Wide Area Wireless Networked Navigators

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Abstract

Networked cooperative personnel and multiple manned/unmanned vehicles play important roles in the Future Combat System (FCS), Future Force Warrior, Future Special Operations Forces (SOF), Land Warrior and Homeland Defense applications. Multi-sensor fusion based navigation and high bandwidth wireless communications are two of the key techniques for these applications. The navigation system is required to be a wide area wireless networked real-time multi-agent information fusion and decision-aid system to deploy in a battlespace environment. AGNC's coremicro® Palm Navigator (CPN), inherently embedded with the networking functions for multiple platform tracking, is chosen as the Wide Area Wireless Networked Navigator System for the US Army ARDEC's Multiple Platform Coordination (MPC) demonstration system. The CPN is a self-contained interruption-free multiple platform communications, non-GPS tracking and decision aid system. It is not a closed system. It is modularized and open to other systems. Applications of the CPN system include tracking of family members; tracking of cab vehicles of a taxi company; tracking of law enforcement officials pursuing suspects. In a military environment, the soldiers can track each other during military missions by using the CPN. Pilots of aircraft in a formation can use the CPN to maintain formation flight and evade potential collision.

1. Introduction

The battlespace is a mobile and highly complex environment, and thus the wireless architecture is chosen for multi-agent communication. Personnel/Platform tracking, navigation and communication system is an essential part for the Future Combat System (FCS), Objective Force Warrior, Land Warrior and Homeland Defense applications where one urgently needs to have novel position/location tracking, communications system and decision making devices that would permit multi-tracking, reporting and recording operations. This navigation system is required to be a wide area wireless networked real-time multi-agent information fusion and decision-aid system to deploy in a battlespace environment. The

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resulting Wide Area Wireless Networked Navigators System shall be integrated with ARDEC's Combat Decision Aid System (CDAS) for the above mentioned applications. In this system multi-agent communications, tracking, information fusion and decision aid components can be easily integrated. For all applications, this system allows personnel to be linked through an intelligent software network interface to multiple autonomous robotic vehicles and airplanes/UAVs that provide precision location and other information to each other. The application objectives of the Wide Area Wireless Networked Navigators System for multiple tracking for the US Army ARDEC's Multiple Platform Coordination (MPC) demonstration system include: (1) the demonstration of control and coordination of multiple UAV/UAS/UGV/UGS platforms by a single control device(s) in a small unit tactical network environment; (2) ability to share data; (3) ability to accept tasking/orders from authorized nodes in the network; (4) support reconnaissance, surveillance and target hand-off; (5) support urban operations and (6) support lethal/non-lethal effects delivery. With the implementation of the Joint Variable Message Format (JVMF) and other designated interfacing protocols, all Command and Control (C2) nodes, including the AGNC coremicro Palm Navigator, and UAV/UGV platforms, 4D GIS system, and CDAS will communicate over a wireless or wired network.

The precision wide area wireless networked platform positioning/tracking and navigation system described above is essential for cooperative personnel and multiple manned/unmanned vehicles. Currently, tracking individuals/platforms in a wide maneuvers range is normally accomplished by using Global Positioning System (GPS) equipment. Although the GPS receiver provides an easy positioning and navigation solution for most applications, the signals from GPS satellites can be jammed or blocked in complicated terrains, such as canyons, under metropolitan building canopies, heavy forests, caves, and indoor environments. It is a must to have novel position/location tracking and communications system operations in an open range, as well as in complicated terrains, where GPS signals are jammed or blocked. Also, most military units require the ability to accurately navigate in environments that are traditionally denied communication connectivity with current GPS satellites.

2. Wide Area Wireless Networked Navigators System Architecture

AGNC's coremicro® Palm Navigator (CPN), inherently embedded with the networking functions for multiple platform tracking, is chosen as Wide Area Wireless Networked Navigators System for the US Army ARDEC's MPC demonstration system. As shown in Figure 1 the CPN systems can be used in a wide range of applications, such as, personnel/soldier tracking, fixed wing UAVs, helicopters, robots, cars and other unmanned ground vehicles.

