MASSACHUSETTS INSTITUTE OF TECHNOLOGY
A. I. LABORATORY

Artificial Intelligence
Memo No. 273

January 1973

THE LITTLE ROBOT SYSTEM

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General description of the Little Robot System

The Little Robot System provides for the I.T.S. user
a medium size four degree of freedom six axis robot which
is controlled by the PDP-6 computer through the programming
language Lisp. The robot includes eight force feedback channels
which when interpreted by the PDP-6 are read by Lisp as the
signed force applied to the end of the fingers. The
first six forces are the X,Y and Z forces and the torques
around X,Y and Z . The other two forces are the grippers and
the vice grippers. The three X,Y and Z forces and three torques
are computed from six numbers read in from six L.V.D.Ts
(Linear Variable Differential Transformers) arranged three
in the vertical and three in the horizontal plane within a
stress strain spring loaded wrist. The grip is read in from
a strain guage mounted on the stationary reference finger.
The relative position between the motor shaft
and the vice shaft is determined through means of two
potentiometers to measure the vice force. The two shafts
 are coupled by a spring.

The force feedback wrist has a dynamic range of about
one pound and a resolution of about 0.25 ounces with not more
than one ounce of hysteresis. The grip can measure one
pound of gripping force and the vice can measure about three
pounds of grippinig force.

The robot has its six axes split up into two parts. The first half consists of a nine square inch plate which moves in two perpendicular directions for X and Y. The computer controlled vice is mounted on the plate in one corner. The other half consists of the Z axis which is mounted over the plate. The Z axis hangs down over the plate and has a vertical travel of five inches. On the end of the Z axis is mounted the stress strain wrist and on the end of the wrist is mounted the hand which can rotate and grip. Until a hardware modification is made only the center six of the nine square inch work-space can be used.

The three main axes (X,Y and Z) have a resolution of 0.001 inches and a positioning repeatability of plus or minus 0.003 inches. The X,Y plate is flat and level with respect to the end of the fingers to less than 0.010 inches. The robot can be positioned anywhere within the six by six inch work space in less than twenty seconds.

The Little Robot Controller is mounted on the right hand side of the table where the robot lives. The plexiglass panel on the front of the controller has some light's, switches, and a whistle wich goes "feep" when the robot feels pain. The controller contains six power amplifiers so the computer can control the speed of each motor associated with each of the six axes. It also contains appropriate interfacing of six high resolution potentiometers to measure the position of the six axes, making it possible for the computer to servo to the desired positions of all six axes.

Six L.V.D.T. amplifiers, a strain guage amplifier and
a differential amplifier are contained within the controller
to interface the wrist, reference finger, and the vice force
input. Also contained in the controller are some
electronics which monitor all eight forces felt by the robot.
If any of the forces exceeds the threshold of pain, the
controller is told to shut off all six motors and to start
feeping the whistle. Because of the simple minded nature
of this safety feature, the robot cannot back away from pain
and will get itself latched up merely by squeezing too hard with
the grip or vice, or by moving the arm down into the table, etc.
This latching up problem is something that the user shouldn't have
to encounter because the program running in the PDP-6
contains a model of pain which is both aware of the
latch up problem and allows the robot to move away from pain.
If the robot does get into this latched up state it should
be regarded as a bug in the Little Robot System and
you should turn off the controller. By the way, the whistle
will still continue to feep so you might also flip off the
switch labeled "ALARM" before it drives you nuts.

Using The Little Robot in Lisp

Start the PDP-6 running, then type:

LISPK

(FASLOAD MINOPN FASL COM)

(OPENMINI)

(SETM CALB -1)

Sometimes LISP and the Compiler are incompatible,

in which case when you do the FASLOAD, LISP will type

out a warning message. Try OLISP, and if that fails

then try (UREAD MINOPN >).

OPENMINI will return NIL after the PDP-6 is loaded

and running.

"CALB" will become zero when the calibration is done.

Do not type on the teletype or lean on or bump the table

while the robot is calibrating itself! If you should disturb

the robot while it is calibrating itself, then recalibrate.

Part of the calibrating sequence consists of mapping the

null force for all orientations of the hand. Therefore,

bumping the arm while calibrating will cause the robot to feel a

ghost force whenever it passes through that same

orientation. The robot can feel building tremors.

