Hardware Interface Module

White Paper
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INTRODUCTION

We live in a world changed by the internet and the microprocessor. As both have evolved over time, we are witnessing the expansion of connectivity between small devices and Networks. Smart phones, homes, power, and appliances are examples of devices now being integrated into networks to provide more accessibility and features.

The Military is also looking for more connectivity with new equipment and systems. Older systems or legacy systems (often termed "stovepiped" for their inability to integrate or connect to other networks) are being retrofitted with hardware or software that will provide connectivity and user friendly interfaces. We hear words like Cloud computing, Software Oriented Architecture (SOA), Distributed Data Exchange (DDE) and Interoperability to describe some of the features now sought after in new designs.

The Unmanned Vehicles group is also engaged in seeking out solutions to provide "interoperability" and distributed data exchange for robots in the field. Robots now need to know each the location of other robots in an area, share mapping data and interface with ground sensors such as radar or intruder detection systems.

The Hardware Interface Module (HIM) is a hardware / software solution for these connection problems. Providing support for common interfaces, flexibility and award winning Distrix Software, the HIM provides a low cost and easy to use solution for connectivity problems of today.

OVERVIEW - HARDWARE INTERFACE MODULE

Based upon the Arm 9 processor, the HIM provides the typical features associated with a SBC (Single Board Computer) with added communication interfaces and circuitry designed to provide a powerful cost-effective solution for sensor and data integration. When coupled with Distrix Software, the HIM becomes part of Distrix Distributed Network data enabling connectivity to a host of other systems including Linux, Windows or OS/X based platforms and other Distrix enabled devices.

As shown in figure 1, the HIM comes with two standard connectors. One labeled **NETWORK** and the other **DEVICE.** Typically the *Network* connector will connect to an Ethernet based system and *Device* connector will provide a Serial or I/O connection. The HIM also provides "smart" cable recognition. With a number of premade connectors made available for the HIM, connectivity to the HIM is simplified for standard interfaces such as Ethernet, RS-232, RS-485 and USB. The HIM is also flexible in its design to be customized to support proprietary interfacing and protocols.

Also seen on the front panel is **Distrix** label and Icon. Distrix is communication software enables the HIM to connect to the Distrix Network.

Figure 1
Hardware Interface Module (HIM)

HISTORY OF THE HIM

The Hardware Interface Module (HIM) design was developed as part of a Navy sponsored project to demonstrate "interoperability" between robots. The task of performing "interoperability" has been a topic within the Navy's Unmanned Group for some time and ICI's approach was to introduce a robust data distribution network that would support multiple communication protocols and operating systems.

DESIGN CRITERIA

Design criteria for the interoperability project involved creating a hardware and software solution that met requirements for ease of use, performance and configurability as listed below

1. Support all popular communication interfaces (RS-232 / RS485 / BlueTooth / Ethernet)
2. Design Flexibility
3. Multi-Platform OS support (Windows \ Linux and OS x)
4. "Smart" Connectivity and Power Monitoring
5. Support hardware interfacing for Sensors
6. Distributed Data Networking
7. Robust Design
8. Low Latency communications
9. Implement SOA and OO concepts into design

INTEROPERABILITY DEMONSTRATION

Three iRobot Create robots were used to demonstrate interoperability. Each robot was outfitted with sensors to provide positioning, collision avoidance and primitive distance sensing. Listed below with each description is the HIM and its configured use. The HIM is configured by attaching the appropriate back plate and connectors.

Target Detection – HIM Single RS-232 / Ethernet

The Pololu IR transceiver was chosen to provide target detection for the HIM. The sensor transmits and monitors infrared signals in a 360 degree plane and is controlled via a RS-232 port. The HIM contains a Distrix Agent that controls reads/writes to the sensor. Information published by the Distrix Agent to a central application enables positioning the robot to directly point to the target.

Figure 2

iRobot Create with HIM Modules used in Interoperability Demo

Positioning the Robots within a Grid – HIM Dual Serial Port / Ethernet

Modern robots use a combination of IMU, LIDAR , GPS and Odometry to determine position but for the purposes of this test, a less costly acoustic device was used. The Cricket is an ultrasonic device specifically designed to provide positioning within an enclosed area. The Cricket comprises of ultrasonic and RF transmitters and receivers. To determine distance between two Crickets, a RF signal is transmitted from one Cricket and the receiving Cricket will produce an ultrasonic "chirp". Distance is determined by the measurement of time between the RF transmission and detection of the sonar signal.

For determining position within a grid, 6 Crickets were place in key positions in the Robot demonstration area with two attached to the HIM. The HIM would then "ping" each of Crickets and determine its distance between each one.

