HIKARI SYSTEMS CORP.

July 9, 2001

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: ENSC 340 Indoor Positioning System Design Specification

Dear Dr. Rawicz,

We have developed the attached *Detailed Design Specification for the Indoor Positioning System* based on the functional specification you received last month. It focuses on addressing the decisions made in the functional specifications of the prototype design; design issues concerning a commercial product are discussed when applicable.

Sections in the design specification follow closely with those of the functional specification to allow comparison and correspondence. However, sections outlining the details of documentation specifications are omitted to allow an elaborate explanation of the core design.

For questions and comments, please contact me at gwfung@sfu.ca; any feedback would be deeply appreciated.

Sincerely,

Gregory Fung
Project Leader
Hikari Systems Corporation

Enclosure: *Design Specification for the Indoor Positioning System*

HIKARI SYSTEMS CORP.

Design Specification for the Indoor Positioning System

Team Members:	Gregory Fung Ivan Ho Ming Jiang Aguilar Lam Sherman Yin
Submitted to:	Dr. Andrew Rawicz, Steve Whitmore, School of Engineering Science Simon Fraser University

July 9, 2001
Version: 1.0

Abstract

Extending from the functional specification, the design specification outlines the method of implementation of the system. To provide a concise documentation, only the implementation methods concerning the IPS prototype are considered in this design specification.

The system will consist of a network of unidirectional infrared beacons that transmit a unique location code. A software application running on a PalmOS 3.x device receives these signals and displays the appropriate location on-screen for the user. An additional hardware module adds compass display and voice-message guidance for the user. All components will adhere to appropriate safety and product standards.

The transmitters are designed for one-time installation without maintenance, in either indoor or outdoor environments. The transmitted signals will not interfere with other existing communication devices and will have an approximate range of 5 to 10 meters (depending on the location). It will be compact, robust, and discrete.

The optional hardware unit for the handheld will be built on the Springboard expansion port standard from Handspring (handspring, 2001). With minimal user effort, the module installs and adds a compass to the screen to help users find their heading, and plays voice messages to provide users with step-by-step instructions to reach their desired destination. As a consumer product, it will be compact and cosmetically attractive.

User software will be easy to learn, with context-sensitive help available. Designed for use on the PalmOS platform, the software will contain information about the installed site, such as room identification, floor plans, and route information. Users may search for destinations and be guided to them, or browse the map for information about the locations. Additional features such as compass or audio output can be deactivated using menu commands. Usage models are designed such that the features for visually impaired users are primarily considered.

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Glossary

ASIC	Application Specific Integrated Circuit. We use the compass ASIC from PNI Corp. to simplify compass circuitry.
Bluetooth®	RF networking standard being introduced (http://www.bluetooth.org)
DAC	Digital to Analog Converter, used to reproduce waveforms from digital information
Driver	A library designed to handle hardware interactions
Graffiti	Handwriting style recognisable by the PalmOS software
Handheld	Handheld computers, light and compact. Usually refers to devices operating PalmOS
IR	Infra-red radiation, used short-range for line-of-sight digital communication
IrDA	The Infrared Data Association, standardises IR data protocols
IPS	Indoor Positioning System, our product, which locates and guides a user to his destination.
Library	A distinct toolbox of common software routines for higher level software use
PalmOS	Operation system for handheld computers by Palm Inc.
PDA	Personal digital assistant, also know as handheld computers
RF	Radio frequency transmission, medium for variable-range signal transmission
SmartCard	Small portable information storage device which uses ultra-short-range RF to communicate to usually stationary electronic readers. Popular applications include restricted access ID keyfobs and rapid-pay transit fare machines
SPI	Serial Peripheral Interface, an industry standard for inter-IC serial communication
Springboard	Springboard expansion slot standard by Handspring Inc.
Stylus	Plastic-tipped stick used to tap and write on the screen of pen-based handheld computers
UL	Underwriters Laboratories, an independent non-profit product safety testing and certification organisation

1 Introduction

This document contains the detailed design specification for the Indoor Positioning System (IPS) proposed by Hikari Systems Corp. (For details of the functional specifications of the IPS, please refer *to ENSC 340 Project Functionality Specification of the Indoor Positioning System*, 2001, or visit http://www.sfu.ca/~syin) The document first gives a brief description of the components of the system. It then utilises an association diagram to illustrate the system as an event-driven application. Subsequent sections provide a thorough discussion of each component of the system, with component block diagrams corresponding to the system block diagram described in section 2.1 of the Functionality Specification. For each component, we attempt to propose a time- and cost-efficient design with justification for each important decision.

The choice of a suitable medium for transmission between beacons and handhelds has been a question raised by readers of the system proposal and its functional specifications. To provide a better understanding for the readers, section 2.2 of this document has been designated to give a justification to the decision we have made to use Infrared (IR) as the main medium of transmission between beacons and the handheld, rather than to use radio frequencies (RF).

Design specifications for all documentation described in functionality specification are not included in this document as they are associated with market production only. Test requirements are only mentioned if detailed design is necessary.

The specifications for the system prototype, to be completed by the end of August 2001, differ from that for a mass-produced product in some areas. The design specifications discussed in this document are tailored towards the system prototype. Design specifications for a marketable product are only mentioned if applicable.

2 System Overview

IPS is designed to help determine a user's position in an indoor facility, with features such as guidance to destinations and orientation information. Topographically, a complete system consists of a set of signal beacons in the facility that broadcasts pre-programmed signals, and a handheld computer (PDA) that receives the signals and displays relevant information to the user. The components on the handheld are further divided into hardware and software modules. The following diagram, Figure 1, illustrates the basic components of the system.

