Teaching Instrumentation and Controls using Multimedia and Television Instructional Methods

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ABSTRACT

Teaching Electronic Instrumentation to both resident and distant students in biological and engineering sciences using television presents interesting challenges for instruction. Hands-on laboratory experiences are especially difficult. However, a good laboratory experience not only considers basic principles of instruments, transducers, and sensors, but introduces modern applications and examples. This paper reports results of a televised class originating from the Department of Biological Systems Engineering at the University of Nebraska (UNL) during the Fall 1994 and 1995 semesters. In 1995, twenty-four lectures and nine laboratories were produced using multimedia techniques and video taped for continuing education students in Nebraska and resident students at the Department of Agricultural and Biological Engineering, Pennsylvania State University. Twenty-three resident students on campus also participated in the class. Lectures included theoretical and practical concepts, in-class demonstrations, and reading materials. An extensive interactive lecture guide (an incomplete set of notes) was made available to all students. Laboratories included programming of a micro controller for data acquisition and control, building an instrumentation amplifier, strain-gages, differential transformers, thermocouples, flow measurement and optical sensing devices. Some labs evolved out of an inexpensive kit of electronic components for distant students. Others labs were videotaped, with data collection provided on video. Written reports were prepared by the students. Students purchased Windows-based virtual electronics software for designing and testing electronic circuits. A open-ended design project of a team of 2-3 students was required. Each team prepared oral and written reports of their projects. Student interaction was carried out through telephone office hours, E-mail and FAX.

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I. INTRODUCTION

Engineering education has traditionally taken place using the test- lecture- problem set- laboratory- student design- test paradigm. This activity also calls for student-instructor interaction. Overall, teaching activity is quite complex, involving planning, writing, delivery, interaction, and evaluation. In the last decade, attempts have been made to make significant changes in the way that engineering is taught - primarily through the use of computer-aided instruction (CAI) and, more recently, interactive multimedia (IMM). These have occurred because of vast improvement in human-computer interfaces from improved graphics and availability of digital image processing.[1] Multimedia has been referred to as a marriage between the computer and television.[2, 3] Actually, the elements of a multimedia system include: text, still and animated graphics, audio, and still and motion video images.[4] Portable computers of sufficient capacity are readily available to perform all of these functions. A large proportion of undergraduate engineering students will have purchased such a computer before they graduate. The main question facing most engineering instructors is: do they continue to provide materials in the traditional way or will they adopt some form of electronic instruction such as CAI or IMM to assist the teaching process. Over the past 40 years, the computer has been considered a useful tool when it has assisted the engineer in performing tedious, repetitive activities usually in the areas of mathematical computations, graphics, database management, and word processing. This continues to be so and the human interface is an integral part of the process. For most instructors, it is obvious that some change in the teaching paradigm is on the horizon.

To answer this question, an instructor must decide which functions can be performed by a computer and what activities must be retained by the instructor. Having identified those functions that might be performed by a computer, the next question is whether it will save time or improve the quality of the instruction. One also has to raise the question as to whether students are in the correct learning environment to fully utilize CAI or IMM. Most classroom and laboratory facilities were designed for the traditional paradigm, and require expensive modifications and equipment for this new technology.

Distance education, where the instructor and students are separated by many miles and the classroom consists of the students living room, adds another wrinkle to this scenario.[5] The primary media for distance education is low resolution (live broadcast or video tape) television. (We call this low resolution because digital displays for computers currently far exceed what can be currently displayed on TV. Even the video format MPEG1 is only approximately 300 lines, equivalent to the MCGA resolution on personal computers). Image quality will change as High Definition Television (HDTV) signals become available through improved communications delivery and accepted by the public. In the meantime, the distance educator has to deal with larger than usual font sizes, thick line drawings, and only a few color combinations that will work for video contrast. (Light blue background paper and a thick black sharpie pen will do). Having said that, why would one ever consider using a multimedia computer in a distance education environment? Actually, there is much more to it than that.