The distance data from each of the 6 crickets was then sent to a central computer running an application that would triangulate the position and display on a screen.

As with the target detection, a Distrix Agent running on the HIM provided the communication gateway to provide control and publish data to the central computer.

Collision Avoidance + Robot Control – HIM A/D Conversion, Serial Port / Ethernet

A necessary safety feature with any system is collision avoidance. At the base of each robot is an array of 6 IR proximity detectors. Unlike the previous sensors, the IR sensors do not have an intelligent communication interface and required direct connection to an A/D convertor.

The HIM provides all the necessary interfacing, signal conditioning and A/D conversion routines for the IR sensors. The A/D routine computes the intensity of the reflected signal and translates to an approximate distance. As with the other sensors, the HIM ***publishes*** the data on the Distrix network for availability to an application to show reflected "clearance" area around the robot.

With the IR sensors connected directly to an A/D convertor, the HIM's configurable port for RS-232, RS-485 or USB was available. For this HIM a second agent was implemented to provide the interface to the iRobot through its RS-232 port.

Type	Part Number	Sensor Interface	Description
Sonar	Cricket Crossbow	Dual RS-232	Position Locator
IR Proximity Sensor	Sharp GP2Y0A21YIK	A/D + RS-232	Target Detection
IR Detector	Pololu IR	Serial	Collision Avoidance
Video	AXIS 210 Net Cam	Ethernet	Target Detection
MAC-Mini	Computer	Ethernet	Main Computer

Table 1

HIM Interface and Sensor Integration use in Interoperability Demo

Distrix Agent Creation and Software

All of the HIMs used in this demo connect to the Distrix Network. As noted, Distrix is communication software that provides a "transparent" gateway for all Distrix enabled devices to share data. By using simple software constructs to define the data object and assign publish or subscribe methods, data may be transferred to all devices within Distrix Distributed data Network.

Distrix Agents were programmed for each HIM device on the Robot. These Agents use Distrix API and all contain 3 basic elements –

1. Data Object Definition
2. Publish / Subscribe Method for Data
3. Communication Node or Model

Distrix provides a "System Builder" that provides for a user-friendly GUI that assists in the design, definition and code generation for the creating Agents. For more information on Distrix see www.sparkintegration.com

[Insert Screen Shot of Application Software]

Robot Application Software and Monitoring

Application software for the HIM provided a debugging and verification tool for monitoring the demonstration. For determining the position of the HIM within the grid, the application software performed triangulation from the Cricket position data supplied by each of the HIM in the demo area. This translated to longitude, latitude and direction data that appeared on the application GUI.

For each robot displayed on the GUI, other parameters were now display to show clearance band (collision avoidance data), target location and video from the third robot.

Demonstration Walk-Thru – Putting it all together

To demonstrate interoperability with the Robots, each robot was first confirmed to be working properly by the application.

1. Verifying location and communication with all three robots
2. Initiate search with Robot 1
3. Initiate search with Robot 2
4. Using triangulation, locate target with Robot 3 (with camera)

To see the video Robot Interoperability Video visit www.integratedconsultants.com

THEORY OF OPERATION

The HIM plus the Distrix Software Agent is a core building block in a Distrix distributive data network. Distrix Software Agents running on the HIM enables connection to the Distrix Network and to share data objects with a variety of other devices.

Distrix supports all systems running Windows XP, OS/X and Linux in addition to a number of other embedded devices such as TI's OMAP processor and Atmel AVR. Therefore, the HIM can serve as a communication gateway to a number of computer systems and other Distrix enabled devices.

The HIM will always contain a Distrix Agent to Publish / Subscribe to Data Objects in the Distrix Network. These data objects enable the HIM to function in a number of capacities such as

- Repeater / Router / Distrix Node
- Controller
- Sensor Interface
- Data Translator

An example of HIM use can be seen in the Figure 3 below. Each HIM functions as a gateway to the Distrix Network via an Ethernet connection to a wireless hub. (Note: The connection of the HIM to the Distrix Network can be RS-232, RS485, TCP/IP, Bluetooth).

Each node within the Network can subscribe to data from any source. The Display seen in this example can subscribe to any data object (including Video).

Note that each component has a **Distrix Server** or **Distrix Agent** within each block. In order to understand the communication network shown, a brief explanation of Distrix is provided.

