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SUBJECT: BI-WEEKLY REPORT, PROJECT 6673, MARCH 30, 1951

1. GENERAL

(C. R. Wieser)

During the past week, several visitors have seen demonstrations of tracking-while-scanning and simulated interceptions. This has taken a good deal of the computer time assigned to 6673. During demonstrations, the equipment, programs, and operating teams have functioned very well.

The overhaul work on the radar has been completed, and the quadrant containing the bad ground clutter has been gated out to prevent overloading the digital storage at Bedford. Also, the relay link has been modified to send all azimuths regardless of the presence of targets. Because of bad weather we have not yet observed enough data to evaluate the effects of overhauling the radar.

Modification of the digital storage system at Bedford has been suggested as a means of improving reliability. One piece of data needed for planning any changes is the statistical distribution of the number of ranges (targets) transmitted per azimuth quantizing sector. Arnow will prepare a program to obtain the distribution by having the computer analyze recorded data.

Plans have been made to resume flight tests next week. The first tests will be guidance toward an arbitrary fixed point whose coordinates have been inserted into the computer. Prominent landmarks will be chosen to allow visual checks by the pilot.

When guidance has been performed successfully, the next step is to run an interception program on a stationary radar target, such as an isolated ground-clutter echo. This trial and the guidance experiment require only one aircraft and are therefore a more easily obtainable means of introducing personnel to guidance procedures.

1. GENERAL (continued)

(W. K. Linvill and J. M. Salzer)

The Wayne Conference on Automatic Computing Machinery and Applications held in Detroit on March 27 and 28, 1951, has proved a successful, constructive and congenial meeting. From the point of view of project 6673, it is significant to note that digital computers have entered the control field. It is also clear that generally little has been done to deal with this application analytically.

Both Dr. Aiken in his opening address and Mr. Coleman in his banquet address pointed out the significance of control applications of digital computers, but excepting our speech, no other presentation dealt directly with this problem. The interest shown and the questions asked in connection with our presentation indicate that the problem is a live one and an effective analytical approach to dealing with digital-analog systems is most desirable. Some of the idiosyncrasies of such hybrid systems, which can now be explained by analysis, have already plagued early experimenters. It appears that some have reverted to all-analog control systems because they could not make a preliminary evaluation of a hybrid system, while others have struck it out to apply digital units in control systems depending more on qualitative redundancies and heavenly guidance than on thorough quantitative investigation.

A separate 6345 memorandum will be written as a general report on the Wayne Conference.

2. ENGINEERING

(D. A. Buck)

Operation of the light gun from the 12" digital PPI was found to be feasible if the data being fed into WWI were delayed three milliseconds. This time is needed by the PPI to set up its range coordinate.

Equipment has been designed and constructed to make this mode of operation possible. At present, the light gun output is not synchronized with restorers. As soon as a DC register panel becomes available this will be taken care of. It is at present possible to initiate tracking from the 12" PPI understanding that there is a small possibility that tracking might not get initiated on a sweep due to the light gun output falling directly on top of a restorer pulse.

2. ENGINEERING (continued)

(D. A. Buck) (continued)

The three-millisecond delay is felt to be negligible. An aircraft traveling 600 mph would move but a little over two and one half feet in three milliseconds.

Equipment changes during the period include several modifications to the demultiplex gear, mounting of the voice channel monitor speaker in the light gun rack, re-routing of some of the coax cables, and addition of a relay panel to the DC supply so as to complete the conversion to "one-switch" power control. The chassis required for PPI - light gun operation is mounted in the receiver rack above the synchronizer.

Consideration is being given to the possibility of displaying WWI's output as (r, θ) coordinates directly, as is done in the digital PPI.

Blanking of the inner range circle was investigated. An eight-tube chassis has been built at Bedford to blank out their zero ranges. At present, a black-crayon disc is used for blanking.

Every azimuth is now being sent from Bedford.

(H. J. Kirshner)

A considerable portion of the last bi-weekly period was spent re-aligning AFCRL equipment in room 224. This re-alignment was necessitated both by modifications made in the frequency demultiplexer located here and by changes made at Bedford.

The major change made at Bedford, which should be of interest to the analysis group, is that we now receive information at every quantized unit of azimuth. Absence of target data is indicated by a range of zero miles.

