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SUBJECT: BI-WEEKLY REPORT, PROJECT 6673, January 19, 1951

1. ANALYSIS

(W. G. Welchman)

Memorandum M-2082, dated January 10, 1951, contains a set of assumptions for use in programming studies aimed at estimating the potential value of magnetic drum storage and associated control equipment. The assumptions involve a good many functions of the control equipment, and the implied complexity of this equipment has not been studied. The purpose of the present phase of study is to consider what functions might be useful and to evaluate their potential usefulness before giving serious consideration to feasibility and cost.

Immediate plans for preparatory work in connection with the Bedford experiments were discussed with N. Fahnestock, S. H. Dodd, C. R. Wieser, and D. R. Israel. It was agreed that this group should meet frequently to review progress. Techniques for storage regeneration are to be tried out and an attempt will be made to incorporate such techniques both in the programs intended for use in the Bedford experiments and also in the procedure for reading in programs.

Course 6.535 is over. Complete sets of notes issued in connection with the course are now in the library. The general standard, as shown by quiz marks and by the number of students who asked good questions in class, was higher than last year or the year before. Four members of the course will join Project 6673 in the near future, two of these on a part-time basis.

In addition to these four new recruits, Edward Arthurs has already joined the project and is at present acquiring familiarity with coding procedures. Plans for an expanded program of work are in course of preparation.

(J. M. Salzer)

Finished E-2018 which is a collection of subroutines useful in coordinate conversion. Some of these subroutines are already incorporated in the various tracking and interception programs designed for the near-future use in demonstrations with the computer. Several members of this project have contributed to these subroutines.

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1. ANALYSIS (continued)

(J. M. Salzer) (continued)

It is expected that some of the subroutines will be of general applicability and might contribute to a permanent library of subroutines. Nevertheless, they were designed with the particular application in mind. Most are of moderate precision because of the relatively large quantizing errors in the range and azimuth readings, and their time duration was generally not minimized because of the rather low rate of radar input. Major effort was concentrated on reducing the storage required by the subroutines.

(D. R. Israel)

In an effort to provide for the careful taking of data and maintaining of records, two forms, "Summary of Computer Operations" and "Record of Computer Operations" (SL-148 and SL-147 respectively), have been prepared. A procedure has been initiated whereby data will be taken on those forms during the period when WWI is used by the 6673 group. In particular, data concerning the operation of the computer, especially storage, and associated input-output equipment will be taken. A brief summary of the results expected and the actual results obtained will also be made. Three typewritten versions of each of the two forms will be made as soon as possible after the computer operation -- one copy to be given to Hal Mercer for use in transcribing pertinent data to the WWI log, one copy to be given to Steve Dodd, and one copy to be retained by the 6673 group as an aid in writing a new section of the Bi-weekly Report which will summarize the results of the 6673 computer operation during the preceeding Bi-weekly period.

A rather complete study has been made of the possiblity of using (r, θ) coordinates in our tracking and interception programs. To a great extent this study was prompted by the anticipation of receiving the digital PPI built by ACRL. Discussions with R. Wieser led to the conclusion that this PPI cannot be conveniently used in conjunction with the light gun, nor could we use it to display data other than that being received over the telephone lines. These facts seem to mean that we must convert the (r, θ) coordinates to (x, y) coordinates if for no other reason than to get a PPI display.

As far as the programming is concerned, velocity tracking -- in which we accumulate components of the aircraft's velocity -- can be done as easily in (r, θ) coordinates. By staying in (r, θ) coordinates and accumulating radial and tangental velocity components, we are maintaining the "natural" coordinates of the radar and the quantizing equipment. Conversion to (x, y) coordinates mixes the quantizations. It appears that the (r, θ) velocities might be slightly poorer than the (x,y) components inasmuch as the velocities are constant in the (x, y) or "natural" coordinates of the aircraft.

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1. ANALYSIS (continued)

(D. R. Israel) (continued)

The computation of the collision course in (r, θ) coordinates will require only a few extra orders over the (x, y) computation. Hence, in effect, it appears that the only major advantage to be gained in remaining in (r, θ) coordinates will be the saving of thirty orders necessary for (r, θ) to (x, y) conversion. As indicated above this saving cannot be made now because of the lack of suitable (r, θ) display equipment.