To find out more – visit www.sparkintegration.com

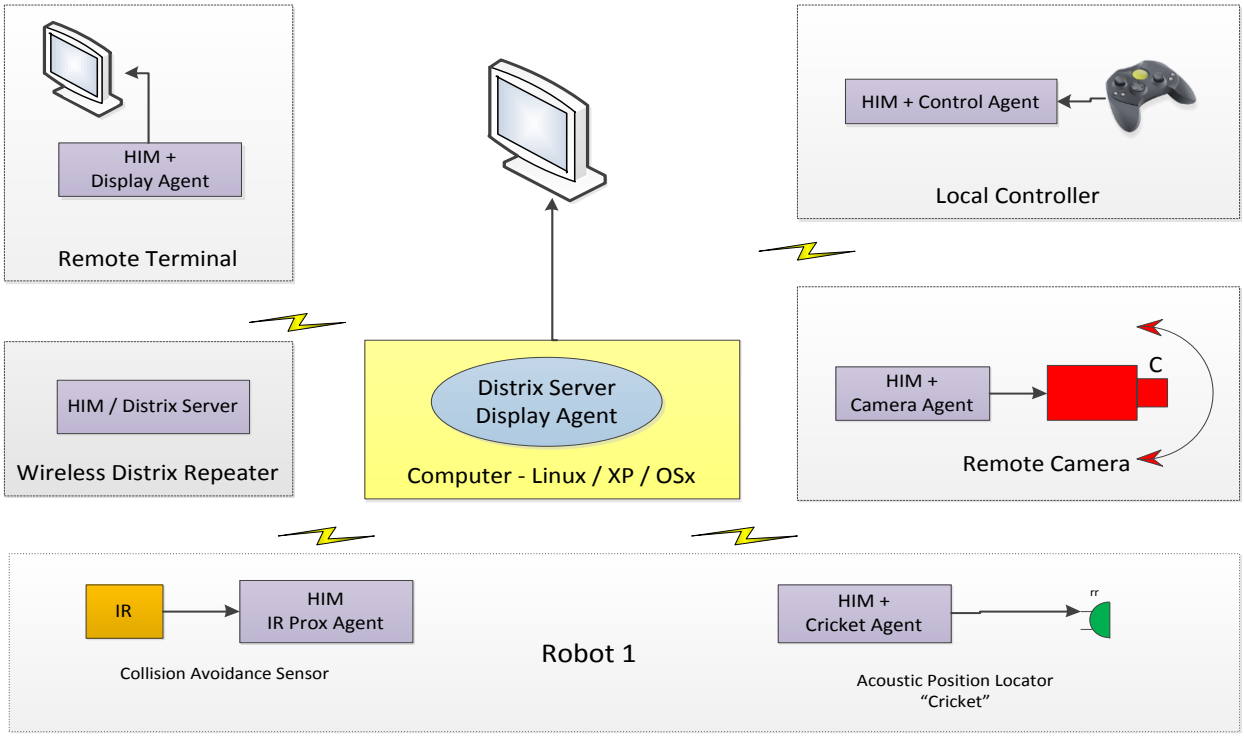

Figure 3

Example of HIM uses within a Distrix Distributed Network

DISTRIX NETWORK

The Distrix Network comprises of a Server-Client infrastructure which are named Distrix Server and Distrix Agent respectively. Each of these software components have unique features that enable the distributive data networking and the interoperability noted in the previous section. Information sharing between Agents in the Distrix Network is accomplished by a Publish/Subscribe method within the system.

Distrix Server

Unlike conventional networks, the Distrix Network can operate with Multiple Servers to provide maximum connectivity and redundant network pathways to ensure data delivery. The **Distrix Server** maintains multiple connectivity and auto discovery mechanisms to continuously monitor and ensure connectivity amongst Agents within the System. The distributed data network also offers other advantages by enabling wireless systems to extend their boundaries into "sub-networks" with preferred connection configurations.

Distrix Agent

The Distrix Software Agent is a customizable software component and can be created by Distrix's System Builder with minimal effort by the programmer. Each Distrix Agent contains definitions for its data Object, available communications channels, publish and subscribe information. Left for the programmer is the task of programing the software interface for the sensor, communication channel or integration into another application with Distrix API.

Distrix Development Tools

Spark Integration provides a series of development tools that enable simplified code development with Distrix System Builder, embedded processor support with Distrix Core Tools and Process / Code Management and SPY tools with Distrix System Manager. With Distrix System Builder, implementation of the Distrix Agent is reduced to simply defining the Data Object and Publish / Subscribe methods for the Object. The Code generator within the software creates the Code Stubs or template to provide customization for C, C++ and Java.

Distrix supports Linux / Windows and OSx platforms and a number of embedded processors such as the Arm, OMap and AVR microcontrollers.

