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THE INTEGRATED RADIATION MAPPER ASSISTANT

Robert E. Carlton and Lloyd R. Tripp
Information Systems Division
Odetics, Inc.
1515 S. Manchester Ave.
Anaheim, CA 92802-2907

ABSTRACT

The Integrated Radiation Mapper Assistant (IRMA) system combines state-of-the-art radiation sensors and microprocessor based analysis techniques to perform radiation surveys. Control of the survey function is from a control station located outside the radiation thus reducing time spent in radiation areas performing radiation surveys. The system consists of a directional radiation sensor, a laser range finder, two area radiation sensors, and a video camera mounted on a pan and tilt platform. This sensor package is deployable on a remotely operated vehicle. The outputs of the system are radiation intensity maps identifying both radiation source intensities and radiation levels throughout the room being surveyed. After completion of the survey, the data can be removed from the control station computer for further analysis or archiving.

INTRODUCTION

A significant advancement in remote radiation surveying is in the testing and evaluation phase of the development effort. At the conclusion of the this phase, the findings from the testing will be evaluated and the commercial product developed. The IRMA System, being developed by Odetics, Inc. and three utility companies is an attempt to reduce radiation exposure to plant personnel by performing radiation exposures remotely, while providing a more comprehensive set of data for use in the planning and execution of plant activities.

This testing focuses on determining the accuracy of the new sensor package, the versatility of remote controls designed into the system, and the flexibility of the data acquisition and display subsystem.

SYSTEM OVERVIEW

The IRMA system concept uses a lightweight sensor package mounted on a mobile platform that is remotely maneuvered for mapping radiation sources and intensities in enclosed areas.

Major elements of the system include:

1. Sensor package
2. On-board electronics
3. Pan and tilt platform
4. Fiber optic data link and tethered control line
5. Control workstation
6. Robotic vehicle

Two enclosures - one for sensors and one for electronic controls - are mounted on a pan and tilt platform, which are mounted on a robotic vehicle. The vehicle is tethered to a personal computer-based workstation, which controls vehicle movement and pointing of the radiation sensors, while processing and displaying sensor acquired data.

The primary technical breakthroughs of IRMA are the reduction in weight and size of individual components, the integration of data acquisition, robotics controls, and data display systems.

SYSTEM COMPONENTS

Sensor Package

The sensor package contains all of the sensors used by the IRMA system. Two types of radiation sensor are - a directional sensor with a narrow field of view for pinpointing radiation sources and two wide area sensors for measuring the intensity of the local gamma radiation field. A bismuth germinate (BGO) crystal, measuring 1.27 cm in diameter and length, is the scintillator used for directional radiation sensing. It is optically bonded to a photomultiplier tube (PMT) encased in a specially designed tungsten collimator. The wide-area sensor assembly consists of an identical BGO crystal and a plastic scintillator of the same dimensions, each bonded to a PMT. Each type of sensor responds differently to incident gamma ray energy, and a comparison of their outputs yields information about the gamma field energy.

Two lasers are incorporated in the package. One is a highly-accurate range finder that feeds distance information from the location of the radiation source to the IRMA sensor package. The distance between the sensor and a radiation source is essential input to determining source strength. A second low-power laser points a red pointer beam in the same direction as the radiation and range finding sensors so the operator can visually identify the precise location of the readings taken by the IRMA system.

Viewing of the pointing laser and other visual feedback are provided by a color video camera on the sensor platform. A motorized zoom and focus lens allows the operator to closely examine specific objects in the room and to assess the general physical conditions of the area being surveyed.

On-board Electronics

A computer in the sensor platform controls the use of each sensor. This processor is a NEC V53 operating at 16MHz on a STD bus. This processor that initiates data acquisition, controls the pan and tilt platform motors, and interfaces with a fiber optic multiplexer to transmit both video and data signals to the control station. In addition to the control computer, the electronics enclosure contains a counter board, power supplies, motor servo boards and the fiber optic multiplexer.

The power supply and detector amplifier and digitizer boards are located on the back of the radiation sensor enclosure. Detector gain and power supply voltage are controlled by adjusting potentiometers inside the electronics box. Cabling from the detector electronics to the control computer transmits the detector output signals. Sensor and electronics enclosures are stainless steel to aid in the decontamination of exterior surfaces.

Pan and Tilt Platform

The pan and tilt platform, with an exceptionally high payload-to-weight ratio, was developed for the IRMA system. The platform weight 14 pounds, yet it can position the 66-pounds sensor payload to within 0.1 degrees repeatedly.

Constructed of honeycomb aluminum encased in a thin steel skin, the platform's range of motion is +/180 degree azimuth and -60 to +90 degrees in elevation. The drive mechanism is embedded in the platform's "L" shaped form. It is designed as a self-sufficient module that may be removed from the vehicle for use on another vehicle or installed in an area on a long term basis.

Fiber Optic Data Link and Tethered Control Line

The reinforced, 62 meters long fiber optic link provides a high bandwidth bidirectional link over one optic fiber. An electro-optical converter at the control station decodes up to three bidirectional data channels, one unidirectional video channel and one bidirectional audio channel.

