Bits

BIOMEDICAL ENGINEERING

As your Simulation Council was one of the sponsors of the Second Annual San Diego Symposium for Biomedical Engineering in June, it is fitting and proper to report on that meeting in these columns. But first a brief explanation.

As the name implies, there was a similar meeting last year. That first meeting grew from a conviction on the part of your Ed and others that the practitioners of the physical sciences could make some tangible contributions to research in the life sciences. Conversely, we, particularly those of us concerned with computers and self-organizing or adaptive systems, might do well to learn more of the methods and mechanisms employed by biological systems to accomplish seemingly miraculous feats of problem-solving and survival in hostile environments. So, backed by the AIEE Committee on Electrical Techniques in Medicine and Biology, your Ed joined forces with George Mealey, who obtained the backing of the IRE Professional Group on Biomedical Electronics, and Captain Philip Cronemiller, M.D., of the U.S. Naval Hospital at San Diego, to organize our first symposium.

That meeting was a success; worthwhile technical papers were presented, we were able to pay our bills (and repay our backers!), and we published proceedings (within six weeks) which made a tangible contribution to the literature. (They are now in a second printing). But best of all, people met people, learned something of each other’s language, of each other’s problems, and of different (and hopefully better) ways of approaching their own problems.

So this year’s Symposium was a natural. The original sponsors were joined by the San Diego Biomedical Research Institute, Scripps Clinic and Research Foundation, the University of California at San Diego—and Simulation Councils Inc.

Pieces

SECOND ANNUAL SAN DIEGO SYMPOSIUM FOR BIOMEDICAL ENGINEERING, JUNE, 1962

The Simulation Council’s participation is the excuse for this writing; the real reason is that I believe—and as they voted to sponsor, your Board of Directors evidently concurs—that Biomedical Engineering offers the greatest potential for the fruitful application of our simulation techniques and equipment of any unexplored field open to us today. I have in the past editorialized on the importance of simulation to save expensive missiles. What if we can help save a life?

This year 325 registrants (as compared to about 180 last year) collectively attended six technical sessions, a cocktail party, and a dinner. The six Session Chairmen, who were given the final responsibility and authority for their sessions, chose from among more than 70 authors who offered papers, 40 speakers and panelists to make technical presentations and participate in discussions with other authors, panelists and the audience.

Of particular interest to those of us concerned with simulation were the following talks, which we will describe briefly.

Hara on Blood Circulation

“Analog Simulation of Human Blood Circulation” by Hiroshi H. Hara of Berkeley Division/Beckman Instruments (Richmond, California) was a report on the author’s extension, expansion, and improvement of some preliminary work reported by your Ed at the AIEE Midwinter Gen-
Multiple variable problems like the ones bothering our friend involve generating a great many independent trial solutions. The combination of GPS high-speed operation, with memory capability, logic-controlled iteration and time-sharing of computer units gives most reliable results. Operating on a compressed timescale of 3000 to 1, the GPS Computer System performs in one-tenth of a second a problem which in real time computation would require five minutes. A wide variety of problems, new to the analog computing art, can now be solved by the GPS Multiple Timescale Analog Computer with speeds and dynamic accuracy unmatched by any other analog computing system available today. Write for Technical Information.
eral Meeting in January-February 1962, New York City. *

Hiroshi had helped me with my early attempts to simulate the cardiovascular system. In fact, it was he who suggested and instructed me in the mechanization of the active (operational amplifier) rather than the passive (R-C circuit) simulation. This change made the work practical. In helping me get started, Hiroshi became interested, and whereas I had used only an open-ended single-ventricle simulation to demonstrate "Starling’s Law of the Heart," he expanded the simulation to include the lungs and the other ventricle. And he closed the loop through a simulated systemic resistance and compliance, as shown schematically in Fig. 1.

Hiroshi then used his improved simulation not only to demonstrate Starling’s Law more completely, but also produced curves showing the effect on the circulatory system of changing pulse-rate and total blood volume (as shown in Fig. 2) and other variables.

**Smith on Physiological Responses**

"Analog Simulation of the Physiological Responses of Men Working in Hot Environments" by Paul E. Smith Jr. of the E. I. DuPont de Nemours Haskell Laboratory, Wilmington, Delaware, was a description of a dynamic mathematical model of the human heat-transfer system. The model is capable of exhibiting both transient and steady-state responses. It includes the following factors:

1. The distribution of metabolic heat generation.
2. Convective transport of heat by the blood stream.
3. Conductive transfer of heat through the tissues.
5. Loss of heat through the respiratory tract.

