

Human Machine Interface is a Crucial Link

Introduction

Good decisions require timely and accurate information. In Process/Machine control the appropriate sensors provide critical information to automated control systems that can and do perform the control functions. In the absence of adverse events, everything works as it should and no human intervention is necessary.

Any enhancements in productivity require a better understanding of the process at hand that can lead to the design and implementation of better monitoring and control strategies. In any process/machine control situation the human operator is the crucial element. The operator can be the strongest or weakest link in the chain depending on the information at hand. Critical process information in your hand enables good decisions. Handheld PDAs can serve as platforms with links to crucial information. Information links to the process/machine under control may be wired (serial / Ethernet cable) or wireless (infrared, WiFi, bluetooth or cellular). Wireless links untether the operator and enable '**any time, any place**' connectivity to the crucial information in a timely manner.

Portability and mobility are essential in many applications involving Configuration, Data Collection, Monitoring, Diagnostics and Trouble Shooting. The Palm OS, Windows CE and Pocket PC operating systems residing in portable platforms such as PDAs from Palm, Dell, HP/Compaq and others beckon application developers to harness these platforms to provide a convenient, cost effective and portable Human Machine Interface (HMI) solution. Companies such as Symbol, Intermec Technologies, Psion Teklogix and Unitech provide PDAs that trade off some compactness for ruggedness while incorporating additional functionality such as barcode scanning. Wired communication links are the norm with most controllers. Since most PDAs also have built-in Infrared transceivers and readily support wireless RF capability, un-tethered (Electro-magnetic) communication links to the controllers is possible wherever the controller communication interface can be converted to a wireless medium.

The Human Machine Interface (HMI) software in conjunction with a wireless link to relevant information lends a helping hand to the human decision maker to zero-in on the critical sub-system that needs his attention and take appropriate timely action. The critical information, which may be logged for later thorough analysis, can be accessed remotely (over cellular network or Internet) and available precious human resource can be redirected or dispatched where needed. The operator does not need to carry any cables, and can upload and download configurations, perform diagnostics etc. using a PDA that he can carry in his shirt pocket.

In this article we explain some of the underlying technology issues regarding PDA communications and present several real world stand-alone PDA based HMI implementations using InstantHMI. Software Horizons' InstantHMI supports several platforms (Windows PC, Palm OS, Pocket PC and Windows CE) and connectivity options (Wireless Infrared, WiFi, Bluetooth, Serial and Ethernet).

Wireless Network Technology Overview

Approval of the IEEE 802.11 standard for 2 Mbps wireless LAN in 1997 and the subsequent 11 Mbps revision 802.11b in September 1999, have made truly mobile HMI a reality. The recent 802.11g standard supports 54 Mbps data rate and is backward compatible with 802.11b standard. Wireless Ethernet Compatibility Alliance's issuance of the WiFi (Wireless Fidelity) stamp of approval

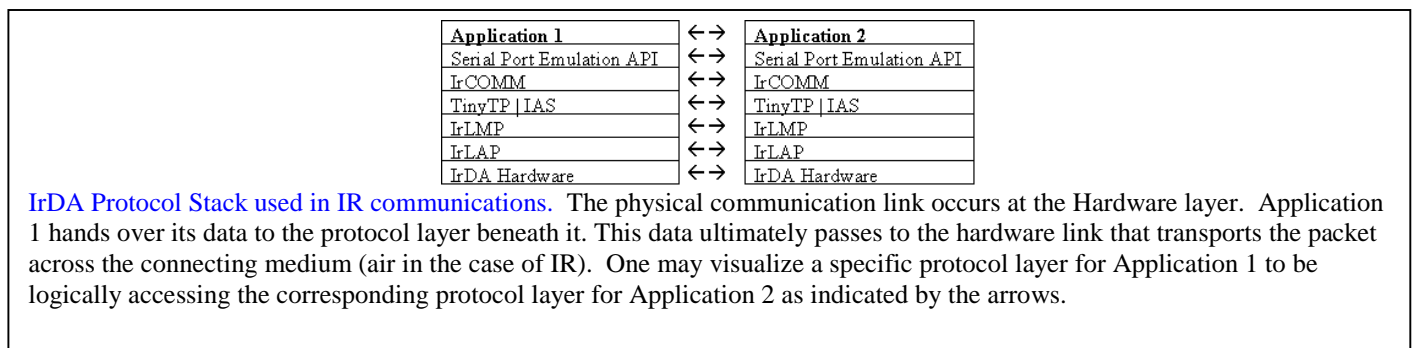
for interoperability for products from different vendors resulted in the availability of cost effective WLAN products for wireless connectivity.