The fiber optic cable is deployed and recovered from a continuously-turning reel on the robot. The direction of the vehicle determines the direction of rotation for the fiber optic reel. A strain guage on the tether senses the direction of tether demand and directs the tether handler motor to turn in a direction to either pay out or take up the tether cable. Tether management is automatic and designed to minimize cable contamination by reducing the amount of cable dragging on the floor. Two electrical conductors enclosed in the same cable provide power to the sensor package, tether handler and trickle charge of the robotic vehicle batteries

Control Station

The control station is based on a 33-MHz 80386 processor with 8 megabytes of RAM, 128K cache memory, a 200 MB hard drive and two floppy drives. A 1024 x 768 VGA monitor with touchscreen capabilities serves as the video and data display terminal at the control station. A video adaptor allows real-time digital video processing with freeze frame capability to capture images from the platform camera.

The DOS system uses Microsoft Windows^{TM} as the user interface. While users may define individual display configurations, the general intent is to provide a video window, status windows, control windows, and the ability to monitor certain types of data presentations during operation. Control actions are entered by touchscreen, and input parameters are entered by the keyboard feature. The primary purpose of the control station is to acquire data for later processing.

Mobile Vehicle

The robotic vehicle used in the prototype system uses an innovative means of locomotion. Four clusters of three wheels each are in a circular pattern about a common axis. All 12 wheels are continuously driven. Each cluster has two lower wheels on the ground, which propels the vehicle. When the vehicle encounters an obstacle, the top wheel is brought into use to engage the obstacle and lift the vehicle over. Limited movement over berms and pipes is possible with limited operator intervention.

The front and rear wheel clusters on each side of the vehicle connect by a drive chain that connects to a drive motor through a reduction gear. Each side of the vehicle is independently driven and controlled to allow skid steering. The vehicle's speed, steering, and direction if controlled by a joystick at the control station. Collision avoidance sensors alert the control station operator to impending collisions.

SYSTEM USAGE

Scanning Process and Data Display

Once the IRMA system is positioned in a room, a series of visual scans are necessary to orient the location of the IRMA sensor relative to the boundaries of the room. Using the cursor, the operator can select a specific area in the field of view of the camera up to and including the entire field of view. IRMA then automatically calculates scanning steps, begins the data acquisition process, and captures a mosaic of the area in video images. Any number of scans may be ordered by the operator, and they are identified and stored in sequential order.

The operator can select a data display and IRMA will calculate the intensity of the radiation source for each data point for which valid data is obtained. This display is in the form of a translucent overlay on the visual image of the camera's field of view when the survey was taken. The operator can vary the intensity of the color overly from invisible to almost opaque depending on his preference at the time of viewing. Software is provided to capture these overlaid images and print them out on hard copy with a color printer.

In addition to the visual radiation image that IRMA generates, the processed radiation intensity data is stored in an ASCII format. In this format, the data is accessible by many standard spreadsheet and data base programs for further analysis. Spreadsheet macros are being developed to provide radiation contour maps and other types of data displays.

Information Generated

The information generated by the IRMA system is different from traditional health physics information. IRMA measures the gamma surface flux from a source within the field of view of the collimated detector. This measurement is repeated for all such source areas within the scanned field of view. In some instances of localized sources within a small area, this gamma surface flux value can be interpreted as the localized contact radiation level. In most instances, this gamma surface flux value as determined by IRMA cannot be directly correlated to the localized contact radiation level due to the contribution to the localized contact radiation level from other radiation sources within or outside of the field of view of the collimated detector. In essence, the IRMA output is a mapping of radiation source intensities by specific location relative to the sensor that can, in turn, be processed outside of the IRMA data collection system to assist in the prediction and analysis of radiation levels in plant areas mapped.

APPLICATION ENVIRONMENT

The IRMA development was initiated in 1990 as a cooperative venture of Odetics, Public Service Electric and Gas, New York Power Authority, and Southern California Edison. The first application of the IRMA system is to assist health physics personnel within the nuclear generating facility. Additional applications will be developed in other areas of the nuclear industry as needs arise.

Radiological surveys are performed to provide precise information about work areas to ensure that any worker entering the area will not be exposed to levels beyond the occupational radiation exposure limit. One of benefits of IRMA is to reduce the exposure to health physics technicians who conduct those surveys. Historically, the health physics technicians receive higher radiation exposures than most radiation worker groups[1]. Methods are continuously being sought to reduce their exposure.

Reduced exposures attributable to the survey function is not the only benefit that can be derived from an IRMA type of system. Other potential benefits include:

1. Accurate trending of radiation levels throughout the plant including the trending of the development of "hot spots".

2. More accurate determination of the effectiveness of radiation level reduction techniques such as flushing or chemical decontamination.

3. Prevention of the increase in radiation fields through the early accurate identification of such increases and the specific sources contributing to them.

