6673
Memorandum M-2088

Electronic Computer Division
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: BI-WEEKLY REPORT, PROJECT 6673, MARCH 2, 1951

1. GENERAL

(C. R. Wieser)

The first priority of work is still the accomplishment of a trial interception. The necessary programs have been completed and tested on the computer. The next experiments, which deal with guidance, require operation of the MEW radar, which is still out of service for maintenance. Until the radar is again operating, the principal effort will be directed toward improvements in prediction.

Several people from the Barta Building attended an AFCRL symposium which dealt with work similar to ours. The meeting emphasized the necessity of obtaining smoothed velocity as quickly and accurately as possible.

There has been some preliminary thought given to non-linear prediction. Because of the large number of independent variables in non-linear prediction a good analytic understanding is needed to synthesize the tracking programs. John Salzer's group has been assigned to the study of this problem.

2. ENGINEERING

(C. R. Wieser)

The MEW radar is still out of service for maintenance. Some specific troubles have been located and are being fixed. During this period maintenance work on the Bedford end of the relay link is going on, and an attempt will be made to install the equipment for automatic prevention of overloading in the digital storage system.

During this period the equipment in Room 224 has been checked over to be sure that it is operating properly. The Fairchild scope camera has been installed in a temporary manner to facilitate analysis studies. Satisfactory photographs have been taken with panchromatic film, which appears to be best for use with a P7 scope screen.

The final draft of the engineering section of Summary Report No. 8 has been prepared.

2. ENGINEERING (continued)

(D. A. Buck)

Consideration is being given to the possibility of using the light gun for target tracking initiation directly off of the digital P.P.I. scope. Although the digital P.P.I. takes a long time to get set up to display a target, it is doing so while Whirlwind is converting from polar coordinates to cartesian coordinates. If the light gun could be made to return a pulse to reset specified digits of flip-flop register zero during the computation time on a given target instead of shortly after the computation is finished as it now does, the computer would know that the light gun is pointing to the target that is being displayed. Tracking could thus be commenced or ceased on that target. The digital P.P.I set-up time is estimated to exceed 4000 microseconds for maximum azimuth. This time is now being measured.

The vacuum tubes in the demultiplexer rack have been given a routine check, and one replacement has been made.

A panel to facilitate the distribution of alternating current to the various chasses is being laid out. At present, four wall outlets are being used.

The coaxial cables leading from the rack of test equipment in 224 to flip-flop register 4 are now permanently connected to the reset jacks. Formerly this connection was made only when the 6673 group wished to use Whirlwind I. The radar data is now being isolated from this register by cutting off the supply of WWI timing pulses from test control to the rack of test equipment in 224. Caution must be exercised when working around this rack to prevent stray pulses from entering the computer.

(H. J. Kirshner)

No difficulties have been encountered with equipment located in Room 224 during this bi-weekly period.

An aural indication device has been added to the light gun equipment. This device produces a chime when a target has been acquired by the light gun.

It has been noticed that if the light gun is used in conjunction with the 10" D.R.R. scope, targets will be acquired whether or not the switch on the light gun is depressed. This condition results from the large differential in spot intensity between the

2. ENGINEERING (continued)

(H. J. Kirshner) (continued)

5" display scope and the 10" scope. The condition may be remedied by decreasing the light gun high voltage power supply potential, and hence reducing its sensitivity. The reduction of sensitivity may be accomplished by lowering the setting of the Variac located on the front panel of the high voltage power supply.

A memo describing the light gun has been written and will be available for reproduction shortly.

(R. L. Best)

A new buffer amplifier and feed-back phase inverter have been built and tested with the 16-inch display scope. In combination with the new pre-amplifier mentioned in the last report, a 20 volt change in the +250 volt supply causes only 1/4 inch deflection out of a total of 14 inches. These circuits will be incorporated into the final deflection amplifiers that will be used with the 16-inch display scope.

3. ANALYSIS FOR BEDFORD EXPERIMENTS

(D. R. Israel)

Work on the description of the programs for the Bedford experiments has progressed, although at a slower rate due to the pressure of other activities. The sections dealing with Identification, Tracking, and Smoothing are completed; these sections formed the basis of a talk given to the Track-While-Scan meeting at AFCRL last week.

J. Arnow's program for printing-while-tracking-while-scanning (PWTWS) has been successfully operated on the computer and a large amount of printed data is being accumulated. This data is being preserved in a laboratory computation book, together with graphs and analyses of the data.