The rationale of the model was presented, together with an indication of the method of programming used. Techniques of validating the model by comparison with data obtained on human subjects were discussed, and the results presented.

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* AIEEE Transactions Paper 62-1033.

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**FIG. 1. ELECTRIC ANALOG of simplified blood circulation model.**

**FIG. 2. CARDIAC output characteristics.**
AT YOUR VERY FINGERTIPS is a completely new idea: the EASE® 2100 Series Analog Computer. From your one position at the console you have centralized problem control, pinboard convenience, fast and efficient programming, iterative operation (optional), and more. This new tool offers great mathematical flexibility and expandable modular design. Some typical applications include simulation, optimization, and control in such fields as aerospace, petroleum, medicine, and chemistry. Also within easy reach is literature or consultation about your specific problems. Ask for Brochure A2100.
Conclusions based on the use of the model also were given.

Fig. 3 is a block diagram of the model. Fig. 4 is a schematic of the simulation of one part, which was mechanized in the analog computer as shown in Fig. 5. Fig. 6 shows typical results obtained.

**Wilson on Hospital Simulation**

“Automated Data Processing for a Modern Hospital—A Simulation Study” by Harold H. Wilson of System Development Corporation (Santa Monica, California) reports on the successful application of automatic data processing (ADP) to the system of patient data of a large Veterans Administration General Medical and Surgical Hospital. These efforts have resulted in a model for simulating the operation of a hospital using real patient data, cycled through the various pieces of equipment of a random-access electronic digital computer.

The major areas of ward-centered hospital operations include data-handling in response to information demands from such areas as bio-
Comcor announces the CI-70*

a digital coefficient entry system for analog computers

The new CI-70 now available from Comcor offers fully-automatic tape or card set-up for coefficient potentiometers, diode function generators and UNE's. Fast, accurate and reliable, the CI-70 system reduces programming time by a factor of 5, and allows the setting of potentiometers to .008% accuracy in less than 2 seconds each. Operator conveniences include automatic sequencing and scanning, color-change error indication, and positive display of keyboard value settings.

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Basic element of the CI-70 is Comcor's CI-75 Servo Set Potentiometer Module. It consists of 5 precision potentiometers, each driven by its own DC permanent magnet motor. The absence of clutches, gears, belts or linkages ends mechanical adjustment and sets new standards for accuracy and reliability. Write or call today for details.

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CI-75 Servo Set Potentiometer Module. ACCURACY OF SETTING: resolution of pot (.008%). STANDARD MOUNTING: 5 modules per mounting unit (25 potentiometers per 8¾" of standard rack space).
chemistry and hematology laboratory tests, medications, collection of vital signs, patient statistics, and bed census.

To avoid disrupting the normal hospital routine, personnel of the Biomedical Systems Department, including VA personnel assigned to the project, developed a computer-based model for the operation of a simulated hospital to help determine the feasibility of applying automatic data-processing techniques to the patient-data system of a Veterans Administration Hospital. An important objective was to relieve the clinician and other hospital personnel from routine tasks associated with the collecting, recording, storing, summarizing, retrieving, transmitting, and displaying of data used directly or indirectly in providing medical care as well as administrative care to the patient. The functions of the hospital which were simulated are shown in Fig. 7.

**Holladay on Lung Simulation**

“A Fluid Mechanical Model of the Lung for Studies in Blast Biology” by April Holladay of the Lovelace Foundation (Albuquerque, New Mexico) reported a study in which a mathematical model of the lung was conceived to help explain the direct effects of an overpressure pulse on mammals in terms of the fluid-mechanical response of the thoraco-abdominal structures. The differential equations defining the model were solved numerically to obtain the pressure in the simulated lung as a function of time for a given forcing function—a blast wave. The pressures predicted by the model were found to correspond reasonably well with those recorded in lungs and thorax of test animals subjected to a blast overpressure. Equations were derived relating each of the parameters if the model to animal body mass so that the model might be used to simulate the blast response of an idealized animal of arbitrary mass. An application of the model to the problem of step-wise pressure loading was made.