A start has been made on writing a program for automatic initiation of tracking. At the beginning a reasonable set of assumptions had to be chosen. It was decided that the computer should initiate tracking on any aircraft outside of, say, sixty miles which has a negative $\frac{dr}{dt}$. Actually the program must investigate all targets outside of the sixty mile circle, and then must have a means of discarding all aircraft with a positive $\frac{dr}{dt}$. In effect, the computer must remember all targets which it is not tracking, or which the computer has been told not to track, so that these targets will not effectively keep coming up as new targets. In order to properly remember these targets, the computer must track them.

Two forms of tracking can be used for this identification -- velocity tracking which accumulates velocity components, and box tracking which does not accumulate velocities. The box tracking is far more economical of orders and hence will be used for the identification purposes.

A preliminary version of the flow diagram (for automatic initiation) has been prepared, and after further study the actual programming can begin.

With the recent completion by Salzer of a new method for determining an arcsine, two general methods are now available for computing the collision course. The "successive approximation" method was tested on the computer recently with favorable results. This program however requires a rather large number of operations, and it has been decided to "time-share" the solution with the other subprograms of the overall interception program.

The interception program has been written up, and considerable effort has been put into the shortening of it by Arnow and myself. At present the program will fit into 256 registers, however if a "storage rejuvenation" program is also to be time-shared more storage will be required. Efforts at decreasing the program length will continue, inasmuch as the initial tests of the tracking program which will begin next week may reveal the need for changes in the program and the need for extra orders. As regards the interception

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1. ANALYSIS (continued)

(D. R. Israel) (continued)

program it should be noted that it is not "rigged", there being but two major assumptions:

a. in the computation of the collision course it is assumed that the target is flying a straight path

b. although the program accumulates the x and y velocity components of the interceptor there is no square root program by which we can obtain the magnitude of the velocity, this being needed in the collision computation. Hence it is assumed that we shall be supplied with the speed of the interceptor.

(R. L. Walquist)

Almost all of the past bi-weekly period, other than the time utilized in computer operation, has been spent in completing a program for the collision course bearing angle calculation. Due to the lack of sufficient ES storage capacity, the main attempt has been to decrease the number of orders required at the expense of an increased calculation time. Timing difficulties have been circumvented by calculating the collision course only when zero ranges are received from the radar set. The calculation is accomplished by an iterative procedure which might involve up to 512 iterations, one iteration occurring each time a zero range is received. The interceptor bearing angle (including a 15° correction for magnetic north) is displayed whenever the iterative procedure yields a solution.

The collision course calculation has been kept completely asynchronous with the tracking program so that any number of revolutions, or fraction thereof, of the radar antenna may occur before the interceptor bearing angle is displayed. However, the bearing angle is continually recalculated and corrected as the target and interceptor positions change, this correction occurring at least once for every 512 zero ranges received. The calculation of the bearing angle may be started or stopped at any time while tracking by merely changing the sign digit of a flip-flop storage register.

Details of the program are as follows:

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1. ANALYSIS (continued)

(R. L. Walquist) (continued)

Orders----------71
Variable Storage------- 7
Constants Storage------ 6
Temporary Storage------ 2

Accuracy . . . $\pm 1^{o}$

A sine-cosine subprogram is also used, but this is considered as being part of the main display program.

Note that the accuracy given for the collision course bearing angle is not the overall accuracy, but merely the accuracy of the iterative program mentioned above. The accuracy of the target and interceptor velocities and positions have not been considered.

(J. A. Arnow)

Most of the last Bi-weekly period was spent in studying Radar Tracking Programs II and IV of D. R. Israel with the aim to minimize the number of orders required in these. A considerable amount of time was spent in operating the computer. During one period of operation, a round-off error in the method used to convert from binary to decimal integers was found. This error would put certain small (r, θ) coordinates printed previously in error by one unit.