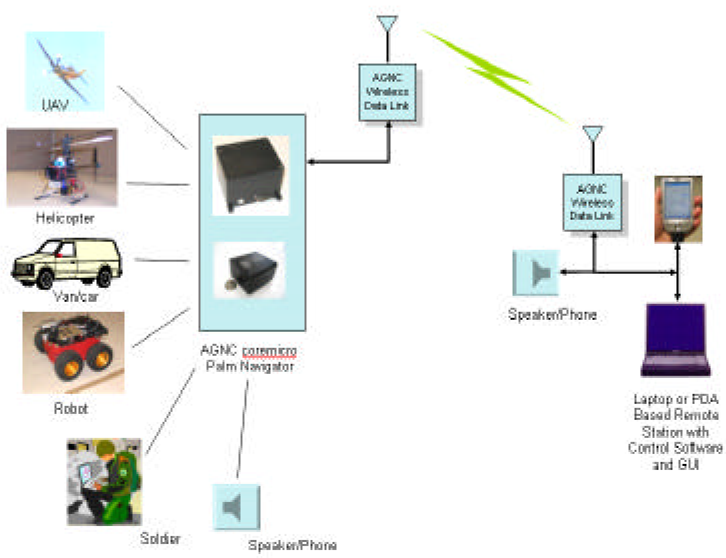

Figure 1 The coremicro® Palm Navigator Demonstration System with RF Data Link

The CPN is a self-contained interruption-free multiple platform communications, non-GPS tracking and decision aid system. It is not a closed system. It is modularized and open to other systems.
The volume of the CPN is less than 10 in^3, as shown in Figure 2. The weight of the unit is about 0.3 lbs. The current system coordinates non-GPS accuracy is about 2% of the distance traveled in a 2 or 3 dimensional environment up to a maximum error of 30 feet. The prospective system coordinates non-GPS accuracy will be within 1% of the distance traveled in a 3 dimensional environment up to a maximum error of 10 to 20 feet. The unit has the capability for instantaneous, real-time position/coordinates output and display at start-up. The coremicro Palm Navigator multiple sensor data fusion is shown in Figure 1. AGNC's coremicro AHRS/IMU/INS Integration Unit embedded inside the CPN is the core of the position determination system. To compensate for the error of the INS, multiple navigation sensors are integrated into the system.

Less than 10 in^3
2.65X2.5X1.5 in^3
The non-GPS coremicro Palm Navigator has a position accuracy of 2% distance traveled with 1%, desired in a 3D environment.

Figure 2 The coremicro Palm Navigator (CPN)

The CPN unit has been linked to CDAS. By providing position data the CDAS can show where on the floor plan the robotic vehicle or coremicro Palm Navigator unit is. There is a commander's display in CDAS. Applications can be cases where people through the network can access positioning information. There are two layers to that. One is a self contained network and the other a link to an application layer that monitors the network. This provides flexibility to various applications. The radio link can accommodate the network which is the environment for the future warrior. It can display desired waypoints. Once the information is on the network many applications will be developed. The interface to CDAS will be very fast. A link to a central station is provided and then the central station can talk to CDAS. Also, CDAS can talk to the central station and send waypoints.

