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SMARTSHELF™: REPORT OF ACTIVITIES FOR FISCAL YEAR 1996

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FFR 28 1997

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December 5, 1996

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Prepared by the
Oak Ridge Y-12 Plant
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for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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SmartShelf™: Report of Activities for Fiscal Year 1996

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Executive Summary

This report covers activities on the SmartShelf™ project for the period 1 October 1995 through 30 September 1996. During this year, project team members have advanced the state of the hardware and software from rough prototypes to a working system ready for field trials. The project team has developed an intimate working knowledge of the hardware and software, and has become expert at implementations of Dallas Semiconductor touch memory devices. System hardware includes a desktop PC running LabView and Microsoft Access, and an STD-bus 8086 computer to monitor container storage locations (nodes). The STD-bus computer monitors up to 128 nodes, and responds to operator actions (adding or removing containers) within 10 seconds. The PC uses LabView software to query the STD-bus machine to obtain records of transactions, and to download configuration information. Microsoft Access is used to store the transactions and configuration data in a user-accessible form.

Introduction

The SmartShelf™ system is designed to maintain an up-to-the-minute inventory of containers or other assets. Through the use of Dallas Semiconductor touch memory devices affixed to containers and entrusted to authorized operators, the system can determine which operator added or removed which container and when the transaction occurred. Through the use of a PC-based data base system, reports of the current status of all containers and nodes can be generated in minutes.

The overriding design principle of the system has been cost. With this in mind, hardware was selected to keep the per container cost under \$50. When possible, off-the-shelf equipment was procured and adapted, rather than designing custom items. Only when the cost of in-house design was outweighed by the savings in the labor needed to perform modifications was custom equipment developed. This design goal was met with "first generation" hardware that carries an estimated cost of \$45 per container, including labor. "Second generation" node hardware, coupled with the apparent ability to monitor a greater number of nodes with a single computer, is expected to bring this per capita cost down to \$35.

The SmartShelf™ system consists of a (possibly large) set of nodes (to each of which may be connected a container) monitored by a controller which, in turn, is monitored by a PC. The sole function of the controller is to interrogate each node to determine what, if anything, is presently attached to it. If the same is found as was found at the last interrogation, then all is well. If not, then action appropriate to the situation is taken. Operators communicate with the controller by presenting an identification button to the node and watching for the controller to signal back by

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flashing a light-emitting diode (LED) mounted at the node. Each transaction is recorded by the controller and held until it is queried by the PC.

The function of the PC is to be the intermediary between the human supervisor of the system and the node network. The PC maintains a data base of node information (identification numbers associated with each node, node location, item presently attached, etc.), and container information (present location of each container, identification number or numbers, etc.). It interfaces to the human supervisor through the data base program to which queries can be posed to obtain system information. Several queries and reports have already been prepared; the variety is limited only by the imagination of the users.

The remainder of this report describes the various pieces of hardware and software developed during fiscal year 1996. Hardware is discussed first. Software descriptions follow, and are subdivided according to the platform on which the software runs.

SmartShelf™ node hardware

The network of nodes is realized as a set of 8 serial communications lines emanating from an STD-bus computer. Each line (4 conductor flat modular telephone cable) is realized as a chain of up to 16 nodes, each of which is housed in an off-the-shelf dual modular telephone jack box (Radio Shack part number 279-348). The two RJ-11 telephone jacks in each box are used for "data in" and "data out" connections for the chain. Within each box is contained a printed circuit board with two Dallas Semiconductor DS2405 addressable switches, and an LED and its current-limiting resistor. A pig-tail wire is soldered to the circuit board, passes out through the side of the box, and terminates in an RJ-11 telephone plug. This pig-tail is coupled to a Dallas Semiconductor DS1402-R3 connector that allows touch memories to be electrically attached to the node.

The two switches serve three purposes: Since each switch has an unalterable unique serial number etched in its integrated circuit by Dallas Semiconductor, the pair of them uniquely identify each box. In addition, one of the switches is used to control the LED to signal the operator to perform some action, while the other is used to sense the presence of a container attached to the pig-tail.

