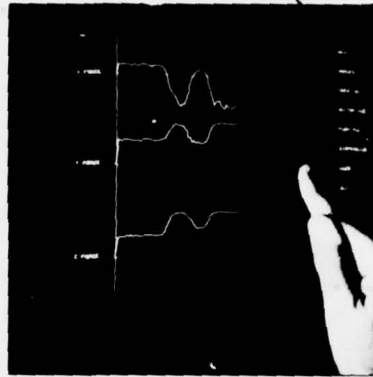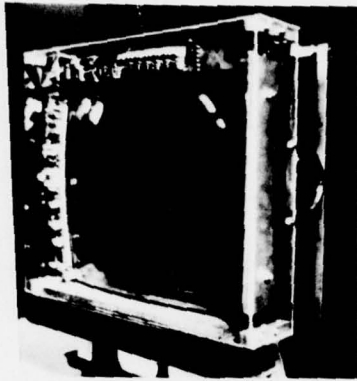LEVEL

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TR-78-TH3

One-Point Touch Input of Vector Information for Computer Displays

Nicholas Negroponte
Christopher Herot
Guy Weinzapfel

October 1978

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U.S. ARMY RESEARCH INSTITUTE for the BEHAVIORAL & SOCIAL SCIENCES
5001 Eisenhower Avenue Alexandria, Virginia 22333

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The finger as a graphical stylus enjoys a coefficient of friction with glass sufficient to provide input of direction and torque as well as position from a single point. This report describes a pressure sensitive digitizer (PSD) capable of accepting these force inputs, and discusses a set of five simple input applications used to assess the capabilities of this device. These applications include techniques for specifying vectors, and pushing, pulling, dispersing and reorienting objects with a single touch. Experience gained from these applications demonstrates that touch and pressure sensing

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20. open a rich channel for immediate and multi-dimensional interaction.

The project is an example of basic research with potential for future application. The report will be of interest primarily to research scientists in the field of graphic CRT displays.

The Human Factors Technical Area of the Army Research Institute is concerned with demands of the increasingly complex future battlefield for improved man-machine systems to acquire, transmit, process, disseminate, and utilize information. The research is focussed on the interface problems and interactions within command and control centers and is concerned with such areas as topographic products and procedures, tactical symbology, information management, user oriented systems, staff operations and procedures, and sensor systems integration and utilization.

One area of special research interest is the design of effective and efficient on-line interaction between the operator/user and the computer. Research is focused on enhancing computer-based query languages and associated features of tactical data input, retrieval and analysis. The present publication explored interactive graphic techniques employing a touch/pressure sensitive panel placed over a display. The panel allows even a computer-naive person to use fingers for manipulating displayed information. The effort is part of the exploration of improved ways for the user and computer to communicate and provides a necessary technological base for effective design of the interface.

Research in the area of concepts for man-computer synergism is conducted as an in-house effort augmented by contracts with organizations selected for their specialized capabilities and facilities. The efforts are responsive to general requirements of Army Project 2Q162722A765 and to special requirements of the U.S. Army Combined Arms Combat Development Activity, Ft. Leavenworth, KS. This specific effort was conducted under Army Project 2Q161102B74F as basic research responding to the above requirements.

TABLE OF CONTENTS

1.0 INTRODUCTION.

Recently, interest has grown around a class of instruments known as touch-sensitive digitizers (TSD's). Using a variety of technologies [1], these devices are capable of determining the X, Y position of a finger's touch without resorting to an intermediate physical stylus.

The excitement generated by TSD's derives directly from their ability to provide a more natural input path to the computer. The umbilical cord attached to the conventional stylus is removed; in fact the entire notion of a physical stylus is voided. Also, dislocations caused by separate input and presentation surfaces can be circumvented by superimposing transparent TSD's directly over display surfaces.

While the potentials for more natural, coincident and even multi-finger input are obvious and are being developed by other programs, little exploration has been undertaken in the area of multi-dimensional input - the sensing of pressure as well as location parameters. Yet this domain offers a rich potential for man-machine interaction. The work described in the following pages was designed to explore that potential -

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to test the ability of the human stylus to moderate pressure and direction inputs from a single touch.