The coremicro® Palm Navigator is implemented with the Networked Position Multiple Tracking Process [3,4,5] wherein the CPN system is processed via a data link, where the data link is responsible for location and command data exchanges between individuals among a networked group. The individual platforms are networked in a group so that each individual platform can search and track other platforms. All individual CPN units are organized in a plurality of unit groups, and the unit groups are further organized into larger groups, and so on. Accordingly, the networked CPN system substantially saves communication resources for a communication network and provides efficient data exchanges among many individuals [3,4,5]. This application includes extensive coding to connect the coremicro Palm Navigator into a network, implement network management functions, perform data acquisition at the central data acquisition station, and visualize the position/location information from different unit groups and individuals. They can be further divided into the following subcomponents:

- Network protocol.
- Position reporter – reports the position/location information to the unit group leader and other members in the same unit group.
- Data acquisition – acquires the position/location information of all the unit groups, and the position/location information of each individual unit in the unit group.
- Visualization – with this program the movement of each unit group, and each individual member in the unit group, can be dynamically displayed on the screen. The visualization is highly scalable and highly flexible in that the user can control the level of complexity of the content to be displayed.

With this networked coremicro® Palm Navigator system, the position/location of an individual can be accurately determined and transmitted to the central data acquisition center. Thus, for example, the intelligent threat prediction system provides the position to the network, retrieves the information from the network, predicts the potential threats for homeland defense and greatly facilitates appraisal and execution of corresponding coordinated response measures. The position data provided by the networked CPN system yield the key spatial and temporal basis that allows a distinct advantage to be gained in the formulation of threat responses and coordinated counteractions. A fuzzy logic/neural network decision aids architecture captures the uncertainty levels of threat situations and aids decision making by encoding both past experience and levels of expertise of counter-threat experts into its rule base.

The coremicro® Palm Navigator network system comprises a plurality of individual units each of which is carried by an individual platform, which can be a person, a vehicle, or any other property. The individual units are organized as intra-groups and a predetermined number of unit groups are further networked into link-groups to facilitate the data transfer in a large area or different geographical areas. The CPN network system further comprises a communication mechanism in each unit-group of individual units which is designed to facilitate the data transmission among the individual units, wherein a data exchange package is also defined.

3. Location-based Positioning/Tracking and Navigation Demonstrations

Figure 1 shows the coremicro Palm Navigator integration approach for wide area wireless networked precision multiple manned/unmanned vehicles geolocation. A large number of non GPS tests and demonstrations for Wide area wireless Networked System for Navigation, Communication and Tracking were carried out using the coremicro Palm Navigator. Three types of non GPS tests and demonstrations were performed:

1. Outdoor long range non GPS automobile vehicle tracking.
2. Indoor/outdoor personnel tracking;
3. Indoor robotic vehicle and personnel tracking;

The following is a brief summary of the tests and demonstrations results:

coremicro Palm Navigator Outdoor long range non GPS automobile vehicle tracking

Van tests are carried out to test environments where GPS is available or not, as shown in Figure 3. The integrated multi-sensor and wide area wireless networks of the coremicro Palm Navigator were also installed on many automobiles. Some real data is collected on the road to demonstrate the effectiveness of the integrated wide area wireless networked geolocation system for commercial applications.

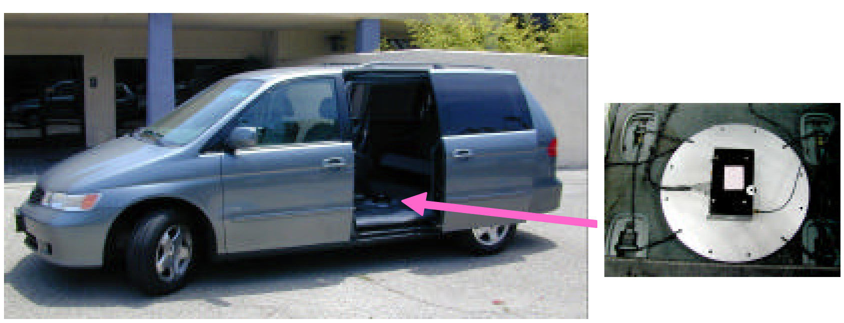

Figure 3 Wide area wireless Networked coremicro Palm Navigator Van test.