Since the IEEE **802.11** Medium Access Control (MAC) layer can work seamlessly with the IEEE 802.3 standard Ethernet via a bridge or Access Point (AP), wireless and wired nodes on an enterprise LAN can inter operate with each other. Wireless Network Interface cards are assigned 48-bit MAC addresses, which look like Ethernet network interface cards. Rather than collision detection (CSMA/CD) employed by 802.3 Ethernet, 802.11 wireless uses collision avoidance (CSMA/CA). To prevent collisions, 802.11 allows stations to use RTS/CTS 'handshaking' to clear out an area for RF transmissions; in this case communication frames are positively acknowledged.

Two or more wireless nodes may recognize each other and establish an ad-hoc network with Peer-to-Peer communications over a given cell coverage area. The smallest possible 802.11 network is an independent basic service set (IBSS). In most instances such a basic network also contains an AP and all communications between wireless stations, or between a wireless station and a wired LAN node, go through the AP. The APs are not mobile and form part of the wired LAN infrastructure. Association is the process by which mobile wireless stations join an 802.11 network; a mobile station can associate with only one access point at a time. Each station must listen for other stations and begin transmission only if the channel is idle. If the channel is busy, each station waits until the channel is clear and then starts transmission after an additional interval of time (based on the random back off procedure).

IEEE 802.11 RF transmissions take place in the 2.4 GHz ISM (Industrial, Scientific, and Medical) band with worldwide allocation for unlicensed operation (US 2.4000 - 2.4835 GHz). The 2.4 GHz ISM band in 802.11 may have one of three physical layers (PHY): Frequency Hopping (FH PHY), Direct Sequence (DS PHY) and high rate direct sequence (HR/DS PHY, 802.11b). The FH PHY is now obsolete. Three HR/DS networks can be deployed in an area at once while ensuring sufficient channel separation.

The original 802.11 also provided for an **infrared** physical layer (IR PHY). The limited range of IR (3' - 10') makes this medium not suitable for wireless networks. The IR ports implemented on laptop computers and controllers follow the IrDA (Infrared Data Association) standards.



The emerging **Bluetooth** technology also provides RF communications in the 2.45 GHz spectrum with a range of about 30 feet. Serial adapters can provide Bluetooth capability for controllers which makes another option available for wireless mobility for PDA based HMI.

RF and IR in the Electromagnetic Spectrum

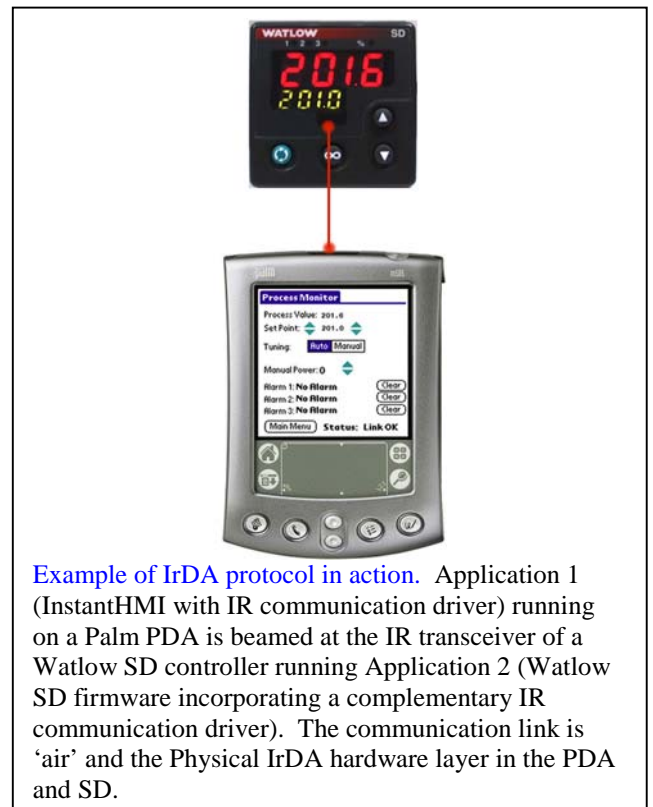
The most dramatic prediction of Maxwell's equations is the existence of electromagnetic waves that propagate through empty space at the speed of light (3.0×10^8 meters/sec). Light is itself such a wave. When electric and magnetic fields are time dependent they influence each other and this coupling produces electromagnetic waves. What is special about light as an electromagnetic wave is that we humans can see (the colors of) this light wave – at least the visible spectrum with wavelengths in the range 0.38 – 0.72 microns (10^{-6} meters). Infrared light is invisible and has wavelengths in the range 0.72 – 1000 microns. Half of Sun's energy is IR radiation. Short wave infrared in the range 0.85 – 1.05 micron is used in IR communications with PDAs; these wave lengths correspond to the frequency spectrum 3.0×10^{14} Hz. Medium wave IR (2-4 microns) and long wave IR (4-1000 microns) are used in industrial heating.