1.1 OUR LABORATORY'S TSD.

In April, 1976, the Architecture Machine Group acquired a TSD from Instronics, Ltd. of Ontario, Canada. This device consists of a sheet of clear glass with piezoelectric transducers mounted on two adjacent edges. The glass is doubly curved to match the face of a display tube. The transducers are used to induce acoustic waves in the surface of the glass. These waves are reflected back to their source by fingers touched to the glass surface. The location of the touch is determined by ranging those echos.
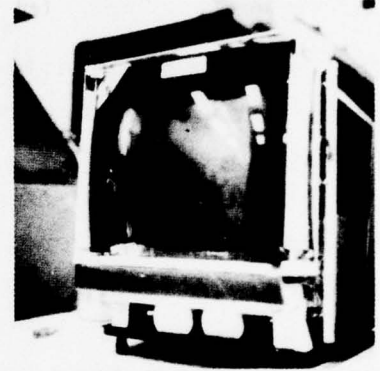
It was hoped that the TSD would enable users to sweep their fingers over the display surface thus drawing, even "fingerpainting" with the computer. It was found, however, that in order to insure proper input readings, users had to press the TSD with a force that generated friction between finger and glass sufficient to prevent smooth, sweeping gestures. As a result, the device seemed better suited to pointing than to drawing or painting.

This reality, however, opened the possibility of using the finger-glass friction to unique advantage. Namely, the TSD could be mounted on the display with strain gauges such that forces induced by the finger could be used to specify pressures both normal to and parallel with the input surface. In this way, the device could become a pressure (as well as touch) sensitive digitizer - a TSD/PSD.

Such a configuration was implemented (as described in Section 3.0) and provided the basis for a four month research program designed to evaluate the characteristics of pressure sensitive input. The following section discusses the methods used to conduct that evaluation.
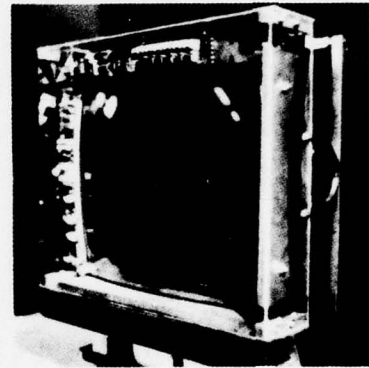
2.0 APPLICATIONS.

Five input routines were developed to assess the input characteristics of the PSD. These included:

1. Force Cursor,
2. Vector History,
3. Pushing/Pulling,
4. Dispersion, and
5. Rotation

In addition, an attempt was made to utilize the X and Y torques to determine the position of the finger,

so as to eliminate the need for a TSD
altogether.

2.1   FORCE CURSOR.

The initial routine provides the pres-
sure sensing equivalent of a conven-
tional cursor. It does this by dis-
playing a vector, or arrow, whose ori-
gin coincides with the touch point,
whose head lies in the direction of
the force being exerted by the finger,
and whose length is proportional to
that force. At the same time, the z
force (pressure normal to the face of
the screen) is reported as a square,
whose size is proportional to that
force.

Use of the force cursor has produced
some surprising results. While its
function is obvious to all who observe
it, many people experience initial
difficulty making it behave as they
expect. Most notably, novice users
have difficulty making the vector point
in the directions they desire. This
difficulty derives not from the equip-
ment, but from the fact that people
do not always press in the directions
which their fingers appear to indicate.
Typically, this problem is encountered
with the user's first vector. The no-
vice will press the tablet causing an

-4-
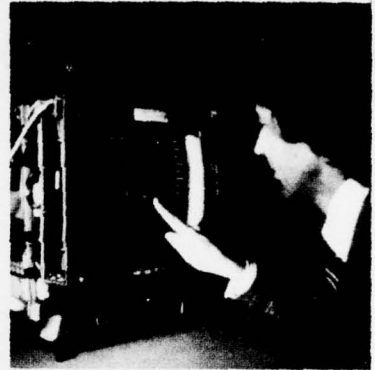
arrow to appear in proper alignment
with the finger; but as the finger
is rotated, the direction of the
vector often fails to follow. Close
observation has revealed that this
results from the fact that the user
actually maintains pressure in the
original direction though the fin-
ger changes orientation.