Before you flip the motor swich to on always check the
following:

1) Check the five red power supply indicator bulbs
   labled +15 -15 -10 +25 -25 . If any of these indicators are
   out, turning the motor switch on can cause damage to the hardware.
2) Check the switch labled "ALARM" and make sure it is on.
   If when you flip it on the alarm starts to feep, or any
other time the alarm starts feeping give up, and
   let me know. Make sure to flip off the alarm switch and
   the motor switch before you leave.
3) Check and make sure that LISP has returned NIL after
you have typed (OPENMINI) or (REOPENMINI).
Flip the motor switch on. The initial state of the
Little Robot variables are such that the arm will
assume a position which is centered over the table as
soon as the motor switch is turned on.

Theoretically, the Little Robot can not be
damaged under program control. But please note
the following: try not to apply more than one or two
pounds of force to either the X,Y bed or the hand
and wrist. When setting up the scene, for example, if your
shirt sleeve were to get caught on part of the hand
as you pulled your hand away, you might sprain the robot's
wrist. Remember that the wrist is only supporting the
hand with four pieces of 0.04 inch piano wire.

LISP Functions

SETM - The LISP function SETM (SET Mini) of two arguments
is used to set variables. For example,
(SETM XDES 3.0) will move the arm to a position three
inches up the X axis.

GETMF - The function GETMF (GET Mini Floating point)
of one argument is used to read variables.
For example, if XDES is 3.0, (GETMF XPOS)
might return the value 2.999 meaning
that the potentiometer is measuring the X axis to
to be 0.001 inches from its destination.

GETM - (GET Mini fixed point). Care should be taken to
read fixed point variables with GETM and floating
point variables with GETMF.

WAIT - The function WAIT of one argument first waits for
the variables in the PDP-6 to become consistent and
then evaluates its argument every thirtieth of a second
and will sleep until evaluating the argument returns T.

SEQ -   The function SEQ (Sort of EQual) of three arguments

returns the value T when the first two arguments are

equal to within the tolerance of the third argument,

otherwise NIL. The following example will first set the

arm's destination to 1.5 inches above the table

and will then sleep until the arm actually gets to within

three mils of 1.5 inches above the table.

(SETM ZDES 1.5)

(WAIT '(SEQ (GETMF ZDES) (GETMF ZPOS) 0.003))

OPENMINI - Type (OPENMINI) to load and start the PDP-6 robot

program.

REOPENMINI - Type (REOPENMINI) to reload and start the PDP_6

program.

CLOSEMINI - Type (CLOSEMINI) to close the PDP-6.

The I/O Variables

You may find the list of variables to be somewhat
random because of the flags and the apparent
redundance of some of the variables. The following list
is the subset of all the variables which should most
commonly be used. You may need to use some of the other
variables if you require tolerances which
are close to or are limited by the specifcations
listed in the beginning.

Output variables (Abbreviated description)

```
CALB - When set to -1 runs Calibration program.
RESET - When set to -1 Resets the variables.
XDES-VDES - Floating point Destination.
XFDS-VFDS - Fixed point Force Destination.
XFRE-VFRE - When set to 0 servos to DES.
            When set to -1 servos to FDS.
```

Input variables (Abbreviated description)

```
XPOS-VPOS - Floating point Positions.
XFRS-VFRS - Fixed point Forces.
XTRC-ZTRC - Fixed point Torques.
XDLT-VDLT - Fixed point Deltas.
```