Wired communications (with separate wires for Transmit and Receive) can transmit data in both directions simultaneously; however, IR communications can take place in only one direction at a time because the IR path in the air acts as a single wire link. This link (actually, a 30-degree cone with a range of 3' – 10' emanating from the transmitter to the receiver) is turned around at least every 500 msec under IrDA protocols.

Real World PDA based HMI Implementations using Infrared

Configure and Monitor Temperature Controllers

InstantHMI has provided a portable IR link to configure and monitor data from Watlow SD Temperature Controllers with built in IR transceivers. The operator does not need to carry any cables, and can upload and download configurations, perform diagnostics etc. using a Palm PDA that he can carry in his shirt pocket. The efficiency and simplicity of being able to pre-create, save, and download controller configurations in multiple controllers saves valuable engineering time and guaranteed high return on investment.



Commercial Sewing Machine Setup and Control

This application implements a 'language free interface' for the setup of a line of commercial sewing machines from a multi-national corporation. The Palm PDA displays iconic touch zones for the various functions implemented in a Yaskawa programmable motion controller. The InstantHMI interface includes a PLC program flashing capability. The communication link is either serial or infrared using an IR-Kit to convert the serial port to infrared.



Semiconductor Tool Setup and Monitoring

PDAs can be useful in semiconductor clean room environments for data collection from SEMI equipment. Semi tools may involve in excess of 10000 equipment constants and many recipes; these can be transferred to and from the equipment. Equipment constants stored on the PDA can be compared against the constants currently running in the equipment. InstantHMI will then display any differences to the operator and allow the operator to review the only the constants of interest and change the constant in the equipment or the stored value on the PDA as necessary.

The PDA also allows for easy transfer of equipment constants and process recipes from equipment to equipment by downloading a known good set of equipment constants or process recipes to the PDA. Once this information is stored on the PDA it can be transferred to another equipment that requires the same equipment constants and process recipes in a fast and efficient manner. The communication link is either serial or infrared using an IR-Kit to convert the serial SECS port to infrared.

Robot Programming using IR link

InstantHMI on a Palm PDA enables 6 axis ABB Robots to be programmed and serviced without lugging a cart full of equipment around. An IR-kit was used to convert the serial port to IR, to link with the built-in IR port on the Palm.

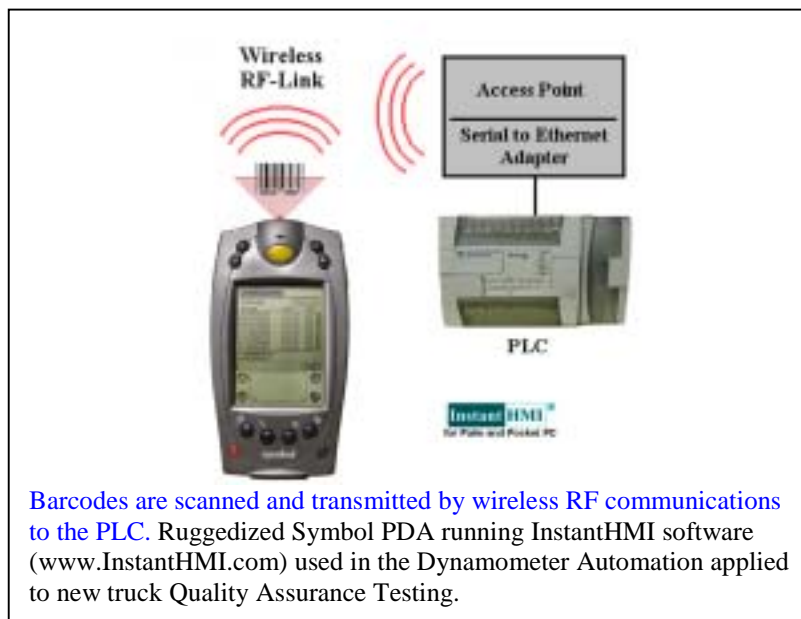
Real world PDA based HMI implementations using RF

Many PDAs (Dell X3i, HP/Compaq iPaq and Palm Tungsten T) have built-in Bluetooth radios. Since Bluetooth RF links have better range (30' - 100' omni-directional compared to 10' 30-degree cone for IR) the availability of cost-effective serial to Bluetooth converters and/or Bluetooth equipped controllers may prove to be a better technology alternative for one-on-one controller communication link in the long run.