Fortunately, the learning curve with
this routine is quite steep. Following
initial difficulty, most users are
able to control the direction of their
vectors with less than a minute's prac-
tice. In fact, many users, realizing
that the orientation of their fingers
is irrelevant to the direction of the
vector, are able to manipulate the cur-
sor from a single, natural hand position.

Beyond this initial training problem,
there is a more chronic difficulty;
placing the tip of the arrow with
acceptable accuracy. This is especially
true as greater extensions (and hence
larger forces) are attempted. This
problem is similar to that of using
a long pointer at a blackboard; the
vector bobs and wobbles at its greatest
extension. In an attempt to counter-
act this drawback, a damping effect
was added to the cursor routine to

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filter out minor pressure fluctuations.
However, users continue to find the
device a difficult mechanism with which
to point accurately. This may be due
to the relationship between force in-
put and vector length, which was ar-
bitarily chosen to be linear. Had a
logarithmic relationship been used,
the problem of accuracy may have been
alleviated. This possibility was not
pursued, however, due to the time pres-
sures of the project. Nonetheless, the
force cursor demonstrates that the PSD
can be used for general statements of
direction and magnitude.

2.2 VECTOR HISTORY.

The second routine was designed to eval-
uate the potential for guiding a cur-
sor from a stationary input position.
In this case, the cursor scribed a
path as it moved under control of the
finger's pressure. This routine under-
went two implementations. In the first,
the speed of the cursor was constant;
only its direction was controlled
through the PSD. A later implementa-
tion allowed the speed to be controlled
as well.

Most users, having trained with the
force vector encountered little dif-
ficulty in directing the mobile cursor.

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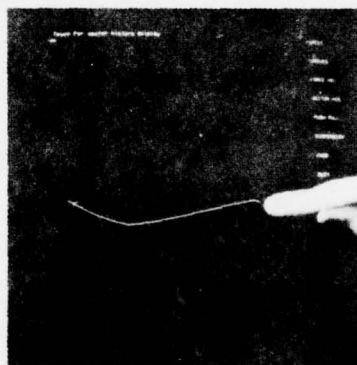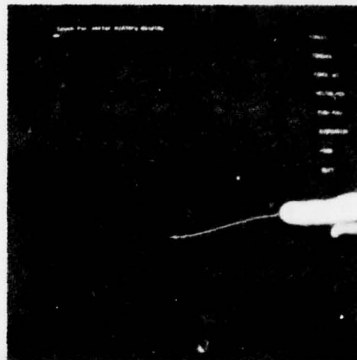
For example; many people were able to write their names on their first attempt.

Surprisingly, though, the variable speed version was more difficult to use. This results from the fact that the cursor deviates from an intended path, most people's reaction is to press harder on the input surface. Since this does not necessarily change the cursor's direction but does increase its speed, "errors" are exaggerated.

Nonetheless, the process of controlling a mobile cursor from a single point on the screen appears to be an engaging and successful use of the device. Real world applications (such as navigating about a map display) can easily be imagined for its use.

2.3 PUSHING/PULLING.

To explore the PSD's potential for moving objects other than a cursor, a routine was implemented which allows users to move squares about the screen. Here, the user points to an object and gives it a push. The touch is used to identify the object, the pressure to impart a direction and speed. Thereafter, the user does not need to track the

-7-
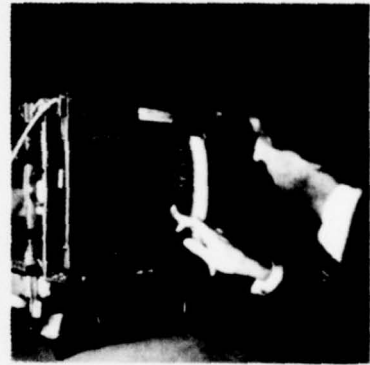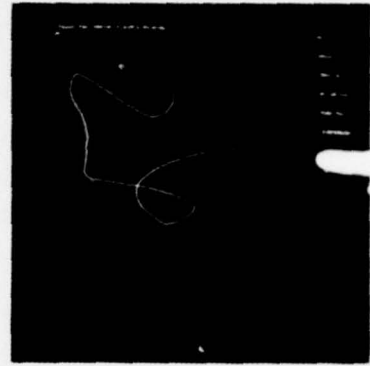
figure, but can direct its movements
remotely.