We use a predetermined test track for the verification of the navigation performance. The coremicro Palm Navigator RF data link located in the indoor lab was used to track the coremicro Palm Navigator unit installed in the van and display the navigation data in real-time and record the navigation data for post analysis. After the test, the recorded data are downloaded to a test analysis computer for further processing and analysis. The following two figures show the plots of two test missions. Based on the calibration of the navigation sensor and tuning of the CPN processing parameters, a series of non-GPS navigation van tests were carried out. The navigation system is working in the aided INS mode and is self-contained. The test results show that through sensor level and system level calibration, the navigation accuracy is significantly improved. The testing progress indicates that incorporation of sensor and system calibration, and laboratory and van test verification is an effective approach for performance improvement.

Figure 4 shows the Wide area wireless Networked Test and Demonstration System User Interface. The Test and Demonstration System can wirelessly track, display and record all the CPN output data and most internal status.

Figure 4 Wide Area Wireless Networked coremicro Palm Navigator Test and Demonstration System User Interface

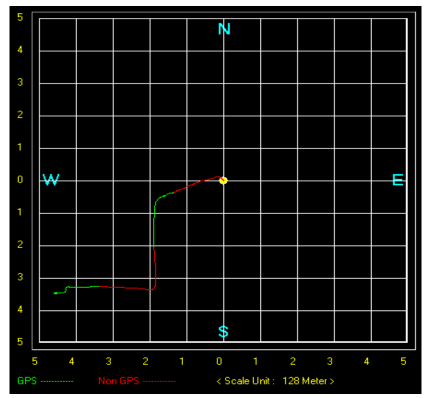

Figure 5 Wide Area Wireless Networked coremicro Palm Navigator Recorded Tracking Trajectory

Figure 5 shows a typical Recorded Tracking Trajectory of a CPN user. The yellow center is the start point. At the beginning, the GPS antenna is not connected. The red line represents the trajectory of the coremicro Palm Navigator without GPS. The GPS is then connected. The green line represents the trajectory when GPS is available. It shows that the coremicro Palm Navigator provides smooth interruption free navigation when GPS is available or not.

coremicro Palm Navigator Indoor/outdoor personnel tracking

Figure 6 The coremicro Palm Navigator for Personnel Tracking

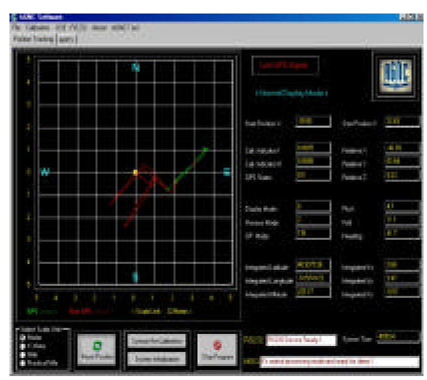

Figure 7 A coremicro Palm Navigator Recorded Indoor/Outdoor Tracking Trajectory

Figure 6 shows the coremicro Palm Navigator for Personnel Tracking. Figure 7 is another typical Recorded Indoor/Outdoor Tracking Trajectory.

The tracking system started from the yellow point and came back to the same point, as shown in Figure 8. The start point and end point error is about one meter. Integration demo of the coremicro Palm Navigator has been successfully demonstrated, as shown in Figure 9.

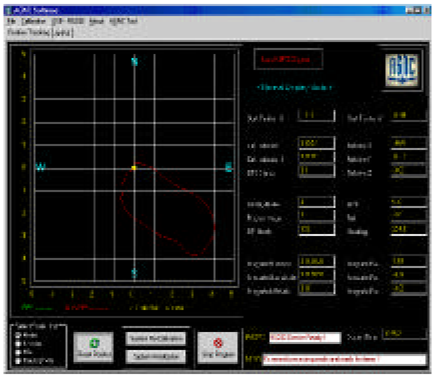

Figure 8 Wide Area Wireless Networked coremicro Palm Navigator Indoor Personnel Tracking