IEEE 802.11b RF (WiFi) links have proven to be cost-effective communication links where omni-directional RF links over larger distances (100'-1000' and more) are required. Some estimates of worldwide 802.11 market indicate \$500 million in the last quarter of 2003.

Dynamometer Automation in Quality Assurance Testing of New Trucks

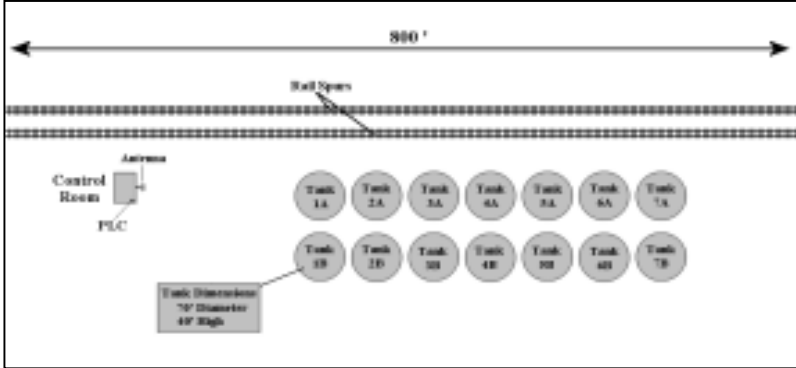
A large truck manufacturing company is interested in quality control of the drives on their two axle and three axle, 185 – 365 HP trucks on the dynamometer. The control system includes programming for 4-axle testing capability and the selection of four wheelbase lengths. The operation requires the operator to drive the truck on to a platform lift and then lower it on to four sets of rollers for testing. Using InstantHMI software on the Symbol ruggedized PDA serving as an Operator Station, the operator can perform all his tasks from the driver's seat in the cab of the truck. The Operator uses the integrated Barcode scanner on the handheld PDA to scan the VIN (Vehicle ID) into the system in addition to the Operator ID. This allows activation of the test procedure. InstantHMI processes the scanned bar codes and uses the wireless RF (11 Mbit IEEE 802.11b standard) capability built into the Symbol PDA to transmit the barcode to the Allen Bradley PLC (Programmable Logic Controller), which is programmed to perform the test sequence. The wireless unit allows for operation of the motor lifts and test sequences all from the cab of the truck. Test results are presented by HMI software on a Windows PC monitor positioned in front of the truck. InstantHMI provides this Windows based HMI access to the crucial barcode information wirelessly over RF link. Testing includes brakes, flywheel horsepower, cruise control, parasitic losses, and transmission shifting all initiated from the cab of the truck. Upon completion of tests the results are printed. The Operator then drives the truck off the test stand and starts the procedure over with the next brand new truck. The test duration is approximately 20 minutes.



InstantHMI makes it more convenient to initiate the different aspects of the test without leaving the driver's seat in the cab of the truck and thus affords a hassle-free setup. In addition, avoiding cumbersome cable and other wired connections to the new truck protects damage to the new truck body and protects its mint-condition. Simplified testing procedure helps minimize errors, allows fault diagnosis, and provides corrective actions to ensure reliable testing. Efficient throughput in terms of number of vehicles tested is assured with minimal waste of time. Due to immediate feedback on the handheld, barcode efficiencies are 100%, human errors due to data entry are eliminated, and test results are reported promptly, thus ensuring the highest possible system efficiency.

Off-loading of Ship cargo onto Railroad cars

InstantHMI has been used in an application involving off loading of ship cargo onto railroad cars where the operator moves from car to car while the PLC and the control room are several hundred feet away. It is not feasible to have a display monitor for operator feedback. A handheld PDA equipped with a Compact Flash (CF) RF adapter and InstantHMI software gives immediate real time wireless access from anywhere in the coverage area (800'x 200') to the relevant PLC variables and enables remote monitoring and data entry. Mobile range of over ¼ of a mile was accomplished with a di-pole antenna mounted at the PLC end while the PDA had an easily portable tiny CF adapter with built in antenna.



Example of IEEE 802.11b protocol in action. InstantHMI in HP/Compaq iPaq Pocket PC uses RF communication to monitor and/or modify data in Allen Bradley PLC remotely from anywhere in the antenna coverage area.

Engine Control in Gas Compression Applications

This application uses a Pocket PC with built-in WiFi to communicate with the controller on the engine. A serial to Ethernet converter and an access point were used to give the modbus port RF capability to link with the Pocket PC. The 24 channel trends of interest are monitored on screen using any selected group of channels. The screens consisting of data fields, touch zones (with bitmaps to provide desired appearance), screen navigation zones, trend plots etc. are created using the InstantHMI LaunchPad development system and deployed on the platform(s) of choice. Trends may be captured and their History reviewed and analyzed later as desired.