Use of this routine demonstrated it to
be a obvious and comfortable means for
directing the movement of selected
objects. Unfortunately, time constraints
prevented an elaboration of this algo-
rithm to incorporate parameters for
objects of differential weight and/or
coefficients of friction. As a result,
there is no means of knowing if a user
could gain a sense of an object's "phy-
sical" attributes by using the PSD.
However, experience with the simple
implemented routine suggests such
feedback is within the capabilities
of the device.

2.4 DISPERSION.

In perhaps the most engaging of all the
PSD applications, graphic shooting gal-
lery was devised to test the system's
ability to accomodate dispersing inputs.
This routine causes small, bb-like cir-
cles to emanate from the user's finger
tip as it is pressed on the screen's
surface. Since the number, speed and
direction of the bb's can be controlled
by the finger, a procession of moving
targets (in fact, small ducks) is played
across the top of the screen to test
the accuracy and flexibility of those
inputs.

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Interestingly enough, even users who
had experienced some difficulties with
the previous routines, adapted to the
requirements of this application quite
rapidly. In fact, some "hunters" ad-
vanced to the point where selected
ducks could be felled with single shots.
This represents remarkable control,
indeed.

2.5 ROTATION.

The final routine was designed to eval-
uate the PSD's ability to measure tor-
que inputs and to use those measure-
ments to advantage in interaction. For
this purpose, a simple knob is displayed
on the screen with an arrow indicating
its angular position. It was hoped
that torque about the z axis could be
measured with sufficient sensitivity
that even minute twists of a single
finger could be used to turn the dis-
played knob. However, when tuned to
a level sensitive enough to measure
these subtle inputs, the user's in-
tentions were overshadowed by vibrations
in the room and in the equipment it-
self. Fortunately, after lowering the
sensitivity of the z torque pickup, it
is now possible for users to turn the
knob with two fingers. In fact, the
position of the knob can be adjusted
to within 5 degrees of rotation with
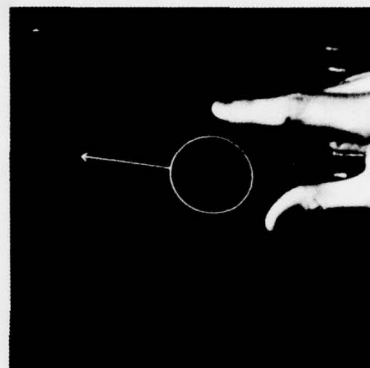
little difficulty. Further tuning of
the algorithm and the hardware would
permit even greater accuracy. Though
a single, rather sizeable knob was
used for this application, the suc-
cess achieved opens numerous additional
possibilities. For example, specific
machine parts in a complete display
could be identified and reoriented via
simple, direct manipulation, this ob-
viating the need for multiple (object
selecting and action specifying) commands.

2.6 POSITION DETECTION.

In addition to the five capabilities
described above, it was hoped that a
means of detecting the position of a
surface touch could be accomplished
directly by the PSD without using the
echo ranging of the Instronics device.
The algorithm used for this measure-
ment divided the X and Y torques by
the Z force. The results of this func-
tion were normalized for the direction
of forces parallel to the input surface
and amplified to produce the location
of the finger. While the results of
this approach were consistent, their
accuracy was too poor to be of use;
the points reported would oscillate
about an area nearly one tenth the
size of the screen.

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The source of this inaccuracy was ul-
timately ascribed to the configuration
of the strain guage mounting. Namely,
the sensitivity of the torque pickups
was so great that room vibrations gen-
erated a 10 percent noise factor in the
measurements. While this noise was not
problematical in the other routines,
the error induced in position detected
greatly exceeded acceptable levels.
It was concluded that a different
mounting configuration might overcome
this drawback. This is discussed in
Section 3.0, description of the hardware.

2.7 EXTENSIBILITY.

It should be noted that these five ap-
plications described above were selected
because they were each imminently doable
in the time available. It was clear from
the onset how each capability should
work; and the amount of programming re-
quired by each was quite limited. In
short, the five routines were appro-
priately matched to the scale of the
four month duration of the research.