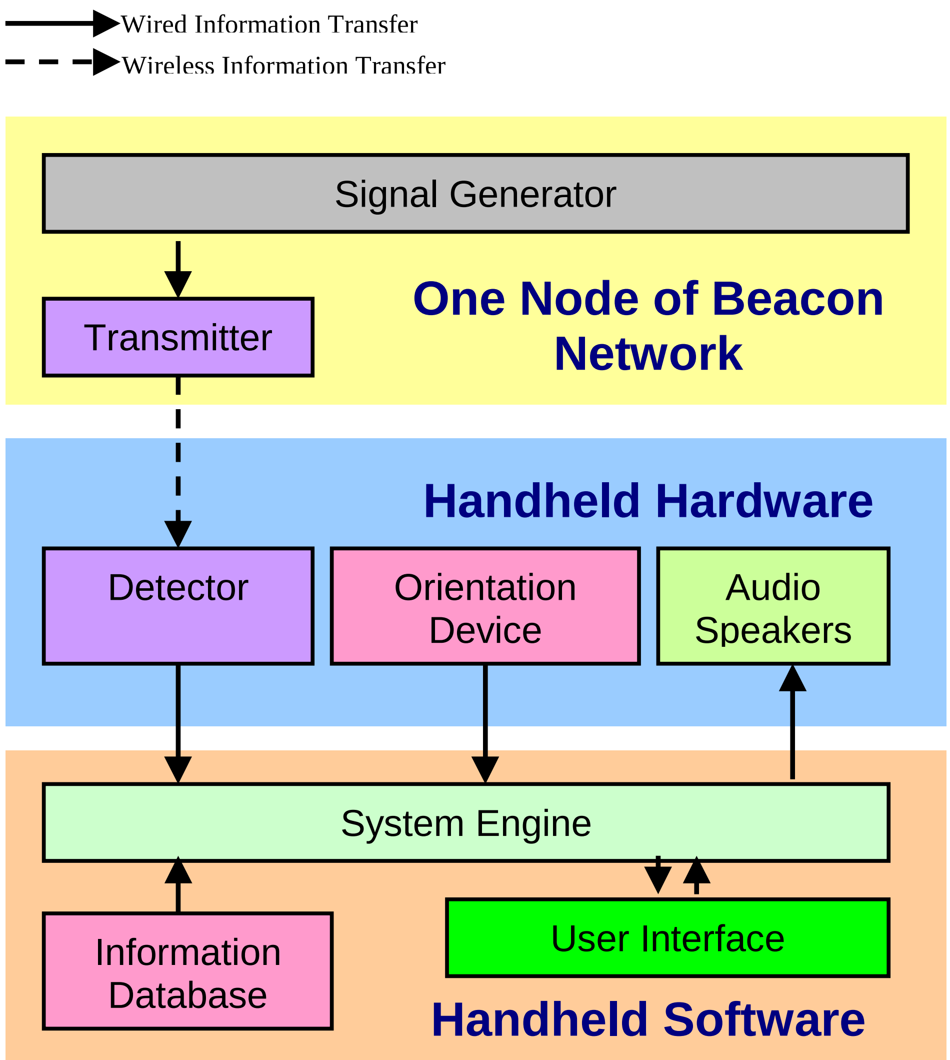

Figure 1. System block diagram

The system begins with the beacons from the facility broadcasting unique infra-red (IR) signals within the specified range. A Visor handheld within the range will detect the signal information through its IR detector; it can then determine its location by matching the signal with that from a database and display it to the user graphically on a map. Using an electronic compass as an orientation device, the user's real-time geographical orientation can be shown on the screen for a clear interpretation of the map. A user may select a pre-defined destination on the map; the system will then present the shortest route to that destination from the current location and guide the user with appropriate directions. Audio guidance is also available to the user through an audio speaker output. Both the electronic compass and the audio speaker are not standard Visor handheld components and will be developed by Hikari Systems Corp.

2.1 System Operation

For the IPS application to be operable on a Visor handheld, the application software must run on PalmOS 3.1 or higher. Any extra hardware associated with the handheld may be connected to the Springboard slot available on the handheld (Handspring, 2001b). From the perspective of the handheld computer, the IPS is an event-driven application that gives outputs to screen display and audio speakers. The events that are associated with the IPS may be described as follows:

Incoming IR signals – the recognition of an IR signal transmitted by a beacon of IPS. The signal information is unique and it dictates the location display on the screen.
Electronic compass information – this information is passed from the hardware to the system engine periodically to update the orientation of the map on the display.
Button-press on the handheld – this is an action by the user on the handheld to perform operations such as system settings and application selection.
Screen-tap on the handheld – this user action may result from functions such as destination selection, and audio guidance.

Each, or a combination, of the above events may correspond to a different setting on the display or audio output. The following association diagram describes the relationship between events and outputs:

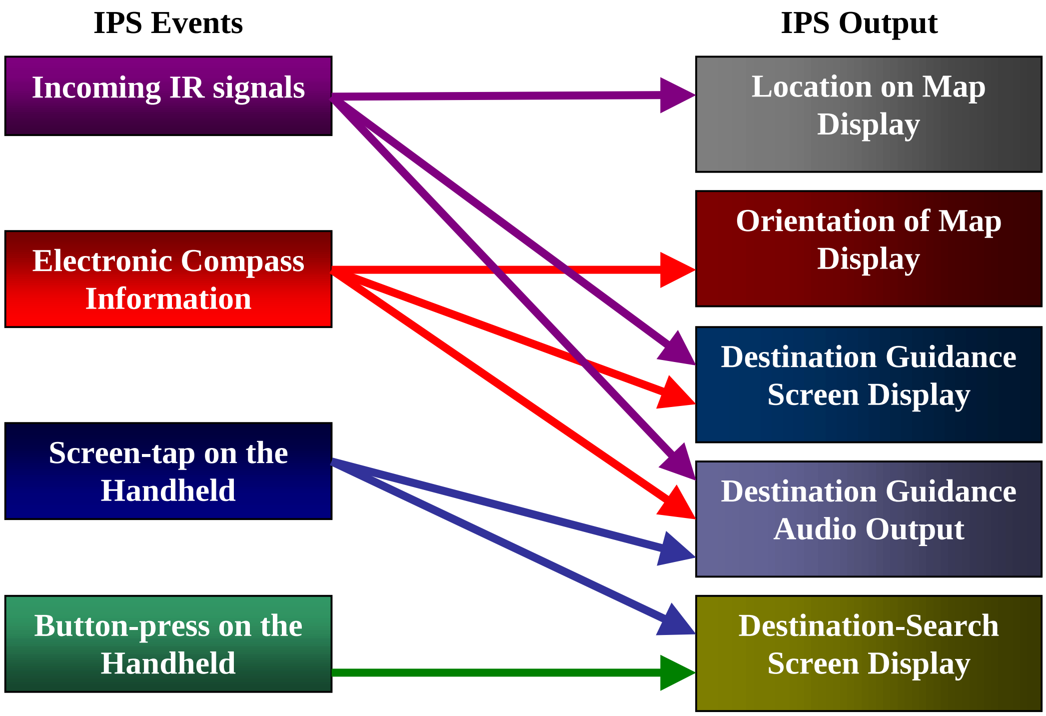

Figure 2. IPS event-output association diagram

Other system events such as power down are processed accordingly to ensure a smooth transition between IPS and other applications in the handheld.

2.2 IR vs. RF – A Justification

Infrared data communication has been employed by many portable and stationary devices since the induction of the Infrared Data Association (IrDA) in 1996. Even long before high speed data communication was possible for IR devices (up to 16Mbps now by new IrDA standard), basic electronics such as TV remote controls have used IR as the medium of information transmission in short-range settings. Its advantages include low-cost of transmitters and receivers, high achievable data rate, and simple implementation. However, one major disadvantage is the requirement of a line-of-sight between the devices, which requires the user to aim the device. While still being wireless, this limits its use in many applications.

Radio frequency carriers have traditionally been used for long-range data communication such as broadcasting and cellular phone networks. However, in recent years, the invention of Smart Card and Bluetooth technology has enabled short-range, high-speed data communication between portable devices. This type of communication is well suited for mobile devices, as radio transmission has no line-of-sight constraint. The transmission range is also larger than that of IR transmission.