Telecommunications is not new to the University of Nebraska. The University is home to the nationally famous Nebraska Educational Television Network (NETV). The University has modern television production, recording, and satellite uplink and downlink facilities. Engineering courses are routinely televised between the Lincoln and Omaha campuses using a delivery system called CORPNET. It also provides continuing education for practicing engineers. In 1990, a new teleclassroom facility was built in L.W. Chase Hall. Agricultural and Biological Systems Engineering courses have been presented on satellite distance education systems NEB*SAT and AG*SAT.[6,7] Distant learning students from Nebraska, Kansas, Idaho, Kentucky, and Cornell were involved in these courses. During the past year, a number of classes either originated or were received in L.W. Chase Hall via A*DEC, a consortium for distance education. Feedback from the students who participated in these courses indicated that graphics, student-instructor interaction, sample problems, and real-world applications through class-room demonstrations and visualization were very important. The use of chalk and the blackboard on TV got low ratings. Close-in camera work was highly rated. The use of a hard-copy interactive study guide while watching television lectures received very high ratings. Short video clips of concepts and practical applications got high ratings. We started using the computer in the teleclassroom as early as 1992. Its primary use was to demonstrate software and to show digitally scanned pictures.

IMM provides high quality prepared text and graphics, with overlays to highlight specific issues. Telestration is an ad-lib tool for additional highlighting and instructional flexibility. In 1993 and 1994, we tested telestration using a light pen system and an electronic wireless pen writer, respectively. Both had technical problems and were discontinued. In 1995, a new pen system was purchased that worked extremely well for telestrating. An IMM software package was selected that handled pen telestration well, locking the pen when in the drawing or writing mode to prevent incidental advancement to the next presentation frame.

II. DESCRIPTION OF FACILITIES

The resident teleclassroom used is shown in Figure 1. It has forward, rear, and overhead cameras, with a video production, control, and recording facility. The facility is run by technicians skilled in commercial television production. The control facility has its own computer to generate production titles and credits, split and video-in-video screens, and special graphics under the control of a director. High resolution television monitors are used to present lecture materials to resident students. Rear, front, and overhead cameras with zoom lenses are used to present detailed close-up images during the lectures and demonstrations. Microphones are provided to each student. Audio communication is provided between the instructor and the director.

To facilitate multimedia education, the instructor must have a computer directly under his control. A 66 MHZ 486, active-matrix color notebook computer. A scan convertor with an advanced flicker reduction module was used to transfer 256-color VGA display directly into the composite video stream. The scan convertor had a zoom control which was good enough to resize text displays which would be normally unreadable on television. This computer was equipped with a pen-writer system, which was used for both mouse and telestration functions. Pen-writing (electronic blackboard) works well after a little practice in hand-eye coordination. In case of computer failure, Sharpie pens and a hardcopy set of visuals on blue background paper were kept as backup.

III. COURSE DESCRIPTION

The Electronics Instrumentation course has been taught since 1987. However, it nas been taught on TV only during the last two years. The course statement is given as follows: Modern agriculture and biological processing utilizes electronic analog and digital instrumentation, electronic sensors, and computer interfaces for machine and process control. This course is considered fundamental for Biological Systems Engineers for developing design skills in instrumentation and controls. Many Biological Systems Engineering graduates will be involved in testing, research, and data acquisition. The course covers the analysis and design of modern electronic measurement, microprocessors, and digital control systems. It also addresses the physical theory of practical environmental, mechanical, contact, and non-contact sensors and transducers. Biosensors, optical sensors, and ultrasonics are introduced. Electronic measurement and control circuits and their interfacing to computers are presented. The course assumes a limited, but basic background in electronics from physics. The course stresses hands-on applications through nine two-hour laboratory exercises, twenty-four 50-minute lectures, two periods for student project presentations, and two hour and a final exams. The course was conducted over a 16-week semester period. Laboratory exercises included experiments with temperature, humidity, air and water flow, stress-strain, displacement, load-cells, and optical sensing. The student was offered the opportunity to interface each sensor and transducer studied to a single-board computer. Computer interfacing included hardware analysis and programming in micro-C®. Hardware and software interfaces included parallel, serial circuits, analog-to-digital, digital-to-analog, and simple networking applications. Student design team projects were developed and presented orally during one of the final two lecture periods of the course. This three credit course contains the following weights in ABET categories: Science - 0.5, Engineering Analysis - 1.0, and Engineering Design - 1.5. The course is oriented primarily toward analysis and design, integrating electronic and sensor components.

IV. COURSE MATERIALS

The course materials consisted of a set of detailed interactive study guides and reading material for following lectures, problem exercises, and laboratory handouts. The course content is outlined in Table 1, with the video, CAI, and IMM technique used. Course materials were developed in an electronic format, but printed, and bound into a ringbinder. All lectures were developed in Microsoft PowerPoint® under Windows 3.1®. Graphics, still pictures, and video were incorporated in the lectures. These were purchased by all official registrants at the beginning of the course. The cost of these materials was included in a continuing education tuition-registration fee for distant learning students. That fee included instate tuition, a distance learning fee, the instructional materials, a lab kit, and the video tapes. Taped lectures were archived in super VHS, but distributed only in extended VHS format. Video tapes are copyrighted.