The I.R.E. convention in New York was attended during this period. Some papers on Air Traffic Control and Aids to Navigation were listened to, but probably because of security restrictions, nothing especially new in the way of systems was discussed. One paper which was of interest to our project concerned the reduction of radar precipitation returns by changing antenna polarization from linear to circular. Experiments conducted have shown that precipitation returns can be reduced by approximately 30 db by change of polarization. A practical limit of target to precipitation signal ratio of about 15 db was achieved with the particular radar employed in the experiments.

2. ENGINEERING (continued)

(R. Hunt)

Satisfactory progress is being made on the 16" display oscilloscopes. The focus coil positioning assemblies (3) are completely fabricated and assembled. The preliminary drawings necessary to construct a prototype scope unit should be ready soon. Construction should start almost immediately.

The automatic camera control has been completed, tested and installed. Operation is quite simple; remote control panels are located at TC-0 Test control and room 224. The manual control switch or camera may be plugged into either panel or one at each.

3. ANALYSIS FOR BEDFORD EXPERIMENTS

(D. R. Israel)

The past bi-weekly period marked by the completion, test, and successful operation of a program for automatic initiation and a program for a simulated interception. These programs provide rather interesting displays for visitors, and indeed most of their operation in the past week has been solely for that purpose. In this connection, we now have a set of four programs which we can show visitors:

1. Printing of TWS data on one a/c
2. Multiple Tracking--Five a/c
3. Automatic Initiation--One a/c
4. Simulated Interception

The experience in operating these programs in the past week or so has indicated several minor changes which would improve our demonstrations. These changes will be undertaken as soon as possible.

Experience in these demonstrations to visitors and discussion of our programs--especially the smoothing sections--has indicated the advisability of printed and pictorial material to aid in our presentation. This includes pictures of interception courses, flow diagrams, and examples of the PWTWS data. An effort is being made to accumulate material along these lines.

The PWTWS program has been altered to use a circular search area with $\alpha = \frac{1}{16}$, $a = \frac{5}{16}$. Radii of 2 and 3 miles are now being used; however, we have not yet had enough operational experience to permit a decision as to the wisdom of this choice.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(D. R. Israel) (continued)

At the beginning of this bi-weekly period some previously undiscovered difficulties were found in the two-a/c interception programs. The difficulties in Attridge's program (iteration by time) were minor and have been corrected; Walquist's program (iteration by angle) has a difficulty which seems to be inherent to the process. Changes in the latter program have been made and tentative tests seem to indicate that the program will operate reliably. There has not been sufficient computer time available for further testing.

Members of the group working on programs for the Bedford experiment have begun to consider programs utilizing the revised form of data transmission from Bedford in which all azimuths are sent. This revised transmission does not affect any of the present programs, but will permit economies in new programs or revisions. Along the same lines, consideration is being given to the use of a signal from Bedford indicating a beacon response from a friendly aircraft.

As noted in the previous bi-weekly, experimental work on selection of parameters for non-linear smoothing has been temporarily suspended while certain analytical work has been undertaken. A particularly important result of this study has been an understanding of the linear smoothing problem with respect to the impulse and step input response of the equations. This has led to a clearer concept of how correlation techniques might be put to use.

(J. Arnow)

A program for determination of the amount of data sent by the DRR has been written. It is expected that this program will be in final form during the next week.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(W. S. Attridge, Jr.)

I have worked with D. Israel to produce a synthetic interception program which tracks an actual target from the radar, calculates a collision (or pursuit) course for an imaginary interceptor, and displays the actual interception. We have run this program successfully.

We have also written a program for two aircraft interception which displays the time to the collision.

I have been writing a synthetic combat program which will artificially create a target plane which will try to elude an artificial interceptor. This program has possibilities as an aid to combat tactical problems. (see section 4.0).

(O. N. Becker)

I studied the problem of developing a program which will take information from a single radar set, limit the amount of data considered to that which is most likely to be useful, and locate and display only moving targets within the limits. To accomplish this a range gate will be used, and information passing the gate will be checked for consistent motion.

Produced a flow diagram which will accomplish the above; at present engaged in process of further breaking down and implementing functions outlined on the flow diagram.

(F. E. Heart)

In conjunction with C. Gaudette, wrote a program, now ready for test, which punches simulated radar data in (r, θ) on Flexowriter tape, and prints (r, θ), ϕ (heading), V (velocity) on the typewriter. These tapes will then be used as input data for smoothing programs; the output of the smoothing programs will be a smoothed ϕ and V, which can then be compared with the original typed ϕ and V.