Fig. 8 shows typical results, and Fig. 9 the effect of step-wise pressure loading, concerning which the author comments:

“The model was used to investigate a remarkable phenomenon studied during a series of shock-tube experiments by the Department of Comparative Environmental Biology at Lovelace Foundation. It was found that test animals were protected significantly by the incidence of a square wave existing for mere fractions of a millisecond before the arrival of a stronger shock wave; i.e., percent

**FIG. 7. SIMULATED hospital functions.**

**FIG. 8. COMPARISON** of computed and recorded external pressures for short duration blast wave.

**FIG. 9. EFFECT** of step-wise pressure loading on pressure in simulated lung (cavity pressure); $t'$ is duration of initial wave.
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...experienced in direction of technical operations—dedicated to the production of advanced analog computer equipment of highest quality and reliability—confident of the new CSI capacity for leadership in this field.

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Computer Systems, Inc.
Culver Road, Monmouth Junction, New Jersey
mortality dropped when the pressure load occurred in two steps. Furthermore, the percent mortality seemed to depend, within limits, on the duration of the initial wave."

Mrs. Holladay said that she used the digital computer for this analog-type simulation "because it was there."

**Moser on Fetal Circulatory System**

"Simulation of the Human Fetal Circulatory System" by G. G. Moser of Electronic Associates Computation Center (El Segundo, California), in collaboration with George Bekey of Space Technology Laboratories, (Los Angeles, Calif.) was a progress report on unfinished work.

The model that Guy described is hydraulic in concept and is being studied on an analog computer. Of primary interest is an understanding of the functional closures of the Foramen Ovale and the Ductus Arteriosus.

In the fetal state, oxygenation of fetal blood occurs at the placenta. Oxygenated blood passes from the umbilical vein, through the ductus venosus into the inferior vena cava and finally to the right atrium of the heart. Blood in the right atrium is allowed to enter the right ventricle (as in the adult heart), but in the fetal heart blood also flows into the left atrium through the foramen ovale. Left atrial blood flows into the left ventricle and is pumped throughout the system.

Blood which flowed into the right ventricle is pumped into the pulmonary artery. A portion of this blood passes through the lungs, but the ductus arteriosus allows a shunt flow of blood to bypass the lungs directly into the aorta.

Both the ductus arteriosus and the foramen ovale exist to permit blood flow to bypass the unexpanded fetal lung. At birth these two paths must be closed to blood flow to allow complete oxygenation.

The foramen ovale closure is, apparently, explained by the reversal of pressure gradient occurring at birth. A left atrial pressure predominantly greater than pressure in the right atrium forces the "flap" valve to close, and ultimately the flap becomes an integral part of the wall separating the right and left atria.

Closure of the ductus arteriosus is not understood completely. One theory suggests that the closure is brought about by increased oxygenation in blood flowing through the ductus following birth. Another possible explanation, and the one incorporated in this model, is concerned with reversal of blood flow through the ductus at birth.

Pressure histories are of initial importance. The model is a hydraulic representation of the fetal circulatory system, as shown in Fig. 10. The four heart chambers are pumps whose volumes are forced sinusoidally. Pressures and flows are computed throughout the system. At birth, the umbilical cord is clamped and lung resistance to blood is reduced. The model must then reproduce pressure and flow-time histories recorded from experiment.

Currently the model is being refined to reproduce experimental data. Although many coefficients must be determined, intermediate results are encouraging.

**DeHaven, DeLand, Assali and Manson on Placental Transfer**

"Physiological Characteristics of Placental Transfer" by J. C. DeHaven and E. C. DeLand of the Rand Corporation (Santa Monica, California) and N. S. Assali and W. Manson of the University of California Medical Center (Los Angeles, California) described a digital computer solution of a mathematical model which is too complex for presentation here. Ed DeLand's shortened description of the work left no doubt as to the validity of the model or the importance of the results.

A study of the shortened version as it will appear in the Symposium Proceedings, or of the complete report as published by the Rand Corporation, is recommended to those who have sufficient interest to really "dig in."

**Satter on Breathing Problems**

"A New Approach to Breathing Problems" by Neil Satter of Somnetics (La Jolla, California) is a new twist: a machine is constructed to simulate the sound of human breathing in order to induce a human to simulate the machine!

All parameters of the "breathing" of the machine are adjustable. Thus, because anyone listening to it, awake or asleep, seems to have a strong compulsion to simulate it, the breathing of persons with some types of respiratory problems can be improved.

**Minot on "Understanding"**

"Toward Understanding by Device" by Otis Minot of Minot Informatic Devices (Lexington, Massachusetts) was too "broadband" in its coverage to be amenable to condensation here. However, those interested in the present state-of-the-art and the trend as seen from the point of view of the author, who has had years of experi-
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ence and is now working full-time in
the field, should check the text, which
will be in the Proceedings, or get in
touch with Otis directly (22 Eliot
Road, Lexington 73, Massachusetts).