Interactive study guides were developed, following published guidelines.[8] Figure 2 shows a sample page from the study guides. Intensive note copying was discouraged. Key note taking was encouraged. These notes were developed using the handout template found in PowerPoint. The handout template was created only once for each lecture and PowerPoint automatically inserts the frames. Each lecture was presented as a series of 18 - 21 frames (roughly 2.5 minutes per frame). Each frame contained incomplete notes to which the student added missing material from audio and visual information presented during the lecture. The missing material was provided with telestration or layering. Telestration was accurate enough to provide mathematical equations and sample calculations. These guides were organized so that the students could write additional notes at the right of each frame.

Selected problem exercises and solutions were made available using Interactive Image Technology's Electronic Workbench Version 4.0 (EWB)® and MATHCAD®. Electronic Workbench is a visual analog, digital, or combined analog-digital electronic circuit solver, based on SPICE®. A sample is shown in Figure 3. These programs were made available to resident students for problem solving using the department's computer network. Half of the students also purchased personal copies of EWB for their home computers through the University Bookstore. Excerpts of graphics for handout materials were acquired using the capture option of LEADVIEW 3.0® and then pasted into PowerPoint. Pictures of sensor applications were scanned from 35-mm color slides using a Nikon Coolscan® scanner and also pasted into lecture presentations. An example shown in Figure 4. During the course, four video tape segments of ten minutes or less were provided during lectures using a VCR. These segments included research prototyping of optical sensors in field agricultural machines and infrared thermography inside of a greenhouse using a Xedar 420 pyroelectric thermal vision camera.

V. Laboratory Exercises

A laboratory kit was purchased or rented by distant learning students for hands-on exercises. This was the same kit used by resident students during a scheduled two-hour laboratory period. The kit consisted of a Motorola 68HC811® micro-controller (MCU), a public domain micro-C compiler and assembler, a basic set of sensors, and unassembled circuits. The MCU support circuit was originally designed as a public domain teaching device and robotic controller by the Massachusetts Institute of Technology with free support software available over the Internet. This MCU has 256 bytes of Random Access Memory (RAM), 2048 bytes of

Number of Weeks	Topic Areas	In-Class Demonstration	Graphics	Still Imagery	Motion Imagery	Laboratory Exercise
1	Review of Instrumentation Electronics - Power Supplies	yes Electronics Workbench EWB®	yes	no	yes	Power Supply, Instrument Amplifier Kits
1	Digital Concepts	yes EWB®	yes	no	no	no
3	Microprocessors Concepts for Instrumentation	yes	yes	no	no	MCU Computer Kit
1	Parallel/serial Interfacing	yes	yes	yes	no	MCU Computer Kit
1	Analog-to-Digital Digital-to-Analog Interfacing	yes	yes	yes	no	MCU Computer Kit
2	Instrumentation Error analysis	yes MATHCAD®	yes	no	no	Commercial Data loggers
1	Stress-Strain	yes	yes	yes	no	Kit
1	Differential Transformers	yes	yes	yes	no	Hands on and Video
1	Flow Measurement	no	yes	yes	no	Hands on and Video
1	Temperature Measurement	yes	yes	yes	yes	Thermocouple Welding Video
2	Electro-optical sensors	yes	yes	yes	yes	Hands on and Video

Table 1. Course Content and Use of Computer-Aided Instruction and Multimedia Techniques.

electronically-erasable Programmable Read-Only Memory (EEPROM), motor drivers, analog-to-digital and digital-to-analog convertors, timers, and parallel and serial connectors. Each MCU was programmed using micro-C and operated by the students, with use of a personal computer. The MCU was used during laboratory exercises and lecture demonstrations as a measurement indicator and controller. During lecture demonstrations, the WINDOWS TERMINAL program was used to display activity from the MCU. The data exchanged between the MCU and the PC was enlarged for TV using the zoom feature of the scan convertor.