Began the study of various criteria for smoothing methods. As a first attempt, a program is being written which will operate on the standard a, α smoothing program so as to find the values of a and α which best satisfy certain criteria; those a's and α's which give velocity and position curves having the smallest summation of error magnitude, and those a's and α's which give velocity and position curves having the smallest summation of squared error.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(F. E. Heart) (continued)

Began preparation of a program for smoothing in (r, θ) coordinates. This method of smoothing will be tried first on simulated data.

(D. A. Kemper)

The trigonometric check program is finally in usable form and a memo will be issued describing its use in the near future.

A successful program has been written which will track any aircraft that flies through a specified area. This area can be moved anywhere desired and its size varied. This program also ceases tracking the aircraft after missing it for n consecutive sweeps, where n can be varied from 0 to 7. It then returns to pick up the next aircraft that flies into the trigger area. This is intended as an exploratory step in the direction of automatic initiation. Some refinements could be made in the program, and they will probably be incorporated in the next version.

A program has been written to track two aircraft, one of which is carrying a transponder beacon. Since the velocity and position of the beacon aircraft are smoothed, no reduction in storage registers is realized; however, some reliability is gained and some time is saved. If the beacon aircraft were not smoothed, a very short tracking program could be written.

A possible future project would combine the above two programs into a two-aircraft tracking program, one aircraft of which is carrying a beacon and the other is picked up automatically.

(J. Rossbach)

I have been trying to derive recursion formulas for smoothed velocity and smoothed position in terms of the observed positions. I found that the n^{th} smoothed velocity could be expressed as follows:

$$V_n = \alpha X'_n + \alpha\beta X'_{n-1} + \cdots + X'_{n-i}\left(\beta A_{n-i+1} - \alpha \sum_{j=n}^{n-i+2} A_j\right)$$

$$+ \cdots + X'_0\left(-\sum_{j=1}^{n} A_j\right)$$

where A_i = coefficient of X'_i, $\beta = (1 - \alpha)$, and X'_i = i^{th} observed position.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(J. Rossbach) (continued)

This formula is not satisfactory, however, since the smoothed velocity cannot be expressed in closed form. The 1st 7 smoothed positions were even more complicated than the smoothed velocities and no general formula could be obtained from them.

I also solved the difference equation used by R. Walquist in the last bi-weekly:

$$V_{n+2} + AV_{n+1} + BV_n = \alpha D_{n+2}$$

where $A = (-2 + a + \alpha)$, $\beta = 1 - a$ and $D_n = \frac{X'_n - X'_{n-1}}{T}$

Assuming a homogeneous solution of the form $V_k^H = \beta^k$ and substituting into the above equation, two values for β are obtained:

$$u = \frac{2 - a - \alpha + \sqrt{(a+\alpha)^2 - 4\alpha}}{2} \quad \text{and}$$

$$v = \frac{2 - a - \alpha - \sqrt{(a+\alpha)^2 - 4\alpha}}{2}$$

therefore $V_k^H = c_1 u^K + c_2 v^K$, c_1 and c_2 are arbitrary constants. The method of variation of parameters yielded the particular solution. Assuming that

$$V_k^P = c_k' u^k + c_k^2 v^k, \quad c_k^1, c_k^2$$

are variables, the following two conditions on c_k^1 and c_k^2 result.

$$u^{k+1} \Delta c_k^1 + v^{k+1} \Delta c_k^2 = 0$$

$$u^{k+2} \Delta c_k^1 + v^{k+2} \Delta c_k^2 = \alpha D_{k+2}$$

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(J. Rossbach) (continued)

Solving these for ΔC_k^1 and ΔC_k^2 and then summing,

$$C_k^1 = \sum_{n=1}^{k} \frac{\alpha D_n}{u^{n-1}\sqrt{(a+\alpha)^2 - 4\alpha}}$$

$$C_k^2 = \sum_{n=1}^{k} \frac{-\alpha D_n}{v^{n-1}\sqrt{(a+\alpha)^2 - 4\alpha}}$$

Therefore

$$V_k^P = u^k \sum_{n=1}^{k} \frac{\alpha D_n}{u^{n-1}\sqrt{(a+\alpha)^2 - 4\alpha}} + v^k \sum_{n=1}^{k} \frac{-\alpha D_n}{v^{n-1}\sqrt{(a+\alpha)^2 - 4\alpha}}$$