The node box itself is composed of a mounting base that accepts screws for permanent attachment to a wall or post, and a cover in which are mounted the two RJ-11 jacks and the printed circuit board. The LED and pig-tail slip through small holes drilled in the cover. The cover screws to a mounting boss molded into the base. The circuit board has a hole in it that allows the mounting boss to protrude through to mate with the cover.

The mounting procedure is to attach the base to the desired site, and then to slip the cover with the circuit board over the base taking care to maintain the alignment between the mounting boss, printed circuit board, and cover. Then the cover can be screwed to the base. The procedure is reversed to remove or replace a node box.

This procedure and the assembly procedure for the printed circuit board were found to be onerous in practice. A "second generation" node that overcomes these difficulties has been designed and tested. The new node utilizes a circuit board and electronic components that are amenable to automated assembly. In addition, the pig-tail and coupler have been eliminated and replaced with a third RJ-11 jack, and the circuit now incorporates a new Dallas Semiconductor product that combines two addressable switches into a single integrated circuit. The new node is mounted in a custom modified enclosure whose mounting brackets are outside the enclosure. Thus, the node need not be disassembled to install or remove it. The cost of the components of the new node is approximately \$2 less than that of the original node, and automated assembly of large quantities is expected to yield even more savings. Furthermore, since each new node contains only one switch (rather than two), the number of nodes on each serial line can be doubled.

Methods of attachment of touch memory buttons to sealed and unsealed containers were also investigated. A stainless steel plate that traps the button and that can be welded, riveted, screwed, strapped, or glued to a container was designed and fabricated. Such a plate is suitable for attachment to an unsealed metal container, to any wood or cardboard container, or to sealed metal containers that can be punctured or heated by welding or soldering. It can be glued to stainless steel, but that is not recommended because the plate can still be pried off with a pocket knife or screw driver.

Plastic button holders have been found that can be strapped to a container by plastic or steel cable ties. This method of attachment offers the advantages of ease of implementation and the fact that almost any shape or surface condition can be accommodated. Tools for the automatic tightening and cut-off of cable ties are readily available. The major disadvantage of this method of attachment is that in some cases, it may still be possible for the cable tie to slip or be slid over the edge of the container, thus separating the container from its identification tag. This problem may be mitigated, however, by the use of an adhesive or tape to hold the cable tie in place.

Cable ties may also be used with an alternate form of touch memory. Dallas Semiconductor manufactures the DS2502 touch memory which is electrically identical to the DS1992 button and is supplied in a TO-92 package, a common form for transistors, approximately 0.125 inch in length and 0.125 inch in diameter. The device may be soldered directly to 4-conductor flat modular telephone wire and then directly attached to the pig-tail (eliminating the need for the DS1402 connector). The wire and DS2502 are very easily attached to containers by strapping. They are most useful in store-and-forget applications where the container need not be moved after being placed at a storage site.

Adhesives for sealed stainless steel containers have also been investigated. Adhesive foam pads supplied by Dallas Semiconductor have been found to work well in dry conditions and when the container surface is free of oil, dust, and peeling, flaking, or chalking paint. The pads generally do not detach when subjected to shock, but do yield in conditions of steady force applied for long periods of time. The torque generated by the weight of a DS1402-RP3 connector (a few ounces) over a period of several days was sometimes sufficient to detach a pad from a stainless steel container. However, the effect was considerably lessened if the button and pad were allowed to

sit undisturbed horizontally for at least 24 hours before a connector was attached. The button-to-pad-to-container bond appeared to strengthen with time.

Several glues for affixing the buttons directly to stainless steel cans have also been tested. It was possible to detach all glued buttons with some amount of effort. Epoxies were found to be effective only if the button was not subjected to shock, such as dropping or striking, or prying with a knife. Contact cement was very effective in resisting shock and prying with fingers, but was easily undone with a pocket knife. Rubber cement and casein glues were not effective at all. Super glues were not investigated because it was not expected that such glues would be able to fill the small void that occurs between the slightly concave bottom the button and the can.