Video coverage of resident student laboratory exercises was provided. Where distant students had all of the materials in hand, a one-half hour video introduction which included laboratory instructions and a demonstration was provided. Where distant students did not have the facilities or equipment, a one-hour segment of the resident lab was video-taped, showing basic laboratory activities and student data collection. A set of the raw data collected was sent to distant learning students. Three 1 to 1-1/2 hour video tapes of labs were provided using the computer, analog-to-digital and scan convertor to display raw data, as they were actually acquired electronically, directly onto split-screen television. Resident student volunteers provided the laboratory action with commentary by the instructor. During these labs, the distance students were responsible for data collection right off their video tape. Students prepared written reports describing each laboratory experience.

VI. TEAM DESIGN PROJECTS

A design project was a required component of the course and consisted of any sensor or transducer system, control system, or sensor-control system applied to an agricultural or biological application, which was approved by the course instructor. The goal was to provide practical experience in the component design of an instrumentation and/or control system applied to an agricultural or biological application. This exercise provided a social, professional, and a creative outlet for the student, simulating an industrial or group consulting design activity. The exercise was conducted with two or three member student teams, with each team member participating and contributing to the final outcome of the project. It was considered desirable to include one distant learning student along with resident students on the design team to broaden their experience. Nine group projects were pre-approved and integrated or utilized principles from the main lectures and laboratory examples. Projects were the following:

1. Ventilation Control with A Respiration Rate Signal Generator.
2. Electronic Sensing System for Three-point Hitch Tractor Loading.
3. Use of Infrared CO_2 Analyzers for Ventilation Management of Animal Facilities.
4. Sensors for Monitoring Stored Grain Quality.
5. Infrared Thermometer Thermostat for Controlling Infrared Heating in Greenhouses.
6. Surface Irrigation Multi-Row Water-flow Advance Time Recorder.
7. Center-Pivot Control System.
8. A Water-Flow Alarm Device for Irrigation Systems.
9. Timing and Control of a Pneumatic Tomato Pollinator.

Projects included modification or improvement of an existing design or a new design. If the project was to be a modification, the original design and reasons for the modification, along with all pertinent literature citations were included. The outcome of each project included design specifications (drawings, part lists, a bill of materials) for the system, a group written design report of at least four but no more than seven typewritten pages, a 15-minute oral presentation on television, using either visual aids or a prototype demonstration of a working system. If a distance learning student could not come to Lincoln, his or her visuals were sent ahead of the scheduled presentation and narrated through the audio system. The visuals could be either traditional overhead acetates, 35 mm slides, or electronic visuals. However, most groups chose IMM. It was important that each team member contribute to the project and this was often the most difficult to fully assess and grade. It was suggested that as the report outline was planned, that sections be assigned to individual team members in an equitable manner. The oral presentation was divided up and given by an orderly set of planned contributions by each team member.

VII. Evaluation and Future Plans

Both distant learning and resident students were supportive of the new multimedia paradigm. About three percent expressed concern about the process in which case the television monitors were hard to read or the instructional pace was too fast. Students were enthusiastic about the lower cost of materials when compared to more expensive commercial textbooks. They felt that the material given was current and useful, but wanted access to more resource material. Distant students felt that the quality of the graphics was good. Some of the students requested personal video copies of their oral presentation which they thought might be useful in a future job interview. Student-instructor interaction for resident students was primarily face-to-face after class and during regular office hours. Distant students used voice telephone and FAX, while one had access to the Internet. Many rural areas in Nebraska are not currently served by Internet. Students at Penn State had access to their local coordinator, who in turn communicated with Nebraska almost entirely by E-Mail.

From an instructor's viewpoint, organization, and presentation of teaching materials in an electronic format allows easier reuse, improvement, update, and database support. A major proportion of the teachers preparation time is devoted to quality improvement through changes and updating. It parallels the concept of electronic word processing . With better electronic database organization of the syllabus and its support materials, more time can be spent in creative activities and in designing new teaching modules. Modules would provide a mechanism for sharing teaching materials with other instructors and could even be peer reviewed.

The simplest multimedia software should be chosen, especially when the instructor is expected to provide a major proportion of the face-to-face instructor-student interaction. The choice should also tend toward the system that provides the best seamless generation of handout materials for students. For television teaching, which by its very nature is currently limited in its ability to display detailed engineering graphics, an interactive study guide is a must. Other formats of handout materials could include CD-ROM disks, if the students have access to computers with readers. However, even if the distant learning support were dropped, the course could still be presented with a liquid crystal display (LCD) panel and overhead projector in a standard classroom.