Then $V_k = V_k^H + V_k^P$. However, substituting $k = 0$, and $k = 1$, and remembering that $V_0 = 0$ and that $V_1 = \alpha(X_1^1 - X_0^1) = \alpha D$ we find that V_k^H drops out, leaving $V_k = V_k^P$. Thus

$$V_k = \sum_{n=1}^{k} \left(\frac{\alpha u^k}{u^{n-1}\sqrt{(a+\alpha)^2 - 4\alpha}} - \frac{\alpha v^k}{v^{n-1}\sqrt{(a+\alpha)^2 - 4\alpha}} \right) D_n$$

(It is possible that these coefficients can be simplified further.)

4. THEORETICAL ANALYSIS

4.1 General Studies

(D. R. Israel)

Consideration is being given to a series of programs in which the computer would simulate fighter-bomber duels. In an elementary version the computer would direct a simulated interceptor, while a human operator would have control of the path of a simulated bomber. More sophisticated programs would possibly use several interceptors, each on a different type of interception course. It also appears that the computer might control the bomber, the human the interceptor.

A program is now being written by Attridge, and general consideration is being given to the problem. The two major points of interest are:

a. the degree of simulation of the dynamics of the aircraft,

b. the objective of the interceptor--area defense, point defense.

It appears that the joy-stick will be used in effecting control of the bomber.

4. THEORETICAL ANALYSIS (continued)

4.2 Data Smoothing and Aircraft Control

(C. Gaudette)

In conjunction with Frank Heart a program which will compute simulated data and store this data on Flexowriter tape has been written. The Flexowriter tape will be a source of data for use with smoothing programs.

An attempt at operating the "One Coordinate Prediction Testing Program," which was described in the previous bi-weekly, was made on March 22 with unsatisfactory results. A program error was discovered in the cosine subroutine. The error was corrected and a few minor modifications were introduced.

Work has started on a "Locus Display Program." This program will plot the transfer functions.

$$u_o + u_1 e^{-sT} + u_2 e^{-2sT}$$

and

$$u_o + v_1 e^{-sT} + v_2 e^{-2sT} + v_3 e^{-3sT}$$

or their ratios for $s = j\omega$, with ωT varying from 0 to π.

A memorandum describing the common terminology used in aerial navigation has been written.

5. COMPUTER OPERATIONS GROUP

(J. A. Arnow)

During the last week of this bi-weekly period, a number of programs were set aside to be used for demonstrations for visitors. These programs include the following:

1) Printing while tracking while scanning.
2) Automatic Initiation
3) Five aircraft tracking.
4) Synthetic Interception.

A high degree of operating efficiency was attained between the group in room 224 and the group in the console room in the running of these programs.

6. RECORD OF COMPUTER UTILIZATION

(J. A. Arnow)

3-19-51

1600 - 1700 A modified version of the 5 a/c tracking program was run and proved to be satisfactory.

1700 - 1800 A 2 a/c interception program was run with somewhat dubious results.

3-20-51 The program for 10 a/c tracking gave unsatisfactory results.

3-21-51

1300 - 1500 The PWTWS program was used in order to test the effectiveness of a circular search area with smaller size.

1500 - 1600 A 2 a/c interception was run again in order to determine the cause for errors previously noted.

3-22-51

1300 - 1400 A one co-ordinate prediction testing program contained a programming error.

1400 - 1600 A program to test the accuracy of trigonometric functions did not work.

3-23-51

1300 - 1500 A program for synthetic interception contained a few minor programming errors, but gave very satisfactory results.

1500 - 1600 A program for automatic initiation worked with reasonable results.

6. RECORD OF COMPUTER UTILIZATION (continued)

(J. A. Arnow) (continued)

3-26-51

1700 - 2000 Preparations were made for demonstrations to a group of visitors.

3-27-51

1000 - 1600 A number of programs were used for demonstration purposes , all gave excellent results.

1800 - 2000 A number of photographs were taken of the error incurred in various subroutines for determination of trigonometric functions.

3-28-51

1500 - 1900 To different 2 a/c interception programs were used, but one of them contained a few programming errors.

3-29-51

1400 - 1700 Excellent results were incurred in a series of demonstrations for a group of visitors.

3-30-51

1400 - 1700 Another group of visitors saw a few display programs.