Sample Preparation in Electron Microscopy



Qualitative analysis of data from an Electron Microscope demands that samples are correctly and consistently prepared. Denton Vacuum incorporates its thin film experience in the Desk III. Using Denton's patented anode grid, the sputter cathode minimizes heating of the sample, which can cause damage to the sample.

A simple to use and intuitive Pocket PC interface is implemented in InstantHMI to efficiently operate the Desk III sample preparation system. Sample preparation details are stored in the PDA while the powerful 'Transfer Data' facility makes it possible to transfer a record of the sample preparation conditions directly to a remote PC or to the microscope itself. Automation and data storage are achieved using InstantHMI installed in a conventional pocket PC. The deposition characteristics can be saved with the microscope data using a wireless link.

Wireless Control of Cranes used in Truck Body Finishing

This application requires wireless coverage over a large area covered by 22 trolleys and hoists used to transport new truck bodies from station to station. Multiple access points are required to enable the roaming operator(s) with PDA based InstantHMI to wirelessly access the programmable controllers mounted on the 22 trolleys. Operator will be alerted to any alarm conditions at any of the trolleys/hoists as it happens. Operator can selectively view any parameters of interest and initiate any control commands. This application exemplifies the fact that "The essence of wireless networking is mobility" (see sidebar). Site surveys are critical in the deployment of wireless LANs in general and is an important pre-requisite in wireless application of this complexity. A tool such as AirMagnet's Surveyor may be helpful in providing lower cost wireless site surveys.

The essence of wireless networks is mobility

An extended basic service set may be established when we connect multiple access points with their associated basic service set (BSS) to a backbone Ethernet network. In an infrastructure BSS, the BSSID is the MAC address of the wireless interface in the access point (AP) creating the BSS. BSS transitions require co-operation between access points. The access points in the market use an inter-access point protocol (IAPP) to help in a seamless roaming of stations from one BSS to an adjacent BSS. IAPP (draft status IEEE 802.11f) is not standardized yet and hence a single AP vendor may be required. IAPP allows wireless stations to move from one AP to another without interrupting link layer connectivity.

The backbone network linking multiple APs should form a single IP subnet. It is important to understand the difference between portability and true mobility. **Portability** ensures that users can connect to information wherever it is convenient. However, network connection is not maintained while the device is in transit between one location and another. **Mobility** ensures that network connection is maintained while the station is in transit from one location to another. As long as a station stays on the same IP subnet, it does not need to reinitialize its networking stack and can keep its TCP connections open. Due to distribution overhead, the throughput expected in an 802.11 network is only about 50% of the nominal bit rate.

The Mobile IP Working group (Internet Engineering Task Force) has developed routing support to support IP nodes to seamlessly 'roam' among IP subnetworks and media types. The difficulty is that delivery of frames to the mobile node's current location depends on the network number contained in the node's IP address, which changes with each point of connection. Mobile IP solves this problem by allowing the mobile node to use two addresses: a home address and a care-of address, which identify the mobile node's point of attachment. When the mobile node is away from its home address, the home unit gets all the frames and delivers them to the care-of address.

Conclusion

Wireless IR and RF (WiFi) technologies supported by low cost PDA hardware and the availability of stand-alone HMI software for these platforms have made Truly Mobile HMI a reality. In addition, the emerging Bluetooth RF option and the plethora of newly released high resolution PDAs have enhanced the functionality of Mobile HMI. Next generation HMI technology that can be deployed simultaneously on multiple platforms including Windows PC, PDAs (Palm and Pocket PC handhelds) and Windows CE devices has arrived.

About the Author

Ramal Murali is President of Software Horizons Inc. Ramal has over 20 years experience in Decision Analysis involving Monitoring and Control by Human Operators and in Software Engineering. Ramal holds a Bachelor's degree in Electrical Engineering, a Master's degree in Applied Electronics and a Ph-D in Applied Mathematics (Decision and Control) from Harvard University.



Software Horizons' focus is to develop and market low cost Industrial Operator Interface Software and total solutions based on Windows PC, PDA (Palm OS, Pocket PC) and Windows CE platforms incorporating the latest technology for wireless connectivity to allow 'any time, any place' information access in the field and on the factory floor. Software Horizons provides HMI software to customers worldwide and customized PDA based solutions to OEMs (Original Equipment Manufacturers).

N. Billerica, MA * 800-664-2000 * www.InstantHMI.com