VIII. References

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BIOGRAPHICAL INFORMATION

GEORGE E. MEYER, Professor of Biological Systems Engineering, University of Nebraska. He specializes in plant growth modeling and instrumentation. He has taught an environmental factors course for engineers for 17 years and instrumentation for nine years. He has extensive research and teaching experience on television. He has received several research recognitions and alumni teaching awards.

JAMES K. RANDALL, Extension Communications Specialist in Broadcast Media and Professor of Agricultural Leadership Education and Communication, University of Nebraska - Lincoln. He has been involved in commercial and educational television production for more than 30 years and has been recognized as a leader in distance education by Agricultural Communicators.

CHARLES T. MORROW, Professor of Agricultural and Biological Engineering, Pennsylvania State University, College Park. He has been with the faculty since 1967. He teaches instrumentation and computer interfacing. His primary research emphasis is on automated controls for horticultural crops.

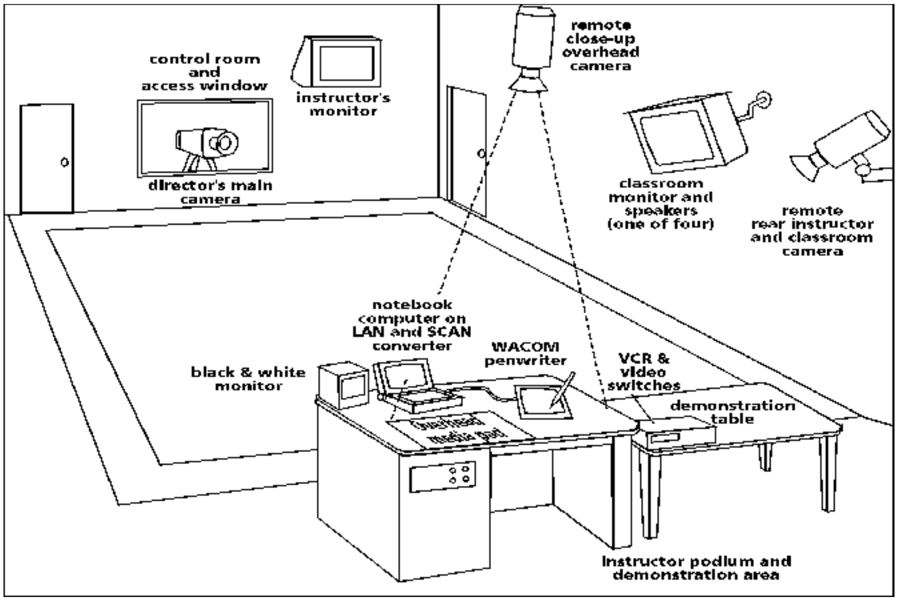


Figure 1: Telecommunications Classroom Layout.

Instrumentation and Controls

BSE 460/860 - Fall 1995

Visual	Notes

INSTRUMENTATION AND CONTROLS

Biological Systems Engineering 460/860

Flow Measurement

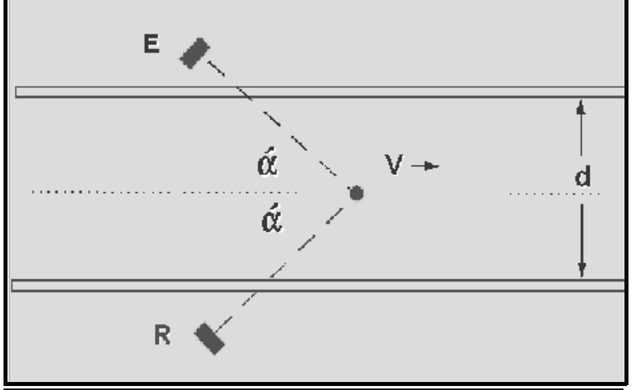
Telelecture 18

November 22, 1995

Lecturer: George E. Meyer

University of Nebraska-Lincoln

ULTRASONIC DOPPLER FLOW METER



ULTRASONIC DOPPLER FLOW METER

- Non-intrusive
- Ultrasonic signal reflected by Suspended particles
- Frequency Shift