The PWTWS program has indicated the existence of a difficulty which we had hitherto not suspected. The deviation of observed target position from the predicted position as given is $\Delta R = |\Delta x| + |\Delta y|$, with an associated scale factor of 2^{-7}. The $|\Delta x|$ and $|\Delta y|$ are added together with a special add, and hence it is possible for $|\Delta x| + |\Delta y|$ to add up to slightly greater than 128 and give a small ΔR. This made it occasionally seem that a distant radar return closely corresponded to the target. An elimination of the error is possible if we use the criterion: $\Delta R^2 = \Delta x^2 + \Delta y^2$. This change will be made in all of our programs.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(D. R. Israel) (continued)

The data made available by the PWTWS program indicated fluctuations in the smoothed velocities of $\pm$ 20 knots. The magnitude of these fluctuations and the setting time of the smoothing closely corresponds to the expected results as indicated by the synthetic smoothing programs.

As a result of analysis of the PWTWS data it was decided to make a full investigation of the linear correction and a final choice of optimum values of a and α. This study was involved with variations of three parameters: α, a, and v(velocity). The availability of the scope camera facilitated the parameter selection inasmuch as pictures could be taken, and then be studied later. Some 30 pictures were taken, and as a result of a careful study it appeared that better smoothing with smaller velocity fluctuations at a small cost in settling time can be achieved with α = 2/32, a = 10/32. These values shall be used in the place of present values for all programs. Further consideration has been given to possible types of non-linear correction. Several discussions with Prof. Linvill have proved to be very valuable and enlightening. Several programs are presently available for experimentation with non-linear smoothing. The lack of computer time precluded the actual experimentation. Whereas in the linear case there were only 3 parameters -- a, α, and v -- the non-linear cases involved between 5 and 9 parameters.

The variation of a large number of parameters to give an optimum result is by no means an easy task, and it has been suggested that the computer be used to aid in the parameter selection. Such an application would be feasible if the various results could be given a meaningful "figure-of-merit" and if we specified a desired (maximum or minimum) end result. Ideas associated with the designation of a "figure of merit" are presently being considered in more detail.

(R. L. Walquist)

The collision course program now being used was run on the computer during this past bi-weekly period, using as a target an arbitrary aircraft track, and for the interceptor, either a stationary noise return or else a second arbitrary aircraft track. Under certain conditions for the positions of the target and the interceptor, the program would give an arithmetic overflow. It was found that the cause of this overflow was due to two minor programming errors which have since been corrected. As an added safety feature, the equation used in calculating the collision course bearing angle has been scale-factored so as to reduce the possibility of an erroneous solution due to round-off error. This new version of the program was tried out in the same manner as that outlined above and appeared to work satisfactorily. The accuracy of the collision

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(R. L. Walquist) (continued)

course bearing angle now appears to be limited primarily by the accuracies of the velocities of the target and interceptor which are obtained from other parts of the program.

The overflow which was occurring in RTP-III (Multiple Target Tracking Program) due to false correlation of input information has been corrected. Although the program will track a maximum of 10 targets, the several inherent difficulties in the operation of the program (as mentioned in the last bi-weekly) indicate that a different program would be desirable. Work is now progressing on a new Multiple Target Tracking Program (RTP-V) which will be simpler from the operator's point of view. Also an attempt is being made to further alleviate the time problem mentioned in the last bi-weekly. This new program should have a target capacity of somewhere around 7, still using velocity tracking and smoothing for all targets.

In order to help acquaint O. Aberth and O. Becker with the operation of the computer and to give them some insight into the present Bedford experiments, two elementary problems associated with noise rejection and automatic target acquisition have been presented them which they will code and try on the computer during the next bi-weekly period. The first of these programs is to place on an R-θ box around the noise returns coming from Mount Monadnock and the associated ridge; any returns falling within this box are to be discarded. The second program is to set an adjustable range gate (done automatically by the computer) so that the number of target plus noise returns between this range gate and the maximum range of the radar set most nearly equals the number specified by the program operator. This range gate is to be adjusted continuously as the number of radar returns changes. Both of these programs are a start on the problem of how best to process a large amount of incoming information without saturating the information processing capacity of the computer.

(J. Arnow)

The program for printing-while-tracking-while-scanning was modified in that one can change the parameters a and α without undue hardship. Also another program along these lines, printing (r, θ) co-ordinates is near completion.

(Walter S. Attridge, Jr.)