4. Better planning of individual work tasks and task sequencing to reduce the time spent near radiation sources.

5. Effective use of Health Physics technicians, freeing them up for tasks other than manual surveying of plant areas.

6. More precise location of "cool" spots in the work area to retire to during period of work inactivity.

7. Better identification of the location of radiation sources to allow for more accurate placement of temporary shielding and reduction in the amount of unnecessary shielding being used due to lack of accurate location of the radiation sources.

SYSTEM PERFORMANCE

Part of the effort of the prototype testing is to evaluate the performance of the overall IRMA system. In actual practice, the performance of the IRMA system will vary with the background radiation, the source strength and the distance from a specific source intensity. The performance of an IRMA type of system is a series of tradeoffs of size, weight and sensitivity, the selection of the parameters for the prototype unit was made to minimize the size and weight of the unit while achieving a level of sensitivity believed necessary for a nuclear power facility. Table 1 provides a summary of the pertinent data and observed performance of the prototype IRMA system.

Table 1

IRMA Data and Performance Summary

Collimated Radiation Detector

Field of View	8 degrees nominal
Sensing Element	Bismuth Germanate(BGO)
Photomultiplier Tube	Hammatsu 647-04
Collimator Material	Tungsten Alloy HD-17
Environmental Enclosure	Type 304 SS.
Electronics	Custom
Size	11"l x 5"w x 5.25"h 28 cm x 12.7 cm x 5.7 cm
Weight	65 lbs. (29.5 kg.)
Dynamic Range	1 mrad/hr to 100 rad/hr 10 μG/hr to 1 G/hr
Lower Limit of Detection(equivalent point source)	1 mCi @ 20 feet 1 mr/hr Cs-137 background; 5 mCi @ 5 feet, 100 mr/hr background.

Area Radiation Sensors

Sensing Element -- Low Range	Bismuth Germanate(BGO)
Sensing Element -- High Range	Plastic -- Bicron BC 400
Photomultiplier Tubes	Hammatsu 647-04
Dynamic Range	0.5 mrad/hr to 100 rads/hr 5 μG/hr to 1 G/hr

Pan and Tilt Platform

Size	15"l x 18"w x 20"h 38 cm. x 46 cm. x 61 cm.
Weight	25 lbs. (11.4kg.)
Payload	70 lbs. (31.8 kg.)
Speed	10 deg. per sec.
Accuracy	0.1 deg.
Materials of Construction	Nickel plated Al. Alloy & coated carbon steel

Table 1 (Continued)

IRMA Data and Performance Summary

Laser Range Finder	
Size	7"l x 4.5"w x 2.8"h 17.8 cm x 11 cm x 7.1 cm
Weight	2.6 lbs. (1.2 kg.)
Range	0.65 feet to >330 feet 0.2 m. to >100 m.
Accuracy	± 2" (±5 cm.)
Resolution	1 cm.
Power Consumption	0.75 A @ 12 V. approx.
Video Camera	
Color CCD	
Remote Focus and Zoom	6:1 Zoom
Camera	
Size	6.7"l x 2.5"w x 2.6"h 17 cm x 6.3 cm x 6.5 cm
Weight	1.34 lbs. (0.61 kg.)
Power	5 W @ 12 V
Lens	
Size	3.5"l x 3.7"w x 3.4"h 8.9 cm x 9.5 cm x 8.6 cm
Weight	1.36 lbs. (0.62 kg.)

REFERENCE

1. L.T. Davis, et al., "Job Analysis of Nuclear Power Reactor Health Physics Technicians," NUREG/CR-3750, BNL-NUREG-51769, Brookhaven National Laboratory, Upton, N.Y., August, 1984.

Author Biography

Robert Carlton is a consultant to Odetics in the area of radiation protection and radioactive waste management. He has over 20 years experience in the nuclear and energy industries with experience in engineering, management and business development. Prior to consulting for Odetics, he was the Manager, Program Development for Odetics, Inc. responsible for the management of Odetics business activities in the areas of energy, hazardous waste and selected commercial ventures. Prior to Odetics, he was a Staff Consultant for Nutech Engineers in San Jose, CA. His responsibilities included the technical management of projects as well as the development of Nutech products and services in the radioactive waste management and radiation protection business areas. Additional related experience included Engineering Supervisor, Southern California Edison, Co. in the Mechanical Engineering Design Group responsible for the design activities related to the radioactive waste treatment and other balance of plant systems. He has also served as a Project Manager in the Information Systems Division for TERA Corporation, Berkeley, CA. and as a Senior Engineer, Bechtel Power Corporation, San Francisco, CA, where he performed on the staff of the Chief Nuclear Engineer as a radiation protection specialist and engineering group supervisor. His education was received at the University of California, Santa Barbara and is a member of the American Nuclear Society and the Health Physics Society. In addition, he has over twenty publications in industry journals.

Odetics, Inc.
Information Systems Division
1515 South Manchester, Ave.
Anaheim, CA 92802-2907

Phone: 714 758 0100
FAX: 714 774 7282