The decision of using IR over RF as the means of signal transmission between IPS beacons and Visor handheld was made primarily because of its low implementation cost compared to that of RF. An IR transmitter costs only a few dollars while a Bluetooth compatible RF transmitter costs roughly $20-60 Cdn. The time and complexity of RF transmission development is also greater than that of IR. With the larger number of IPS beacons that are required for each IPS facility, a low cost of producing each beacon is vital to the success of a marketable product.

Another very important deciding factor is that using IR will allow users to utilise our IPS system without the use of any external hardware. Most PalmOS appliances come equipped with IR transmitters and receivers. Since broad user appeal is very important to the usability of our system, it is intuitive that IR is the better choice for our project.

To minimise the negative effects of the line-of-sight requirement by IR transmission in IPS, several transmitters from different angles may be used at each beacon location to ensure that the signal covers a sufficiently large angle and range for the IR receiver on the handheld to conveniently detect the signal.

Although we have chosen IR to be the medium of transmission for the prototype of our project, this decision does not affect the IPS concept. If other communication media are more marketable than IR, later versions of the product may employ such media to tailor different needs.

3 Beacon Network and Transmission

3.1 Transmission Format

The purpose of each transmitter is to transmit a unique identifier code to the PDA so that the PDA may determine the IPS beacon of which the PDA is in the range. For our prototype, we will use an 8-bit data field for this identifier code. This will allow the IPS prototype to identify a maximum of 32 IPS beacons.

In devising the transmission format, it is vital that it complies with the IrDA standards so that the built-in infrared sensor on the PDA may be used. In IrDA mode, pulses lasting 3/16th of a bit time represent logic zero, while no pulses represent logic one. Shown below in Figure 3 is a typical IR packet that will be used in our project.

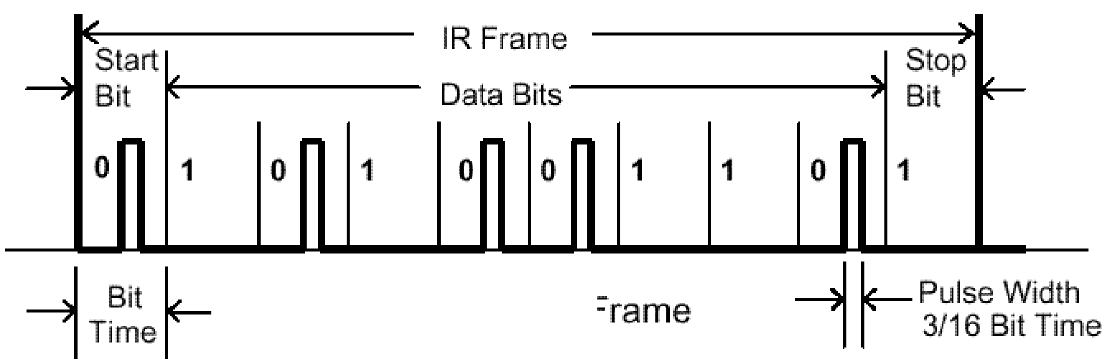

Figure 3. IrDA byte transmission timing example

Please note that an IrDA byte usually consists of 8 bits of data, a start bit, a stop bit and a parity bit. The parity bit will not be used as part of the IPS beacon signal transmission format, which will simplify the transmission algorithm. Instead, other forms of error checking will be used.

Following the IrDA standard, the packet layout shown in Figure 4 was devised.

XBOF	BOF	ADR	Sender	Receiver	Data	FCS	EOF

Figure 4. Packet/frame layout of transmission signal

A more detailed description of each packet section along with size and packet content is shown in Table 1. Note that the packet contents for the sections that have a constant value are also shown.

Table 1. Packet/frame description

Packet Section	Size (Bytes)	Packet content	Details
XBOF	10	0x FFFF FFFF FFFF FFFF FFFF	Defined by IRDA physical standard
BOF	1	0xC0	Indicates the start of frame
Adr	1	0xFF	Logical Address(arbitrary)
Sender	4	0x01010101	Sender Address (arbitrary)
Receiver	4	0xFFFF FFFF	Receiver Address (broadcast)
Data	1	Not constant	Unique address code for each transmitter.
FCS	2	Not constant	CRC error checking
EOF	1	0xC1	Indicates the end of frame

Note: A prefix of "0x" indicates that the following number is in hexadecimal format.

The only two sections that are not uniform for all transmitters are the Data and the FCS fields. The Data field will contain the unique identifier code of the IPS beacon, which distinguishes one transmitter location from the next. The FCS field will be used for CRC (cyclic redundancy check) error checking. In total, each IR packet will be 24 bytes long and it is transmitted at 9600bps.

For satisfactory user response even if packets are only being received correctly on an intermittent basis, packets will be transmitted every 250ms.

3.2 Transmitter

A few major issues had to be taken into account in designing the hardware components and packaging of the transmitters:

- *Cost* - The cost of each transmitter must be as low as possible. Even a small difference in pricing would make a major difference when multiplying the price of each module by the total number of transmitters. In the prototype version of the IPS system, 20 to 30 transmitters will be utilised in our network.

- *Power consumption* – Power consumption must be kept to a bare minimum since the prototype is battery operated.

- *Size* - Modules must be small in size in order to be virtually transparent to user and also for aesthetic purposes.

3.2.1 Overall

A tentative parts list with model numbers and quantity is shown below in **Error! Reference source not found.** and the black box layout for a transmitter module is shown in **Error! Reference source not found.**.

Table 2. Tentative parts list for each transmitter module

Part	Number Required	Model Number
PIC (programmable interface controller)	1	12C508
PISO (parallel in – serial out)	1	MM74HC165
DIP switch	1	76SB08
10 K SIP Resistor	1	
Infrared diode	1	LN66A
BJT	3	2N3904
10 K variable resistor	1	