The collision program described in the 6673 bi-weekly of Feb. 16, (M-2087) has been tested in WWI. For long ranges the calculation is

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(Walter S. Attridge, Jr.)

very quick but in error by a few degrees. With short ranges the accuracy is good but the time for calculation is of the order of several seconds.

At present two sl 12 orders are used to scale factor the increments $\Delta \frac{1}{2TV_i}$. The accuracy can be increased (and the speed consequently decreased) by decreasing the addresses of these sl orders. This might be desired for long ranges. The speed can be increased (with accuracy decreased) by increasing the addresses of the two sl orders. This might be desired for short ranges. A tape has been prepared to demonstrate these changes in the sl addresses.

A new "collision-pursuit" constant γ can be introduced into the equations as follows:

$$\frac{v_{ix}}{2V_i} = \gamma \frac{v_{Tx}}{2V_i} + \frac{x_0}{2TV_i}$$

$$\frac{v_{iy}}{2V_i} = \gamma \frac{v_{Ty}}{2V_i} + \frac{y_0}{2TV_i}$$

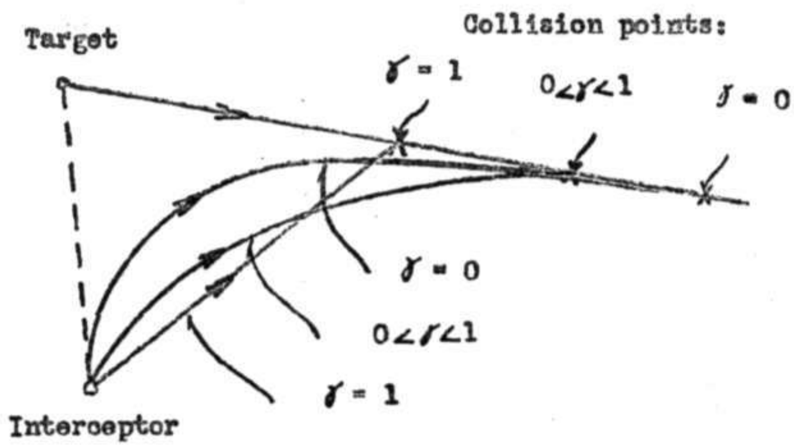
$$\left(\frac{v_{ix}}{2V_i}\right)^2 + \left(\frac{v_{iy}}{2V_i}\right)^2 \geq \frac{1}{4}$$

$$0 \leq \gamma \leq 1$$

With $\gamma = 1$ we have the true collision course solution in which the interceptor is always headed toward the point of collision. With $\gamma = 0$ we have the true pursuit course solution in which the interceptor is always headed towards the target plane. Intermediate values will give "collision-pursuit" courses.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(Walter S. Attridge) (continued)



Sometimes it is desirable to have the interceptor come in behind the target plane for collision astern. For the collision astern solution x_0 must be decreased by an amount Kv_{Tx} and y_0 by Kv_{Ty}. The constant K is related to the distance astern D of the collision point from the target plane by the following equation:

$$K = \frac{D}{\sqrt{v_{Tx}^2 + v_{Ty}^2}}$$

If collision abeam is desired x_0 can be decreased by an amount $\mp Kv_{Ty}$ and y_0 decreased by an amount $\pm Kv_{Tx}$. K is related to the distance abeam D by the same equation as above. The choice of signals used for collision abeam in the shortest time, which is on the near side of the target plane, must satisfy the following equation:

$$(x_0 \pm Kv_{Ty})^2 + (y_0 \mp Kv_{Tx})^2 < x_0^2 + y_0^2$$

However, the difference in times for collision for the two choices of signs should not be great enough to warrant any provision to find the desirable choice of signs.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(Frank E. Heart)

Spent bi-weekly period reading introductory material, programming and testing checking codes for square root routines, and getting an introduction to the problems of "smoothing".

(D. A. Kemper)

The Trigonometric Check program has been corrected and rewritten, but it has not yet been run. All the trigonometric subroutines contained in M-2018 have been prepared and taped for use with this check program.

Some time was spent reading instructional literature on WWI. A start has been made at becoming familiar with the various tracking and guidance programs that have been evolved so far.

4. THEORETICAL ANALYSIS

4.1 General Studies

(John M. Salzer)

Pictures were taken of the computer solution of a second-order differential equation. Of particular interest was the instability of the solution under conditions for which the system represented by the differential equation is stable. The displays verified the analytical results with striking precision. A forthcoming note will discuss this investigation.