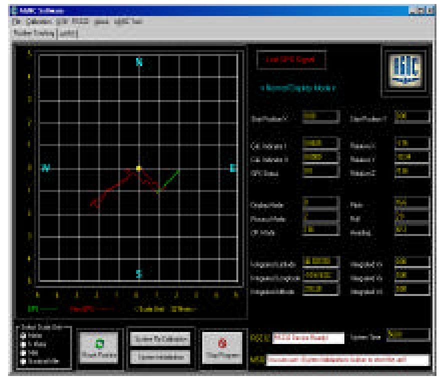

Figure 9 Result of integrated demo of the Wide Area Wireless Networked coremicro Palm Navigator

coremicro Palm Navigator Indoor robotic vehicle and personnel tracking

Wide area wireless networked coremicro Palm Navigators have been successfully applied in the multiple robot indoor and outdoor tracking. Based on the APIs provided by ActivMedia Robotics Interface for Applications (ARIA), we have created a robotic control system that is integrated with the wide area wireless networked coremicro Palm Navigator via a standard serial port with Pioneer 3 onboard computer. The integration of the coremicro Palm Navigator measurements and robotic sensor data was implemented. The overall system accuracy and reliability were enhanced. The wide area wireless networked integrated indoor/outdoor position tracking system has acquired several new features, such as backward motion tracking, sensor interference rejection, wheel skip detection, etc. The following figures are recorded test trajectories for Robot and Personnel indoor non-GPS Tracking.

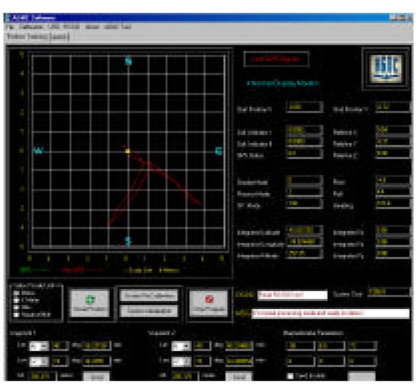

Figure 10 Robot Indoor Tracking

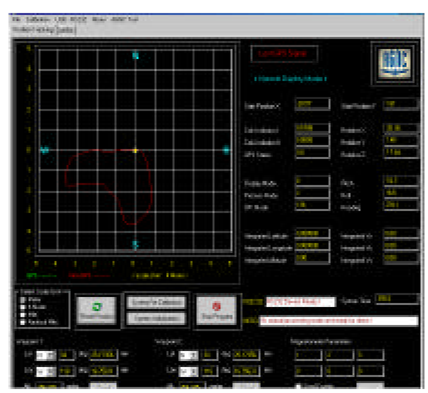

Figure 11 Robot Indoor Tracking

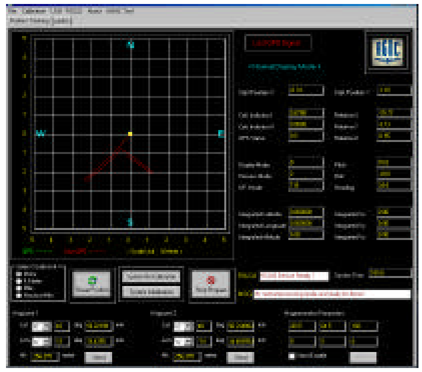

Figure 12 Personnel Indoor Tracking

4. Conclusions

It is urgently needed to have a novel position/location tracking and communications system that would permit multi-tracking, reporting, and recording operations in an open range, as well as in complicated terrains, where GPS signals are jammed or blocked. The precision wide area wireless networked platform positioning/tracking and navigation system using the networked coremicro® Palm Navigator (CPN) described above is essential for cooperative personnel and multiple manned/unmanned vehicles. The results of the system presented have determined that the networked CPN systems can be used in a wide range of applications, such as, personnel/soldier tracking, fixed wing UAVs, helicopters, robots, cars and other unmanned ground vehicles, etc.

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