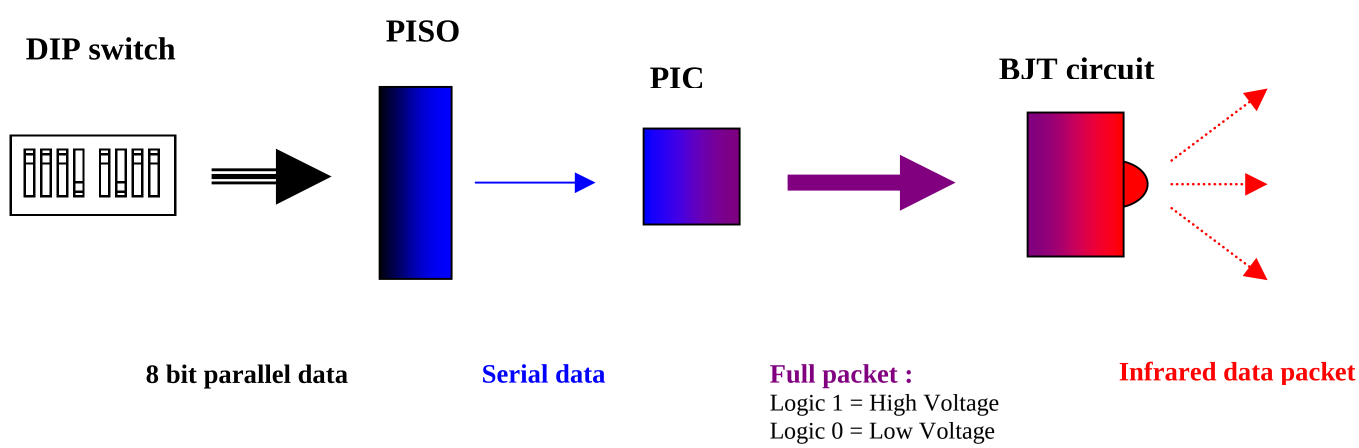

Figure 5. Logical block diagram of transmitter module

3.2.2 Micro-controller

Taking into account the major issues above, the first and most important hardware component to be selected is the micro-controller. All the coding is done on the micro-controller and the rest of the circuit design will be designed around this component. The 8 pin CMOS micro-controller PIC12C508A from Microchip was selected due to its low cost, relatively small size, useful list of assembly library functions and minimal wiring requirements.

3.2.3 DIP Switch / PISO

To determine the unique identifier code of each transmitter, an 8 bin DIP switch will be used. A DIP switch is 8 on/off switches integrated into a dual-inline package where "on" is used for logic 1 while "off" is used for logic 0. Incorporating the DIP switch in our design is very useful if one of the transmitters break down on site and is also good for a field changeable addressing scheme. Since the PIC has less than 8 I/O pins, a PISO (parallel in- serial out) converter will be used to convert the 8 bit parallel data from the DIP switch to a 1 bit serial data into the PIC. The PISO effectively reduces the required number of IO pins from 8 to 3. Code will be written for the PIC to retrieve the unique identifier code from the DIP switch through the PISO and then construct the packet in the format discussed in the previous section.

3.2.4 BJT circuit

The constructed packet will be outputted from the PIC in the form of high voltage (logic 1) and no voltage (logic 0) into a BJT circuit, which uses the PIC output to control the infrared diode. The IR diode was chosen over RF to transmit the data because it is much easier to implement with the palm without any external circuitry or external add-on module. Also, it would be less likely to interfere with other devices.

The BJT circuit will contain a single 10 kΩ variable resistor, which is used to adjust the range of transmission of the IR diodes. This is useful since each site or intersection may require a different transmission range.

3.2.5 Power

To supply the power for the circuitry, a 9V battery will be used. Having a higher voltage is more convenient since it is much easier to step down voltage (using a voltage regulator) rather than stepping up voltage (using switching regulators). The circuit components discussed above require a voltage range between 3.5 to 5V. To avoid having to step up the voltage, 3 AAA batteries could also be used but a single 9V battery is easier to package than 3 AAA batteries, which would require battery holders.

All the circuitry discussed above will be mounted on an etched PCB board. Mounting on a PCB board will increase durability and compatibility greatly.

The outer casing will constructed using plastic because it is easier to mould into different shapes and customise for our own applications. The packaging must be able to protect PCB and hide any indication of the internal operation of the device. The enclosure will be offered in black or white to match ceiling colour. A mounting bracket will be created to provide easy mounting and allow for easy varying of transmission angles.

4 Handheld Hardware

4.1 PDA Resources

IPS utilises the following key features of the handheld supported by PalmOS 3.1:

- Infrared data transfer for beacon detection
- Program storage for application and site database storage
- Audio buzzer for directional guidance
- Direct access buttons and touch screen display for user input
- For audio and orientation functions, the Springboard expansion-slot from Handspring.

4.2 Add-on Hardware Module

The add-on hardware module extends the functionality of the basic handheld to support our unique features. It is intended as an optional enhancement to the IPS user experience.

4.2.1 General

The electronic system layout of our Springboard module, known by the "IpsHw" prefix in software, is shown in Figure 6. Since the Springboard interface is an extension of the main CPU bus, the most logical way to add digital hardware is to map hardware devices with parallel interfaces into a region of memory using appropriate address-decoding logic. The 16-bit data bus is addressed in 2-byte increments by 24 address bits. While the memory must be 16-bit wide, the other devices will use only as many bits as required to transfer the information.

The system runs from a 3.3V voltage supply. Because of the memory access time (programmable over 30-300ns) flexibility of the springboard platform, we will be using the standard low voltage logic such as 74LV from Texas Instruments or 74LVX from Fairchild semiconductor. Other devices are also selected to operate from Vcc=3.3V with low power consumption.

4.2.1.1 Addressing

The springboard can directly address two different devices (Handspring 2001b). To accommodate the extra devices, we use a standard 3-to-8 decoder on three of the address bits. To allow possible device addressing and hexadecimal convenience, D[4..6] are being used for this decoding. The device we will be using is the 74LV138A from Texas Instruments.

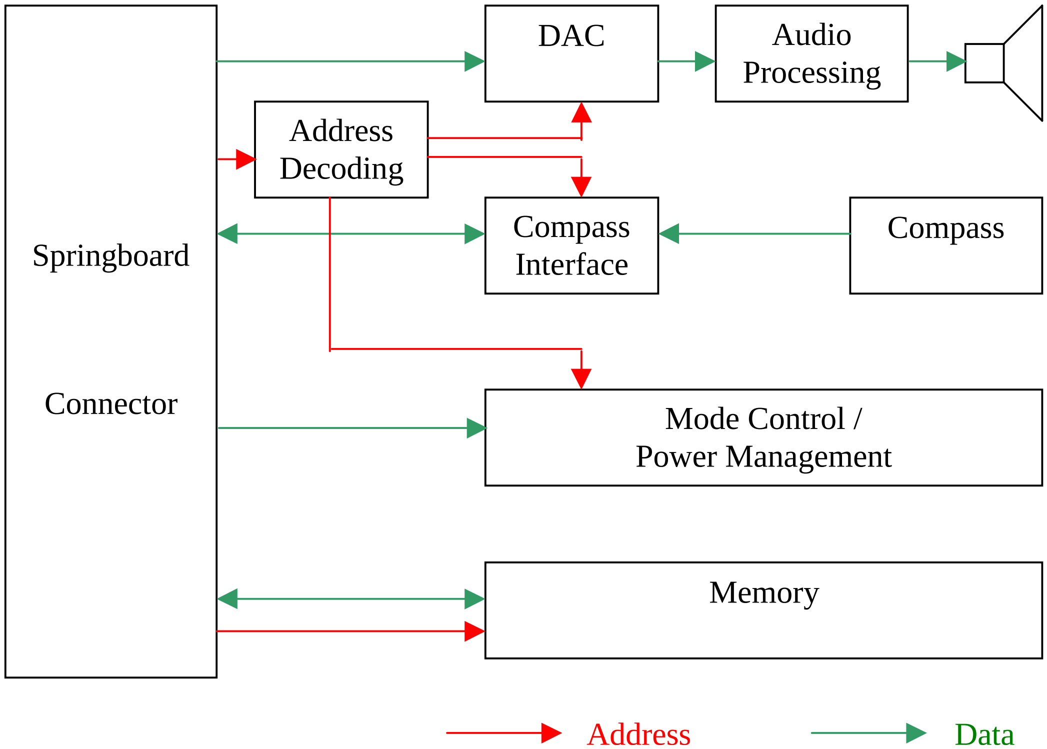

Figure 6. Springboard module system layout

4.2.1.2 Mode Control Signals

In order to hold control signals from the bus so that they retain their values between bus writes, we add D-type flip flops. They are mapped to a memory location as well and their values are updated by a memory write. We chose the SN74LV175A IC from TI. which has 4 flip-flops with complementary outputs for flexibility during prototyping.