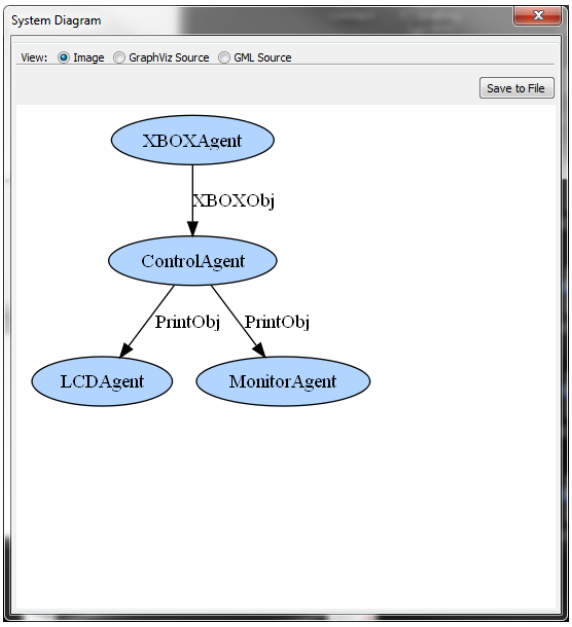

Figure 4
Agent Design Flowchart
Created by Distrix System Builder

The HIM offers a wide range of options for deployment in the field. With the HIM being programmable, configurable and possessing intelligent interface detection, the HIM board can easily be swapped in as a replacement that may be automatically configured itself or be programmed from the Distrix Network.

Automatic Interface Detection

The HIM board comes standard with USB, RS-232, RS-485 and Ethernet. Each cable with its appropriate connector type (RJ-45, 9 pin D-Shell) contains a specific resistor value that enables the HIM board to determine the communication interface type.

The current Standard cable assemblies available for the HIM are

	Communication Type
0	Program \ Reset
1	USB
2	Serial 232
3	RS-485
4	Ethernet
5	None

Software Detection and Programming

Upon connecting to the Distrix Network, identification and software "dynamic discovery" can take place with the HIM. The "dynamic discovery" performed on a new board added to the system provides an automated method of configuring and programming the board to provide the necessary functionality and object handling based upon the HIM interface.

In such a scenario, a HIM can be swapped or added into an already created Distrix Network. Upon Distrix seeing the HIM, the HIM will respond that it has an active Serial Interface. The Server can then query its interface to identify the type and correct setting for the port. Upon successfully identifying its type, the Server will download the Agent (code specifically tailored for the HIM and its sensor interface).

This type of Intelligent Identification and software loading are two features that make the HIM a perfect choice for field operations where maintenance and repair can be simplified.

Figure 5
Standard Connection Options for HIM

**Note*: New HIM module does not require back faceplate change.
Cables are design for universal connection and Auto Cable Recognition for quick replacement/installation in the field.

Applications

Below are listed some suggested applications for the HIM. The XBOX application is also available in a tutorial format for those desiring to duplicate and learned both Distrix and more about the HIM.

Data Translator

The simplest and most powerful use of the HIM for a system is to perform data translation with one of its common interfaces. For example, assume a device with a RS-232 port that you would like to interface with a computer from a remote or wireless location over IP.

To perform this task, the design engineer simply needs to create an Agent with Distrix System Builder. The Builder will define the steps necessary.

1. Define the data object
2. Select the communication protocol and configure
3. Assign Publish / Subscribe Methods
4. Generate the code

From the code produce by Distrix, the software designer will need to implement the translation from the data object into the format to the RS-232. This may require implementing "case" statements or added routines to complete the software.

Customizing the HIM for Legacy Components

Legacy Components and Instruments often represent machines, controls, controllers, radios, sensor interfaces, and computers in areas where the data is often "tightly" coupled or "stovepiped" to the device and have unique interfacing requirements and protocols. As noted in previous application example for Data Translation, interfacing requirements can be simplified by adopting a "data translation" approach to this type of problem.

The HIM board contains additional I/O to provide additional interface requirements. The HIM board can also support hardware level SPI, I2C and TTL level Serial streams.

Distrix also provides for customizing the communication protocols for these difficult interfaces. Templates are available for standard interfaces in which modifications and the addition of a communication configuration file can provide access to the modified protocol.

Despite the difficulty in interfacing with proprietary interfaces, the addition of Distrix design tools with the HIM will make the task as simple as possible.

Application Example – XBOX controller interface

Common on PC's for game use is the XBOX controller. This controller is also very useful for providing control for robots, camera's and sensors etc…. requiring motion and variable speed control

The laptop is an ideal platform from which to connect a XBOX controller to via the USB port and with the XBOX driver, a Distrix Agent can be created for both the desktop/laptop computer to communication with a HIM interface to a robot. (see above example for iRobot create interface)

Contact ICI for further details on creating an XBOX interface for the HIM and using the HIM to control an iRobot.

**Note: This application is presented here only to demonstrate the design process and steps needed to interface to a XBOX controller.*