One glue that has shown promise was obtained locally at an automotive supply store. The glue was advertised to adhere well to both porous and nonporous materials (except styrofoam, which it dissolves) and to form a waterproof, flexible film 24 hours after application. The suggested uses of this product are for the repair of vinyl, forming seals around lead-acid battery terminals, attachment of side moldings and trim to vehicles, and the repair of cracked plastic and mirrors in automobiles.

A button affixed with this product was held to the can despite repeated blows against the edge of desks and drops from 4 feet of elevation. It was not possible to remove the button by prying with the fingers alone, although hard pressure was able to force a thin-bladed screw driver under it and then pry it off the can. The glue adhered so well, however, that the steel of the can was visibly dented and deformed by the attempt to force the screw driver under the button. In fact, the steel was nearly punctured by the screw driver blade. The button was only slightly nicked by the screw driver and not otherwise damaged. The effects of temperature on this glue have not yet been tested.

STD-bus computer software

The STD-bus computer runs a real-time multitasking operating system, TICS, under which tasks that monitor the serial lines run in a time sliced environment. Time slicing means that each task is allowed up to 0.1 second to run at which time control of the computer is yielded to a different task. The tasks take turns using the time slice in round-robin fashion. There are a total of eight serial lines used to monitor containers, which means that each task runs for 0.1 second every 0.8 second. The tasks have been timed and found to require approximately 1 second (unsliced) to monitor 16 nodes (unless otherwise noted, all nodes discussed here and below are "first generation" nodes), which implies that 8 seconds of elapsed time will be the usual response time of the system. Use of second generation nodes will halve that time.

The task software continuously interrogates nodes in its serial line to determine if there have been any changes in attachments to them. The protocol to attach an item to a node is as follows: An operator presents his or her identification button to the connector at the node. Within a few seconds, the computer discovers the button and begins to flash the LED at the node. The operator then removes his or her button and attaches the container. The computer stops flashing

the LED, and records the node identification numbers, operator identification number, container identification number, and the time of day.

To detach an item, the procedure is essentially reversed: The operator removes the container. After a few seconds, the computer notices the removal and flashes the node's LED. The operator then presents his or her identification button to the connector, which then stops flashing. The operator removes the identification button, and the computer records the node identification numbers, operator identification number, container identification number, and the time of day. In this and the attachment protocol, the operator is given 15 seconds to respond to the flashing LED.

Violations of these protocols are detected by the computer. If a container is removed or added without an operator identification, or the operator leaves his or her identification button in the connector, an error is noted. In addition, various hardware errors such as missing nodes, multiple containers attached to a node, containers attached directly to the serial line, and extra nodes are detected and noted.

The STD-bus computer stores records of all transactions (valid or invalid) in its memory until it is queried by the host PC. Communication with the host is over a high-speed RS-485 serial line running at 38,400 bits per second. The time between queries is user selectable, but typically is set at approximately 2 minutes. With each request for transactions, the host PC also transmits the time of day to the STD-bus computer.

The STD-bus computer software also includes a "watch dog" task that runs once per minute to check that the monitor tasks have not stopped. If a task has been found to have stopped, the watch dog attempts to restart it. If that fails, then the loss of that task is reported to the host PC at the next request for transactions.

The STD-bus computer software accepts configuration data from the host PC. On start up, the system does not have information about the nodes. Although it can detect the presence of nodes, it cannot associate the two switches in each node with each other. Since there are two switches in each node, the host PC must "tell" the STD-bus computer the correct association and also identify the LED switch and the pig-tail switch. This information is transmitted from the host PC after the first query for transaction data.

Host PC software

The host PC is responsible for maintaining communications with the STD-bus computer and for keeping a data base of container and node information. Two software components reside on this computer: a LabView program to communicate with the STD-bus computer and the Microsoft Access data base manager.