4.2.2 Orientation Device

4.2.2.1 Detection Method

After researching our options, we found two electronic compassing solutions available for embedding into our device. The first was the 1525 from the Dinsmore Instrument Co (n.d.). It uses a damped ferromagnetic core, free to rotate inside the unit, to detect the earth's field. Hall-effect sensors then detect where the core is relative to the frame to determine what direction the unit is facing.

Because it uses hall effect sensors, this compass consumes much energy during operation, roughly 20mA at 5V. Another drawback is the mechanical nature of sensor: to avoid oscillations, the core is damped so that it takes 2.5s to settle from a change in direction. This is outside our response time requirement and may confuse the user.

The other solution we found is a patented technique from PNI Corp (2001), a maker of electronic compasses and other devices. Their measurement is based on the earth's field's influence on the inductance of a coil. Using a LR astable oscillator, the device measures the time it takes to complete *n* cycle of oscillation, thus measuring inductance. When two of these coils are placed perpendicularly on the surface, the earth's field would influence one of them differently than the other. By comparing the results from the two coils, the device's orientation can be obtained. PNI has an application specific integrated circuit (ASIC) that automates the measurements needed.

The PNI solution is superior because it uses very little energy, important in our portable application. It also responds quickly to changes in direction, which is important for a good user experience. Finally, PNI has generously donated samples of the ASIC and coils in support of our development. Therefore, we will be using their system.

Note that neither solutions mentioned corrects for the strong vertical component of the earth's magnetic field. This means that the device must be held at a fixed angle against the ground for accurate measurements. For ease of use, the specification for this angle is 45°, shown in Figure 7. This means that the sensor coils must mounted so that they are horizontal when the device is in the shown orientation. PNI is currently working on a three-sensor algorithm that compensates for tilt of the sensors.

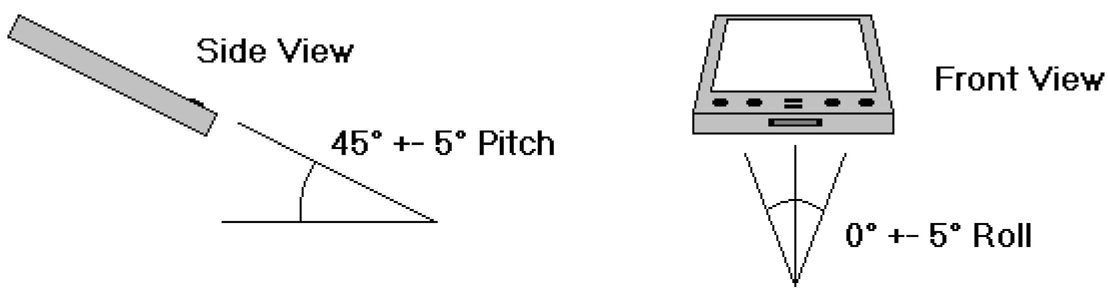

Figure 7. PDA orientation for optimal compass directions detection accuracy

4.2.2.2 ASIC Interface

The PNI Compass Interface ASIC operates from 3.0-3.6V, which is perfect for our application. It is capable of measuring three different sensors. It uses SPI serial communication with the host processor.

Because the springboard interface does not have support for serial communication, we must either add additional conversion hardware or software conversion techniques. Because of our low performance requirements, using multiple software reads and writes to simulate serial transfer is an acceptable and much easier solution than designing hardware to control the transfer. As seen in Figure 9, we only require a few logic gates. The tricky part is to slow the fast response of the Visor memory access to accommodate the 1MHz SPI transfers, which is done with an RC delay.

