Mobile robot gives the moving platform and wireless sensor network give the 3 dimensional acceleration sensors.

There are many places to put the sensors (Fig. 1.). The Pioneer P3-AT mobile robot has rigid axes, so the whole chassis moving in the same way. Because these special condition and sensors high price, we choose only one sensor. The sensor is placed to the center of the platform.

The x axe shows forward in horizontal plate.

The y axe shows left in horizontal plate.

The z axe show upward vertical.

When the robot is standing or moving forward in constant speed the sensors measure the 3D position of the platform (pitch, roll). When the robot accelerates or turns the sensor measure the summation of 3D position and current acceleration. That's make difficult the read, explain the result. Because of this problem, we drive the robot in constant speed, straight. The PWM controller keeps the speed constant, but when some obstacle impacts the platform, a short transient acceleration is added to the 3D position. Release these transients we use statistical methods.

Our first idea was, we measure the z axe acceleration, integrating twice and we get the soil profile.

$$s_z = \int\int a_z \, dt \, dt \qquad (2)$$

There are many little noises in the process, so integrating these noises make unreadable result. Axe z measure both pitch and roll. Measure the pitch in z axe make smaller different than measure in x axe. (a_z=g*cosλ, a_x=g*sinλ). For little angles – mostly in soil profile – sin values are bigger than cos values. That's why we use x axe acceleration, a_x to measure pitch, and y axe acceleration, a_y to measure toll.

Figure 5 shows the measured acceleration values when the mobile robot platform goes down in a „strait". In the left graph the strait is 4 cm height, in the right graph the strait is 6 cm height. The graphs show the acceleration values in g/1024 m/s^2. The horizontal axe is the time in 1/100 sec. Because the robot platform goes on constant speed, the time has a linear relation to distance.

In the first part the robot is going in horizontal plate. When the first wheels fall down (second part) the transient holds about half second. This short time the PWM controller restores the original speed for the mobile robot platform.

In the third part the first axe is down and the second axe is in a higher level. That's make a positive a_x acceleration. The fourth part the second axe fall down, make another transient. The fifth part is like the first.

The two axes make always echo. Every axe takes the obstacle. The time of the echo is equal the time to need to go the axial distance. In a constant speed it is a constant echo time. Depends on the size of obstacle, the echoes can overlap. When two obstacles are closer than the axial distance, the second obstacle come earlier than the first echo.

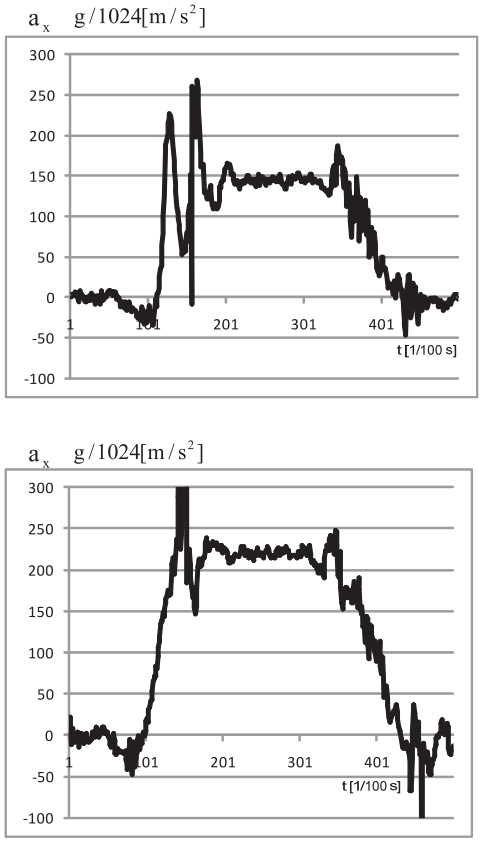

Figure 5. The x axe acceleration going down in stairs

Table 1.a_x values in strait

Height [mm]	average of a_x g/1024 [m/s^2]
20	72
40	146
60 221	

Table 1 shows the average a_x values in 2 cm, 4 cm and 6 cm height strait. These numbers have a quite linear relation.

In statically case when the mobile robot platform goes in constant speed the a_x value equals the projection of the gravity. The gravity constant and shows down. These are in the force triangle. in the figure 6 the other triangle shows the geometrically relation. The axial distance is d, and the high level different is h.

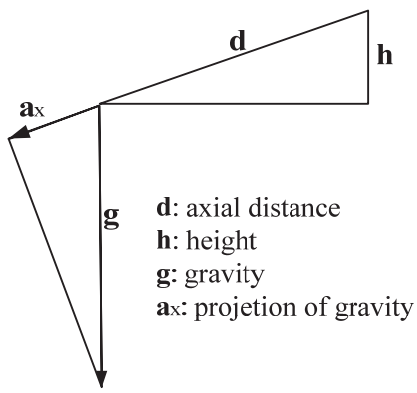

Figure 6. Geometry and force relation

The two triangle in figure 6 are similar. It means:

$$\frac{g}{a_x} = \frac{d}{h} \tag{3}$$

from (2) we can get the h,

$$f = a_x \frac{d}{g} \tag{4}$$

Conclusions

Mobile robot platforms and wireless sensor network is able to measure the soil surface roughness.

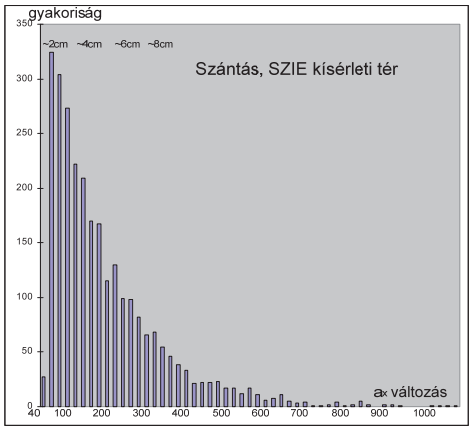

Figure 7. Frequency diagram

(3) says that high level difference between front and rear axes is linear to measured a_x value. Also we can get the high different in left and right site wheels from a_y. From these values we are able to calculate the soil surface, while mobile robot platform goes in straight. Also we know, there are transients when we don't have information about surface. Using mobile robot, or mobile robot swarm, we are able to collect many „line"-s from soil surface.

These values (pitch, roll differences) characterized the surface. Also there are some disturbance (echo, transient) when the values are not accurate and reliable.

Because of these disturbances we made statistically processing too. Figure 7 shows the frequency of a_x differencies, while mobile robot platform goes in an experimental field.

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