It is not difficult, however, to imag-
ine more elaborate uses for a pres-
sure sensitive device. For example,
a three dimensional dynamic modeling
system could use the PSD for tactile
manipulation of machine parts, building

envelopes, and the like. It is easy
to imagine turning a machine part by
twisting its representation on the
screen, or rotating the display of a
building by pushing on the edge of a
facade. In short, the potentials for
tactile involvement and physical feed-
back from such a device were only
hinted at by this brief exploratory
work.

3.0 PRINCIPLES OF OPERATION.

The PSD employs eight strain gauges
two each secured to mounting rings
centered on the four sides of the
TSD. Of the two gauges secured to
each ring, one measures force perpen-
dicular to the glass and the other
measures shear parallel to the glass.
These eight measurements are then
used to derive the three force and
three torque outputs which are used
by the routines described in the pre-
vious section.
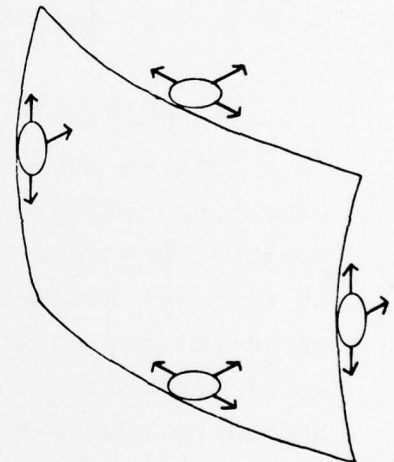
3.1 MOUNTING AND STRAIN GAUGES.

The TSD is secured to the CRT by means
of four, specially machined, octagonal,
aluminum rings. All forces exerted on
the TSD transmitted to these rings, thus
causing deformations which in turn flex
the strain gauges secured to them. The

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two gauges are cemented to each ring
as shown in the adjacent figure.
Their placement insures that the forces
which they sense are orthogonal to one
another.

It happens that the thickness, and hence
flexibility of these rings is critical
to the sensitivity of the gauge's mea-
surements. Unfortunately, the rings
machined for this implementation were
designed to accomodate very subtle pres-
sures; the fact that the TSD necessitates
high finger pressures was not taken into
account in their design. Nor was the
vibration from nearby machinery fore-
seen as a problem. As a result, develop-
ment of the five input routines was
somewhat hampered by vibration and pres-
sures which exceeded the output range
of the guages and related circuitry.
Were the equipment to be rebuilt,
heavier rings would greatly improve
its performance. Alternatively, load
cells, rather than strain gauges
might be used. Load cells measure
pressure without deformation. How-
ever, these devices are significantly
more expensive than the strain guages
used for this implementation.
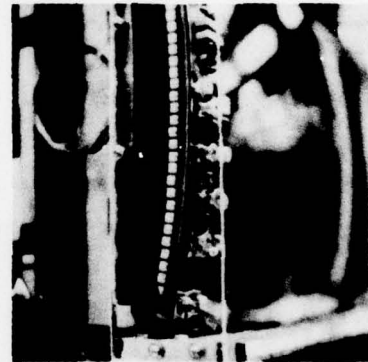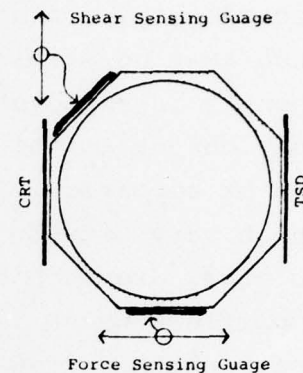
3.2 ELECTRICAL DESCRIPTION.

The PSD utilized nine BLH (SPB3-35-500)

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semiconductor strain guages. Semi-
conductor gauges were selected be-
cause of their sensitivity to mini-
scule strains. However, as semicon-
ductor devices, they are also very
sensitive to changes in temperature.
Accordingly, a ninth gauge mounted
such that no strain could be exerted
upon it is employed to provide a refer-
ence output to which all other gauges
can be compared. The gauge outputs,
which vary between 10 millivolts peak
to peak, are each connected to pre-
amplifiers which import a gain of 50,
the resultant "raw" output is .5 volts
peak to peak.

X-Force

Y-Force

Z-Force

The "raw" voltages from the strain
guage preamplifiers are combined
by sum and difference networks to
produce outputs which correspond to
X force, Y force, Z force, X moment,
Y moment, and Z moment. The sums of
opposite torque gauges are used to
provide forces along each axis, while
the differences are used to provide
the torques about each axis.