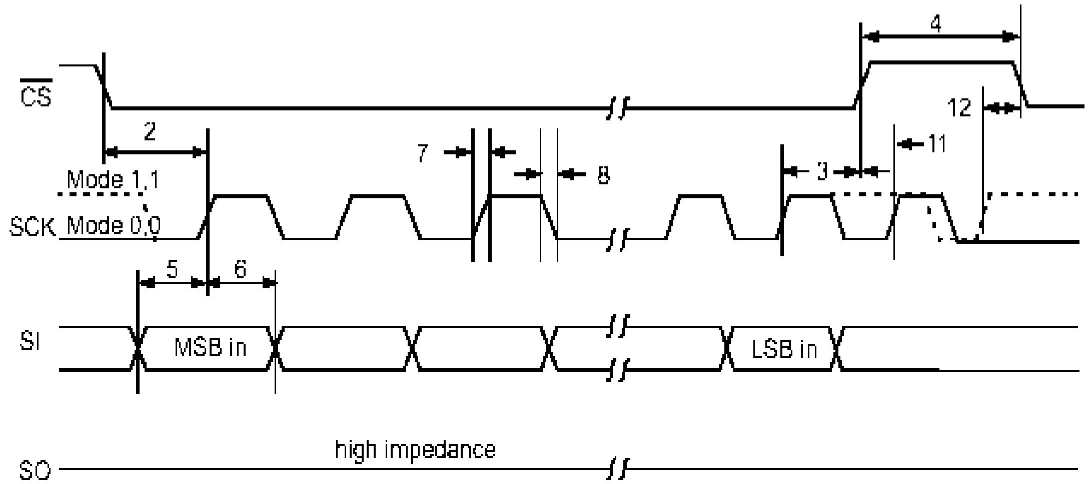

Figure 8. SPI protocol timing diagram

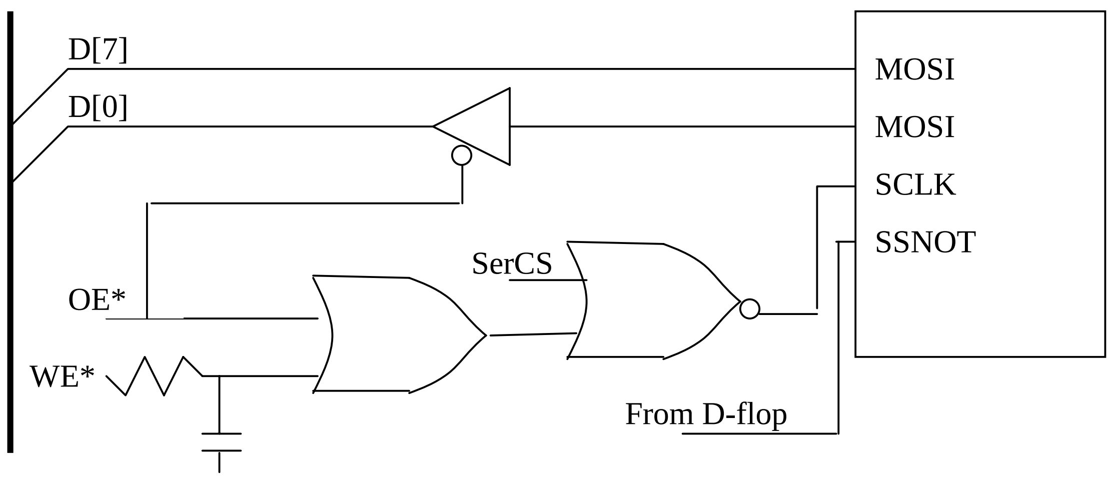

Figure 9. Circuitry for SPI-parallel interface

4.2.3 Speech Output

For voice output, a digital to analog converter (DAC) can reproduce a sampled waveform from memory. Parallel input DACs are designed for bus interfaces and require only address decoding. The lowest standard of 8kHz sampling rate yields a good balance between sound quality and processing requirement. Sounds are encoded with 8-bit codes for a storage size of 8kB/sec.

An analog low-pass filter set for f_c=4kHz smoothes the rippled waveform produced by the DAC. Whether a first-order filter is sufficient will be determined experimentally.

Finally, a 50mW amplifier drives a small 8Ω speaker. A capacitor in series with the speaker blocks the DC current from the non-zero reference we must use to operate on a single supply.

4.2.4 Power

To reduce power consumption, the module circuitry may be activated or deactivated, as controlled by software. MOSFETS gated by mode-control signals interrupt the flow of power to the audio circuitry, compass circuitry, and memory chip. The DAC has a sleep mode under software control as well.

4.2.5 Physical Layout

After development on a prototype board, the module will be packaged in a plastic enclosure. It will sit mostly within the Springboard slot of the Visor, with a protrusion at the top and the back. The circuitry will be packaged inside on a PCB, using surface mount components for their small size. Figure 10 is a drawing of the package, with its internals exposed.

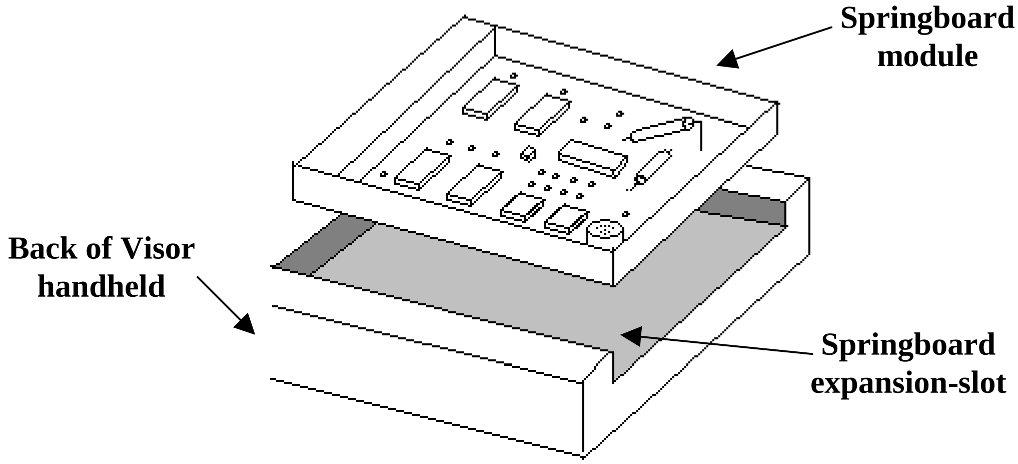

Figure 10. Springboard module packaging concept

4.2.6 Environmental

Electronics designed for the commercial temperature range is sufficient to handle our environmental requirements. Once closed, the plastic enclosure should be splash proof.

5 Handheld Software

In this section, the high-level design of the software part of the IPS will be discussed.

5.1 System Engine

All Palm OS applications are event-driven and have a similar event loop structure. The event loop passes events, which are posted to an event queue by hardware, the operating system, or other applications, to appropriate event handlers. Please refer to Palm OS documentation for details about the standard event loop structure, which is shown in the following figure.

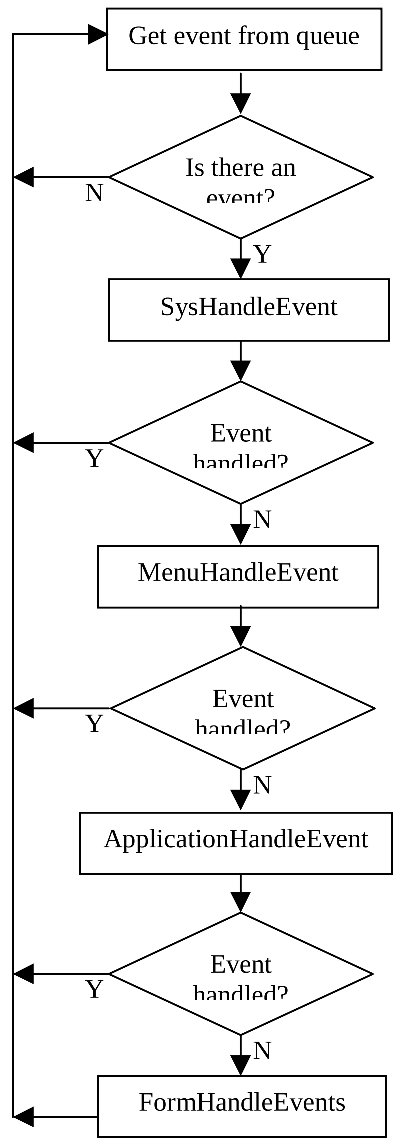

Figure 10a. PalmOS event loop

The IPS application will have such an event loop. The IPS Spring Board Module or the IR port will pass information to the IPS application by posting an event to the event queue. The event object will contain a pointer to that information, which can then be retrieved by the routine that handles that event.

The system engine uses the following algorithms to perform key functions:

5.1.1 Determine Current Node

When there is an event indicating IR data has been received, an IR data handling routine first distinguishes beacon signals from other IR data. If the data received is a beacon ID and is different from the previous received beacon ID, this IR data handling routine will post an event to the event queue for an update routine. The update routine will match the beacon ID to the site information database to determine and update the current location and redraw the display.

5.1.2 Determine Compass Direction

Every time when the screen update routine is executed, the IPS application will call a compass reading routine if the user has selected to display the compass. The compass reading routine will send a request to the IPS handspring module for a compass reading, interpret the data received, and return the orientation of the PDA to the main program.