LabView software

This software communicates with the STD-bus computer over a high-speed two-wire multi-drop RS-485 serial communications line. RS-485 was selected for this function because it allows up to

32 devices (i.e. STD-bus computers) to be connected to a single line. The line may be physically up to 3000 feet in length. LabView uses the RS-485 line to query the STD-bus computer at 1 - 2 minute intervals for transaction and status information. It also sends the current time and date to that computer so that the two can remain synchronized.

The LabView software contains code to generate messages to and interpret messages from the STD-bus computer. These messages contain data, descriptive information, and a checksum to detect errors in transmission. Both computers compare the transmitted checksum against a computed checksum to ensure validity of the data. If an error is detected, then the message is sent again up to a total of 9 times.

LabView also communicates with Microsoft Access to store transaction data in a data base and to retrieve configuration information. When LabView is started, it first launches Access and determines what STD-bus computers are in the system from the data base. It then searches for those computers on the RS-485 line and when it finds them, downloads configuration data to each. LabView then settles in to sending queries to the STD-bus machines on a regular basis.

When transaction information is received from an STD-bus computer, the message is validated and parsed to obtain node, container, and operator identification, kind of transaction (valid, invalid, removal, attachment, etc.) and time of day. This data is converted to a form suitable for insertion into an Access data table and transmitted to Access. Communication between LabView and Access is transparent to the user.

Microsoft Access software

This package is responsible for the maintenance of transaction records, operator, container and node information. The data tables include a list of transactions (both valid and invalid ones), a list of containers with their electronic (touch memory serial number) and printed (such as bar code or other label) identifiers, a list of operators and their identification buttons, a list of nodes and their physical locations and switch identifiers, and a list of error messages so that the numerical codes returned by the STD-bus computer can be made intelligible.

The Access package includes queries to generate a list of containers presently in the system, node configuration information, container status information, transactions in time-sorted sequence, and operator information. Queries can also be developed by the user to suit his or her needs.

Testing

SmartShelf™ hardware was tested at an ORNL environmental chamber. Nodes and touch memories were subjected to conditions from near 0°C to 93°C and humidities from 10% to 90%. While the electronic components did not fail, the plastic cases, jacks, and plugs were damaged by the high temperatures: Cases became pliable and warped; plugs and jacks fused together at 93°C and broke their connections. In addition, high humidity (>80%) was found to adversely affect the adhesive foam pads used to affix the touch memories to stainless steel

containers. Although several glues have been found that satisfactorily attach buttons to stainless steel, research is still ongoing to find an optimum adhesive for attachment to sealed containers.

A 49-node field test has been designed for the system. The test exercises the system by randomly selecting nodes and attaching or removing, as appropriate, a container. The test includes removal with and without operator identification, attachment with and without operator identification, aborted attachments (operator presents identification button, but never attaches container), and abandoned operator identification buttons associated with both attachments and removals.

A schedule of operations has been computed based on an average of 14% of the nodes being involved in each test session. An average of 10% of all transactions are scheduled to result in protocol violations. Sessions are held at least twice per working day. The generated schedule selects all system nodes and all containers nearly uniformly. A report on the results will be prepared during fiscal year 1997.

Conclusion

Fiscal 1996 has been a productive year for the project. A working system has been produced. Preliminary results indicate reliable operation over periods of 48 hours, and a comprehensive test scheduled to last 6 months has been prepared. All initial design goals for the hardware and software have been met. Improved hardware has been designed and prototypes fabricated and tested. The new designs are expected to reduce the cost per container by 25%.

SmartShelf™ hardware and software has been demonstrated to the representatives from domestic industries, the IAEA, representatives from the former Soviet Union, at conferences sponsored by the Institute of Nuclear Materials Management and has been included in a field test for the IAEA. Additionally, testing of some of the electronic components will be performed at one or more sites in Russia. This testing is expected to provide additional data on the response of the components to harsh environments.

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