$$\Delta f = f_E - f_R = (2 f_E v / c) \cos \acute{\alpha}$$

$$\lambda = c / f$$

Figure 2: Sample page for an Interactive Study Guide

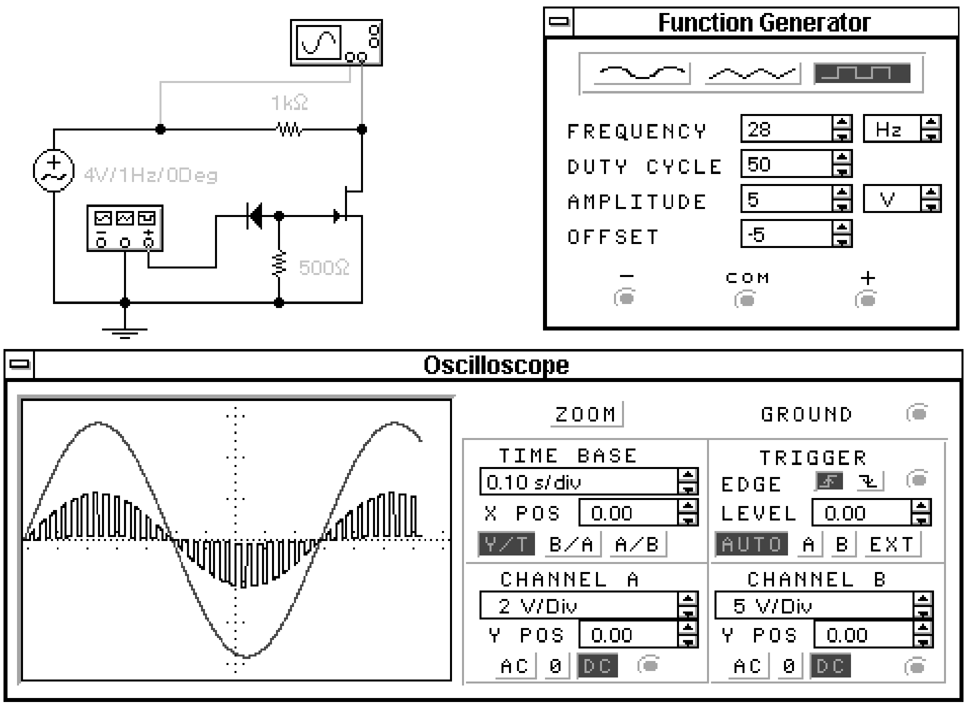


Figure 3: Electronic Workbench Example of a Simple Chopper Circuit.

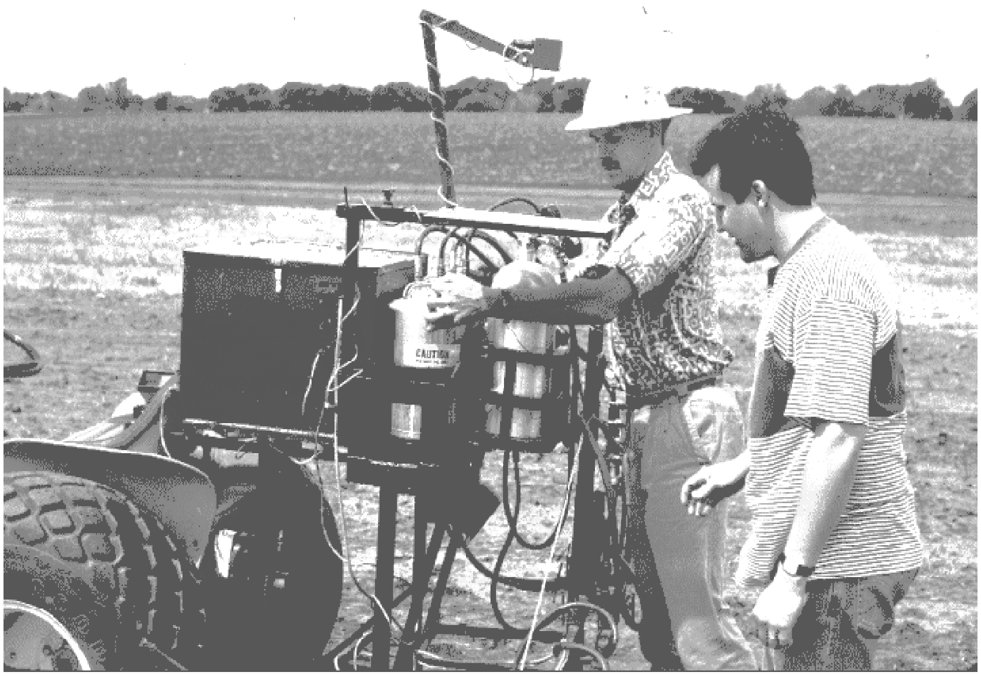


Figure 4: Scanned Slide of a Field Instrumentation and Control Example.