Boyle on Neuron Model

"A Neuron Model Which Performs
Analog Functions" by Don Boyle of
the National Bureau of Standards
(Washington, D. C.) seemed to this
reporter to make a lot of sense. To
see why, let me quote from the auth-
or's introduction:

"Most of the present effort in the
study of neural networks, by engi-
neers, has assumed that the neuron
is a threshold logic device and that
its output is a Boolean function of
its input. This state-of-affairs is due to
a gross oversimplification of neuron
properties which leads to the study of
very interesting networks which, alas,
are not deserving of the name 'neuron
network.' The simplification of neuron
properties was done in the interest
of making the models mathematically
tractable, but, perhaps, the simplifi-
cation should have been less severe.
The above models make use of neuron
properties, such as its binary pulse
output, its threshold behavior, and
spatial summation. Some of the neu-
ron properties which were left un-
used are: latent addition, absolute re-
fractory period and relative refrac-
tory period.

"This paper adheres to the hypoth-
esis that the neuron receives anal-
og information at its inputs and that
it operates on this information with a
continuous function. How else can
one satisfactorily explain the follow-
ing observations?

"Most of the biological sensors pro-
duce, at their output, pulses whose
frequency is proportional to the in-
tensity of simulation. For example,
Brock and Ferguson have shown that
the frequency of pulses generated
from the carotid sinus nerve to the
brain is directly related to the pres-
sure in the carotid artery and to the
time derivative of arterial pressure.
Warner uses this information to per-
form an analog simulation of the op-
eration of the carotid sinus in the
control of arterial pressure. Stark has
studied the pupil reflex to light in
terms of a self-regulated, error-actu-
ated servomechanism. He found this
approach very satisfying because by
applying classical servomechanism
analysis he was able to accurately
predict the pupil behavior to a unique
stimulus. The above examples suggest
the questions: How does the brain
make use of the graded response of
its sensor organs? and how does it
implement the servomechanisms
which control the body functions?
Another observation of interest is
that a neuron, which has been excited
by a presynaptic volley, will continue
to emit pulses after the excitation has
cess. This has been observed by
many; one good example is found in
the work of Kennedy.

"The idea that the neuron handles
analog information is certainly not
original with this author; it has been
implicated and occasionally explicitly
expressed by many others. For ex-
ample, Von Neumann suggested this
idea several years ago; more recently
the cause was taken up by Dorn at
the 1962 I.R.E. International Conven-
tion; and at the Second Annual Sym-
posium on Switching Circuit Theory
and Logical Design, Landahl pre-
sented a continuous model and
showed its application to a number
of psychological problems. The writer
feels that a contribution will be made
by this paper if it succeeds in entic-
ing a few engineers, mathematicians,
and physiologists into thinking of the
neuron in terms of a continuous mod-
el. As an example, this paper will
present a model which is simple
enough to be mathematically tractable
and still retain reasonable fidelity to
the operation of a living neuron, so
that its behavior in networks will be
close enough to nature to be useful as
an analog. The reader is warned that
the following discussion is from the
point-of-view of an electronic com-
puter engineer who has an active side
interest in neural networks. Conse-
quently, for better or worse, terms
from electronics and nerve physiology
are freely mixed in the text."

Exhibits

Among the exhibits worthy of at-
tention by those interested in the
applicability of simulation techniques
and equipment to studies in the life
sciences were "live" analog computer
models of certain aspects of the car-
diovascular system as demonstrated
by Applied Dynamics and Electronic
Associates.

Roger Slocom had an EAI TR-48
and TR-10 tied together to demon-
strate the maternal/fetal circulation
simulation that Guy Moser had re-
ported on in the technical session*.

They also had copies of Moser's pre-
liminary description of his simulation
and Gene Graber had my Starling
Curve model set up on their AD-1-32.
Both of these demonstrations elicited
considerable comment among MD's
and other workers in the life sciences
who, as a group, are less aware of
the power of computer simulation
than are engineers and physical scien-
tists. Such is the raison d'être of the
San Diego Symposium for Biomi-

tec Engineering.

* * *

Just in case you've so far been able
to ignore my not-so-subtle plugs, I
would like to come right out and say:
Copies of the Proceedings of the
Second Annual San Diego Symposium
for Biomedical Engineering will be
available about the time you read
this. Included will be more than 30
technical papers on Training for Bio-
medical Engineering; Progress in
Tools and Special Techniques; Com-
puters for Data Processing, Simula-
tion, and Diagnosis in the Life
Sciences; Circulation and Respiration;
and the Brain and Nervous System.
Copies may be ordered for $12
each from the Symposium at 8484
La Jolla Shores Drive, La Jolla, Cali-
ifornia. Checks should be made pay-
able to the San Diego Symposium for
Biomedical Engineering.