Input variables

TIC	Is incremeted every 1/60 sec in the variable update loop.
Done	-
XDLT YDLT ZDLT RDLT GDLT VDLT	The Deltas are fixed point numbers which are the differences between the destinations and the current positions in pot units. (Pot units being the numbers sent out and read in from the A/D and D/A multiplexor.)

```
XPOS        The Positions are floating point numbers which
YPOS        are the current positions of the axes as seen by the
ZPOS        potentiometers in units of inches for the linear
RPOS        axes and radians for the rotate axis.
GPOS
VPOS


XFRS        The Forces are fixed point numbers which are the
YFRS        signed forces being applied to the hand.
ZFRS        These numbers are corrected to read close to zero
RFRS        for all orientations of the hand.
GFRS
VFRS


XTRC        The Torques are fixed point numbers which are the
YTRC        magnitude and sign of the torques around the three
ZTRC        force axes. For example if the hand was rotating
RTRC        a nut for the purpose of screwing it on to a bolt,
GTRC        you could get the torque being applied to the bolt
VTRC        from ZTRC.


XVLS        The Velocities are fixed point numbers which are
YVLS        the velocities of the axes.
ZVLS
RVLS
GVLS
VVLS


1RFRS       The Raw Forces are fixed point numbers read in
2RFRS       by the A/D. They are the forces measured by the
3RFRS       six L.V.D.T's. in the wrist.
4RFRS
5RFRS
6RFRS
GRFRS       A/D input from strain guage.
VRFRS       A/D input from pot assembly.

1ZFRS       The Zeroed forces are fixed point numbers which are
2ZFRS       the forces measured by the L.V.D.T's strain guage and
3ZFRS       pots which are corrected to read close to
4ZFRS       zero for all orientations of the hand.
5ZFRS
6ZFRS
GZFRS
VZFRS
```

XPPOS   The Pot Positions are fixed point numbers read in
YPPOS   from the pots by the A/D.
ZPPOS
RPPOS
GPPOS
VPPOS

                    Output Variables

CALB   Calb should be set to -1 first thing after
         loading and opening the Little Robot for
         the purpose of calibrating and zero centering
         the force inputs. Calb will become zero again
         when the calibration is completed.

XPDES   The Pot unit Destination specified in fixed point
YPDES   will have effect only if FRE (Limp mode flag)
ZPDES   is zero and CLMD (Calibrate mode flag) is zero.
RPDES
GPDES
VPDES

XGAN   The gains are fixed point numbers which determine
YGAN   the position servo gain only when FRE (Limp mode flag)
ZGAN   is zero.
RGAN
GGAN
VGAN

XFGN   The Force Gains are fixed point numbers which
YFGN   determine the gain in limp mode and are
ZFGN   only effective when FRE (Limp mode flag) is -1.
RFGN
GFGN
VFGN

XFRE   When FRE (Free) is set to -1 the axis
YFRE   is in limp mode and the axis will servo to
ZFRE   a desired force FDS (Force destination).
RFRE
GFRE
VFRE

XDES   The Destination is specified in floating
YDES   point in units of inches for the linear axes
ZDES   and radians for the rotate axis. DES is effective
RDES   only when FRE (Limp mode flag) is zero
GDES   and CLMD (Calibrate mode flag) is -1.
VDES

XCLMD   CLMD is the suffix for six flags
YCLMD   which when set to zero cause the arm to
ZCLMD   servo to the PDES (Pot unit Destination)
RCLMD   and when CLMD is set to -1 causes the arm
GCLMD   to servo to DES (Floating point Destination).
VCLMD

XFDS   The FDS (Force Destination) is effective
YFDS   when FRE (Limp mode flag) is -1. FDS is set
ZFDS   to a fixed point number causing the axis to
RFDS   move in such a way so as to servo the force
GFDS   to the FDS.
VFDS

ARMON   Is a flag which when set to -1 softwarily
         turns the arm on and when set to zero
         turns the arm off.

RESET   Is a flag which when set to -1 restores
         all the robot variables to their
         initial state. Reset will return to zero
         when the reset is done.

EXAMPLES

```
(SETQ UP 4.0)

(SETQ OPN 1.5)

(SETQ SQZ 2000)

(SETM RESET -1)

(WAIT '(ZEROP (GETM RESET)))

(SETM RDES 0)

(WAIT '(SEQ (GETMF RPOS) 00.005))


(DEFUN MOVETO (X Y Z)

(SETM ZDES UP)

(WAIT '(SEQ (GETMF ZPOS) UP 0.005))

(SETM XDES X)

(SETM YDES Y)

(WAIT '(AND (SEQ (GETMF XPOS) X 0.005) (SEQ (GETMF YPOS) Y 0.005)))

(SETM ZDES Z)

(WAIT '(SEQ (GETMF ZPOS) 2 0.005))

NIL)
```

```
(DEFUN GRIP ()
(SETM GFDS SQZ)
(SETM GFRE -1)
(WAIT '(SEQ (GETM GDLT) 0 20)
NIL)


(DEFUN UNGRIP ()
(SETM GDES OPN)
(SETM GFRE 0)
(WAIT '(SEQ(GETM GDLT) 0 20 )
NIL)
```