5.1.3 Determine Direction of Turns

Knowing the path that the user came from, the current node, and the route that the user is supposed to go to, a routine will look up the appropriate guide instruction from the site information database to display on the screen. This routine is only called when the user is in the Guide mode and has arrived at a new beacon.

5.1.4 Shortest Route Lookup

Given a pair of nodes, a shortest path finding routine looks up the pre-calculated tables to find the best route between them. Whenever the user requests guidance from the current node to some destination, the handheld uses this routine. With these results, the program then draws the route on the map.

5.1.5 Retrieve Location Information

Invoked whenever we need to display or process a particular location, an information retrieval routine searches the location database to retrieve the proper information. Many features use this routine during processing.

5.1.6 Identify Location in Map

When users tap on a point on the map displayed on the PDA screen, a reverse look-up routine will find the corresponding location in the information database. For example, when the user taps on a room on the map to view its information, this routine looks up the room number and occupant.

5.2 Information Database

The database that holds information about a particular site is divided into different tables. The relationships between the tables (such as one-to-many, mandatory and optional) are shown in the following figure. For example, a level can optionally be associated to many different nodes and edges but is required to be associated to exactly one site.

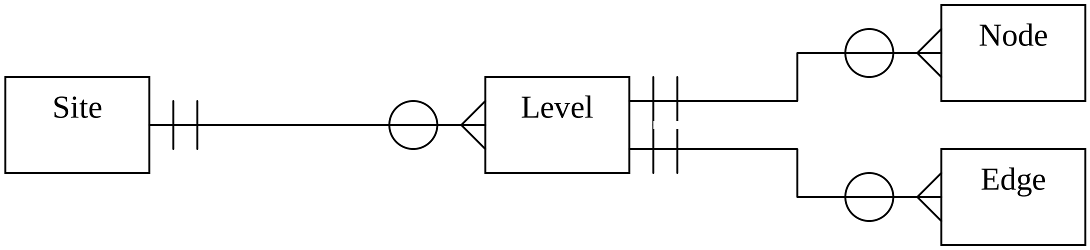

Figure 11. Database structure

5.2.1 Site

This is the part of the database that holds general information about the site.

Properties	Description
Site ID	Site identification.
Site name	Name of site.
Site description	Details about this site.
Creation date	When this site map is last update.

5.2.2 Level

A site is divided into different levels. Each level has its own map and is associated with exactly one *Site*.

Properties	*Description*
Level ID	Level identification.
Parent site ID	The site that this level belongs to.
Level name	Name of level.
Level description	Details about this level.
Pointer to map image	The map to display when user is in this level.

5.2.3 Node

A node is where the beacons are located. These are the locations that the IPS can lead you to.

Properties	*Description*
Node ID	Node identification.
Parent level ID	The level that this node belongs to.
Node name	Name of node.
Node Type	Indicate whether the node is a location of an elevator, room, hallway, etc.
Beacon ID	ID number of beacon installed at the node
Associated locations	A list of rooms or areas in close proximity of this beacon. Once users reach this beacon, they should be able to see all the associated locations.
Adjacent Node/Edge pairs	List of other nodes this node is directly connected to and which path to use.
Guide information	A list of instructions for the users to turn or go straight upon reaching this node, depending on the edge the users enter from and the edge that leads to the destination.

5.2.4 Edge

An edge is a path from one node to another. Since there may not be always straight paths between two nodes (eg. corners), this table stores information about physical properties of an edge:

Properties	Description
Edge ID	Edge identification.
Parent level ID	The level that this edge belongs to.
Components	List of coordinates for drawing the path, including corners and curves.
Distance	The distance this edge covers. Used for shortest route calculation.
Node description	Details about this node (eg. room number)
Adjacent Node/Edge pairs	List of other nodes this node is directly connected to and which path to use

5.3 User Interface Design

5.3.1 Start-up Screen

The start-up screen is the first thing the user sees when IPS is launched (see Figure 12). This screen gives the user a chance to get help if he/she is unsure how to use the program, providing an introduction to the system at the same time.

Figure 12. Start-up screen

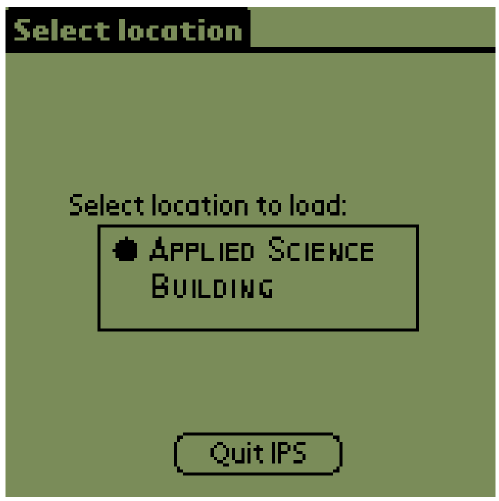

Figure 13. Database selection screen

Table 3. Start-up screen features

Screen Features	Function
Introduction label	• Introduction of the software
First time user button	• Directs first time users to a special help page
Close button	• Button used to close current page and opens up the Database Selection Screen

5.3.2 Database Selection Screen

As this page is being loaded, the system will search through all IPS databases present in memory and display them in a list (Figure 13). The user can then select the database from the list that matches their current location or the location they wish to view. If no databases are found, the list will be empty and the user is forced to quit the program.

Table 4. Database selection screen features

Screen Features	Function
User selectable list	• Displays a list of detected databases/map available • Choosing a database will load the database and open up the Location list screen (Figure 13)
Quit button	• Button used to exit the program

5.3.3 Location List Screen

The location list screen allows the user to search the database for specific locations/destinations by category and also retrieves location specific information (Figure 14).

Table 5. Location list screen features

Screen Features	Function
User selectable list (Locations)	• Listing of all the locations in the chosen category from the database
Drop down list (Category)	• Allows the user to choose the sorting method of locations list • Eg. Offices, washrooms, exits, elevators, etc.
Search box	• Allows the user to search the locations list by entering words
Display field (Details)	• Displays the details of the selected location
Group button (LMG)	• Selects between the List, Map, and Guide screens

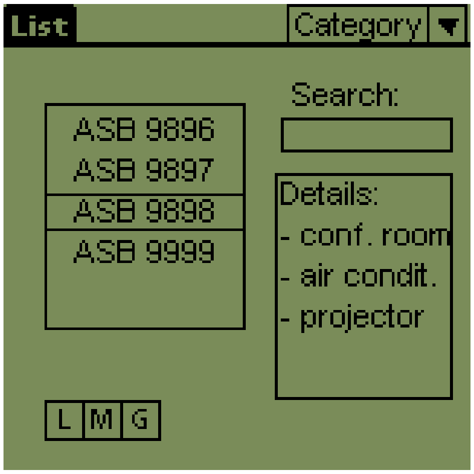

Figure 14. Location list screen

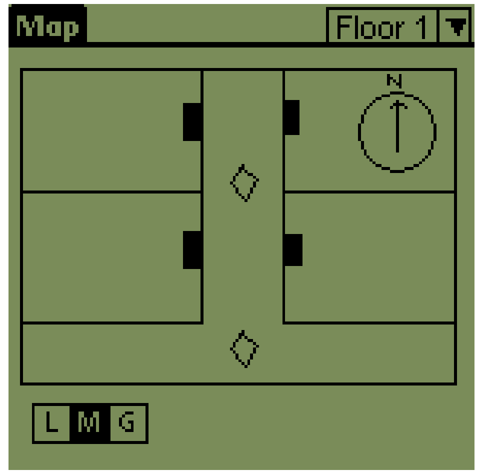

Figure 15. Map screen

5.3.4 Map Screen

The map screen gives the user a view of a sub-section of the map (Figure 15). The map can be dragged in order to display other parts of the map. When the user's position is updated, the map will automatically centres to the new location.