4.2 Data Smoothing and Aircraft Control

(John M. Salzer)

Several simple prediction programs were designed by frequency analysis, and several more are to be designed shortly. The effectiveness of these programs will be checked experimentally on simulated data being programmed by C. Gaudette.

I am devoting some of my time jointly with Dr. W. Linvill in preparing a speech ("Analysis of Digital Computers in Control Systems") to be delivered at the Wayne University Conference on March 28, 1951.

(Charles Gaudette)

A program which smoothes velocity by means of least squares and uses similated data has been written and is being prepared for computer operation during the next bi-weekly period.

4.2 Data Smoothing and Aircraft Control (continued)

(Charles Gaudette) (continued)

The smoothing display which is used to determine the optimum value of the constants, α and a, has been revised to provide a more general approach. α and a are the weighting factors used in determining the smoothed velocity and predicted position, respectively.

4.3 Correlation Studies

(R. L. Walquist)

I have been working on the problem of finding the constants involved in the equation that describes the constant velocity flight path of an aircraft. The data consists of range-rate, azimuth and time readings. In one particular case considered, two consecutive readings (azimuth and range-rate only) from one station results in a cubic equation.

(O. Aberth)

Have continued to work on the problem mentioned in the last bi-weekly report -- that of weighting the azimuth readings of three radar stations in order to locate a target with maximum accuracy.

(O. N. Becker)

Continued study of the problem of 2 azimuth radars tracking a single target moving with constant speed and course. Am studying the effect of errors due to non-synchronization of sweep speeds on the determination of present and extrapolated target positions.

5. COMPUTER OPERATIONS GROUP

(J. Arnow)

An assignment of hours for computer operation was agreed upon by collaboration of the various interested parties. The net result has been to eliminate the long stretches of seven or eight consecutive hours of operation and substitute three hour periods during each day of the week.

A number of photographs have been taken of various display programs using the Fairchild camera, and have given very satisfactory results.

5. COMPUTER OPERATIONS GROUP (continued)

(J. Arnow) (continued)

In so far as the instruction of new personnel in computer operation, most of the emphasis has been upon the individual use of the computer. In particular, Attridge, Heart and Kemper have run their own programs under the supervision of either Israel, Gaudette or myself.

(C. Gaudette)

The revised smoothing display which determines the errors between predicted and actual positions and the errors between smoothed and actual velocities has been successfully operated. Several photographs of the displays were taken, but more photographs must be taken with varying conditions before any conclusive result is made.

A considerable amount of computer operating experience has been gained during the past bi-weekly period.

6. RECORD OF COMPUTER UTILIZATION

(J. Arnow)

2-19-51

1600 - 1730 T131, a program for testing a new approach to the calculation of a collision course heading angle was tried with satisfactory results.

1730 - 1815 A smoothing display program was run, but due to a need for certain revisions in the program, no significant results could be obtained.

1815 - 2100 A program for two aircraft interception was run unsuccessfully due to programming errors in the calculation of the required heading angle.

2100 - 2200 T 88, a smoothing display program, was run, no significant results were forthcoming.

2200 - 2300 T 125, a program for multiple tracking was run unsuccessfully. The program has a need for certain modifications to facilitate operation.

2300 - 2330 An attempt was made to convert a number of tapes but was unsuccessful due to mistakes in preparation of the tapes.

2-21-51

1000 - 1200 A number of pictures were taken with the Fairchild camera of solutions to various second order differential equations.

2-23-51

1715 - 1830 A display program for non-linear smoothing was run during this period. A few pictures were taken but no significant results were forthcoming.

1830 - 2100 A program to check the accuracy of trigonometric and square root subroutines was tried. There were some programming errors and consequently no positive results were forthcoming.

2100 - 2330 A great deal of data was printed on the tracks of various commercial aircraft using magnecorder reel #27. The printed velocities were one half of the true velocities however.

6. RECORD OF COMPUTER UTILIZATION (continued)

(J. Arnow) (continued)

2-26-51

1600 - 1800 A program for two aircraft interception was run with moderately satisfactory results.

2-27-51

1700 - 2000 A smoothing display program was run and a number of pictures were taken.

2-28-51

1420 - 1530 A program for the calculation of a collision course was run with reasonably satisfactory results.

1530 - 1700 The program for checking subroutines contained a number of programming errors.

3-1-51

1400 - 1700 The time was given to the ES group for adjustment of digit 13.

3-2-51

1400 - 1700 An attempt was made to run the smoothing display programs, but due to faulty action of the decoders no significant results could be obtained and operation was suspended at about 1500.