LETTERS

The following excerpt from a letter
is offered to serve as a reminder to
those of you who might have a tech-
nical paper to offer which is too good
for these columns.

"I have enclosed two copies of a
paper entitled "Simulation of the
Dynamics of Fluid Systems" by Ben
Clymer. It is my present understand-
ing that an arrangement has been
established whereby suitable papers
covering computer applications will
be forwarded by I & C to a reviewing
committee which will evaluate them
for publication in the IRE PGE C
quarterly transactions. As you know,
the Eastern Simulation Council has
been encouraging the preparation of
good analog papers for publication
available for distribution, together with
"A CO2 Breathing Study" and
"Human Simulations Résumé" which
includes a 106-article bibliography.
Obviously your Ed is not the only one
who thinks this field is important!

August 1962—Instruments & Control Systems—Page 127
Dear Mr. McLeod:

Please send me one copy each of your papers "Simulation for System Evaluation" and "Analog Simulation of Heart Action." As a relatively new member of Simulated Councils Inc., I would like to mention that I have found the Simulation Council to be both informative and interesting. I am also very glad to see that the roles of analog computers and analog techniques are given to receive broader coverage in the IRE/PGEC.

I have enclosed some material which describes our approach to the problem of simulating systems described by partial-differential equations. The SADSAC (Sampled-Data Simulator And Computer) presents the means for combining switching techniques with passive-element and operational-amplifier analog techniques. This combination may take many forms and be used for many applications such as, for example, "time-sharing" of electronic computing equipment, iterating solutions and storing quantities in analog form, and "direct-analog" simulation models. The SADSAC is particularly useful for this last application since it readily provides the means for obtaining a direct analog for variable-velocity motion. We feel that these techniques are the only feasible ones for achieving a detailed simulation of very large-scale systems such as power plants, nuclear reactors, etc. Other applications include traffic flow studies, stress-wave propagation studies, and nuclear radiation shielding calculations. (These applications are under consideration.) Although our Analog Computing Facility is of modest size, we are still able to handle very expensive problems through the use of these computing techniques.

Please feel free to pay us a visit any time that you are in the Philadelphia area. Incidentally, additional copies of the material enclosed here-with are available for anyone who may be interested.

William H. Steigelmann, Senior Research Engineer The Franklin Institute Philadelphia 3, Pennsylvania

"In a previous correspondence with Ladis Kovach, I had mentioned that Donner is planning to initiate a series of technical notes on the more unusual applications of analog computers. Of course, we are planning to make these available without charge to personnel interested in this field, and we feel that a large bulk of the members of the Simulation Councils would be interested in receiving copies of this material."

(Excerpts from a letter from David A. Tassett, Sales Manager, Computers, Donner Scientific Division, Concord, California)

And in closing here's one from Otis Updike dated March 24th, 1962, that somehow disappeared in my "filing system." However, I believe some of Otis's comments are still of interest:

"The ESC meeting was an excellent one, well-prepared and well-attended (I believe the final count was 122). There were good papers, perhaps half by the host (DuPont) people, but the highlights for me were the study-group session on partial differential equations and the facility demonstration. The PDE session brought out comments on work at a wide variety of places, including some pioneering work by EAI people, Bob Howe (as you'd expect), and some British workers. I am awaiting a copy of a paper by Ben Clymer on assumed-mode methods that sounded very promising. The demonstrations showed some ingenious techniques in showing plant and control system dynamics on a modular panel mockup. The panel combined electrical meters, a DVM, and conventional process instruments (Foxboro or Honeywell) to give an operator or production supervisor a real feel for the embryonic plant. The whole thing was "animated" by the computer, at 1/10 or 1/60 time scale. This was also the first time I'd seen how very cleverly "rep-op" could be used—they displayed the standard CSI tricks plus some new DuPont ones on a sequential-reaction kinetic problem, very effectively.

"The ISA meeting program covers topics we foresaw back in the old IACC* days—stream analyzers and computer control are finally becoming realities all over the chemical industry."

From a letter from Otis L. Updike, University of Virginia, Charlottesville, Virginia

*The Industrial Analysis and Control Council, a project of about eight years ago of your Ed, your See'y, and Ed DeLand.