X-Torque
(About X Axis)

Y-Torque
(About Y Axis)

The six force and torque outputs are
converted to digital signals by a
Burr-Brown SDM853 data acquisition
system (DAS). The inputs to the
DAS are limited to 6.2 volts to prevent

Z-Torque
(About Z Axis)

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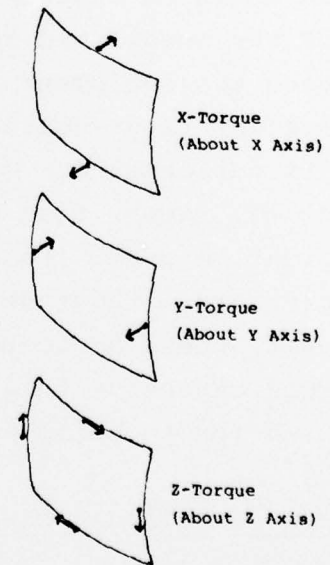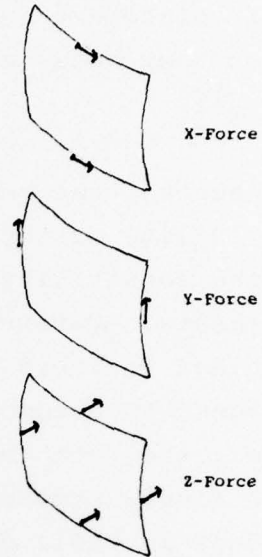
overloading the A/D converters. The
DAS produces a 12 bit output for each
of the 6 analogue inputs.

3.3 DIGITAL INTERFACE.

The outputs from the DAS are stored
in a buffer, allowing the DAS to
assemble the next sample while waiting
for the computer to read the current
values.

The computer interface allows program
selection of either byte or halfword
mode. In byte mode, only 8 most sig-
nificant bits of each force and torque
are used, allowing fast and easy access
to the data. In halfword mode, the
programming is a bit more complicated,
but all of the data bits are available.
Due to the influence of vibration on low
order bits, the device was operated pri-
marily in byte mode for the experiments
described here.

3.4 SYSTEMS SOFTWARE.

The PSD is equipped to interrupt the
computer when data is available. How-
ever, since the PSD is always used in
conjunction with the TSD the interrupt
circuitry of that device was used.
When the TSD detect the finger touch,
the program reads the position from
the TSD and the forces and torques from

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the PSD. Since hysteresis of the strain
rings and uncompensated temperature
drift often cause the untouched PSD to
produce non-zero readings, it is additi-
tionally important that the TSD inter-
rupt be used. When the software detects
that the device is not being touched,
it reads the values of the forces/torques
so as to use them as offsets for inputs
next time the PSD is touched.

Drift due to temperature changes generated
problems for the initial input routines.
This was overcome by adding software
to sample the force and torque readings
when the TSD was not being touched.
The latest reading, then, were used as
offsets for subsequent inputs. However,
this software compensation was made at
the expense of the system's overall
response range: the offsets biased
the device unpredictably. A zeroing
circuit was designed to correct for
temperature drift in hardware. This
circuit was not installed due to the
short duration of the study and the
anticipated cost associated with its
installation.

4.0 CONCLUSIONS.

As a laboratory experiment, the PSD
demonstrated a potential for new and
powerful interaction techniques. Perhaps

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the most significant feature of the
PSD is the immediacy and richness of
the tactile man-machine interaction
which it affords. In one positioning
of the finger, the user can indicate
location, direction, and magnitude.
With such a physically engaging de-
vice environment, complex activities
need not require a lengthy sequence of
typed commands or menu selections.
Clearly the PSD could be used in a com-
mand and control application to overlay
a map, selecting symbols and setting
them in motion. In the manner of the
dial described in Section 3.2, actions
could be performed on any of a large
selection of graphical entities spread
out over the entire display.

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1 A discussion of various TSD technologies
is provided in the report "Touch Sensitive
Displays" by Dr. Richard A. Bolt, Architecture
Machine Group, M.I.T. Cambridge, Massachusetts,
September 1976.
2 A more complete technical description of
the TSD is provided in reference sited in
footnote 1.