Table 6. Map screen features

Screen Features	Function
Map display	• Displays the halls, doors, rooms, and other features of a floor plan map • Diamond shaped objects in the hallways represent the locations of the IPS nodes • Blinking node shows the user's current location • Real time compass diagram updates to the user's direction
Drop down list (Floor)	• Allows the user to switch between floor views of the map
Group button (LMG)	• Selects between the List, Map, and Guide screens

5.3.5 Guide Screen

The guide screen is very similar to the map screen except for direction arrows that display the route to the destination (Figure 16). This screen can only be used if a destination has been selected in the list screen (refer to section 1.1.1).

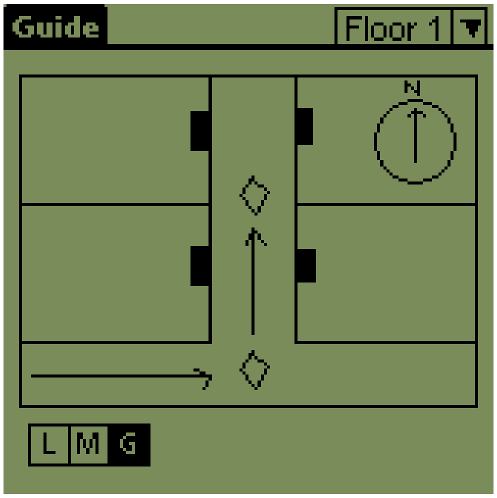

Figure 16. Guide screen

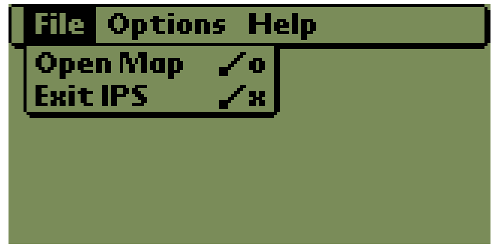

Figure 17. File menu

Table 7. Guide screen features

Screen Features	Function
Map display	• Displays the halls, doors, rooms, and other features of a floor plan map • Diamond shaped objects in the hallways represent the locations of the IPS nodes • Blinking node shows the user's current location • Real time compass diagram updates to the user's direction • Directional arrows showing best route to destination
Drop down list (Floor)	• Allows the user to switch between floor views of the map
Group button (LMG)	• Selects between the List, Map, and Guide screens

5.3.6 Menu Options

The menu bar is common to all screens in the above section except for the start-up and database selection screens. This gives the user a consistent set of features/options that can be accessed at any time. The components and functions of the menu bar are described in Table 8 below.

Table 8. Menu items and their functions

Menu	Item	Function
File	Open Map	Allows user to change databases/maps
	Exit IPS	Quits the IPS program
Options	Toggle Sound	Turns sounds on or off
	Toggle Compass	Turns the compass feature on or off
Help	Contents	Go to the contents page of the help menu
	About	Description of IPS and Hikari systems

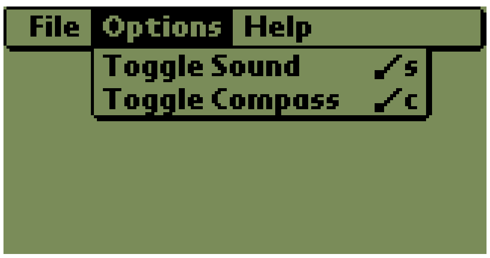

Figure 18. Options menu

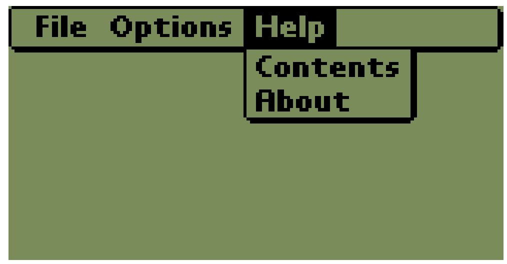

Figure 19. Help menu

5.4 Hardware Support

A library supports the optional Springboard hardware module. This driver software allows the application to use the functionality of the module without knowing its internal workings. For infrared services, PalmOS 3.0 has a standard library that we can use to detect signals from the beacon.

5.4.1 Beacon Signal Detection

Since the library functions follow the specifications of the IrDA Link Access Protocol (IrLAP) and Link Management Protocol (IrLMP) (IrDA, 1996), the format of signal transmission by the beacons must also follow the physical, as well as the Link Access Protocol, specifications from IrDA. This specification allows the data to be recognised by the IR library.

To avoid the complexity of implementing a connected communication protocol between the handheld and each IPS beacon, we will employ a connectionless and unacknowledged method of IR data transmission from the IrDA Link Access Protocol specifications. This simply means that the transmission frame of the IR signal from the beacons will follow the format of a connectionless IrLAP frame. Upon the reception of the frame by the handheld, it will not send an acknowledgement of the frame back to the beacons. This transmission method may not be reliable every time, but it is compensated by the repetitive nature of the beacon signal transmission. In this case, if a received frame has errors, it will be discarded. The receiver will then detect the next available frame.

A beacon signal detection driver will be implemented on top of the Palm OS IR library to raise an event to the IPS system engine upon receiving valid signals from an IPS beacon. The signal data is then passed to the system engine for location identification.

5.4.2 Sound Play

When requested by software, the driver fetches the entries of the sound file and sends them one by one to the DAC at the proper sampling period. Because PalmOS does not support timing for such short intervals, this routine must execute continuously during sound playback and time its own activities.

5.4.3 Compass Read

The compass read routine interacts with the compass hardware through a sequence of events to take the proper magnetic field measurements. Using this information, the routine then calculates the correct heading and reports this to the caller.

5.4.4 Power Management

All springboard modules have power management routines to save energy during shutdown. Our library's sleep and wake routines disable and re-enable the proper hardware respectively.

5.5 Application File Format

The IPS application will be available in a PRC format, which is the format for most PalmOS applications. Site maps, which contains information about a particular area or building, will be available separately in PDB format, the format used for Palm databases, for easy installation. This combination is analogous to MS Word and .doc files. Users can have multiple site maps installed on their PDAs and can delete those that are not needed to save storage memory.

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