(C. H. Gaudette)

The use of (r, θ) coordinates in tracking is still under investigation. Assuming an aircraft is flying at a constant speed and course, the derivatives $\frac{dx}{dt} = V_x$ and $\frac{dy}{dt} = V_y$ are constant. The derivatives $\frac{dr}{dt}$ and $\frac{d\theta}{dt}$ are not constant, but the higher derivatives can be expressed in terms of the first derivatives. That is

$$\frac{dr}{dt} = V_x \cos\theta + V_y \sin\theta$$

$$r\frac{d\theta}{dt} = V_y \cos\theta - V_x \sin\theta$$

and $$\frac{d^2r}{dt^2} = r\left(\frac{d\theta}{dt}\right)^2$$

$$r\frac{d^2\theta}{dt^2} = -2\frac{dr}{dt}\frac{d\theta}{dt}$$

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1. ANALYSIS (continued)

(C. H. Gaudette) (continued)

We can express θ and r as

$$\theta(t) = \theta_0 + \sum_{n=1}^{m} \left.\frac{d^n\theta}{dt^n}\right|_{\substack{\theta=\theta_0 \\ r=r_0}} \frac{t^n}{n!}$$

$$r(t) = r_0 + \sum_{n=1}^{m} \left.\frac{d^n r}{dt^r}\right|_{\substack{\theta=\theta_0 \\ r=r_0}} \frac{t^n}{n!}$$

Both series converge slowly. Two cases were tried, and the value of θ obtained in each case was within a half of a degree by using the equation

$$\theta(t) = \theta_0 + \sum_{n=1}^{2} \left.\frac{d^n\theta}{dt^n}\right|_{\substack{\theta=\theta_0 \\ r=r_0}} \frac{t^n}{n!} + \frac{1}{2}\left.\frac{d^3\theta}{dt^3}\right|_{\substack{\theta=\theta_0 \\ r=r_0}} \frac{t^3}{3!} \qquad t = 8 \text{ minutes}$$

The values of r obtained were within half a mile by using

$$r(t) = r_0 + \sum_{n=1}^{3} \left.\frac{d^n r}{dt^n}\right|_{\substack{r=r_0 \\ \theta=\theta_0}} \frac{t^n}{n!} + \frac{1}{2}\left.\frac{d^4 r}{dt^4}\right|_{\substack{r=r_0 \\ \theta=\theta_0}} \frac{t^4}{4!} \qquad t = 8 \text{ minutes}$$

The results are within the limits of quantization, but the accuracy of the results is dependent on the accuracy in estimating $\frac{dr}{dt}$ and $\frac{d\theta}{dt}$.

During the past two weeks much valuable experience has been gained in the technique of operating the computer. Several afternoons have been spent in the computer room watching the operation of 6673 programs. The program for finding the optimum value of the parameter in the arctangent approximation was demonstrated to Mr. Welchman's class on January 11.

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1. ANALYSIS (continued)

(H. Saxenian)

The smoothing equations of velocity and distance being used for tracking in rectangular coordinates have been investigated in order to see how the correction functions a and α appear in the analytical expressions for smoothed velocity and predicted position after n observations of position. The calculations were carried out as far as x_3 and $\dot{x}_3$. These expressions are quite lengthy, but do clearly show the general form of the power series expansion which results. These expressions may be helpful, along with T18 for determining values of a and α. These expressions do not show the effect of quantization of input data, which can best be done experimentally on the computer.

The program for plotting a circle of constant radius and printing r, θ, x, and y in order to check the accuracy of the sine, cosine polynomial being used in 6673 programs, has been converted to 4-6-6 form. An error in one of the constants used for generating the circle was discovered, and later corrected. The program is ready to be tried again.

The rate of data input and printing time check program is ready to be tried with actual radar data.

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1.1 COMPUTER OPERATIONS

(D. R. Israel)

1-10-51
14 25 - 16 30 A program displaying the errors in certain approximations to the function $\tan^{-1} x$ was tested in preparation for a demonstration to members of the 6.535 class. Sporadic operation of ES hampered and delayed the testing of the program.

16 30 - 17 00 An attempt was made to test a program which calculates and displays the angle between two specified points. The program did not operate successfully, and there was insufficient time to determine the nature of the difficulty.

1-11-51
15 10 - 19 00 A program to follow one aircraft and print the (r, θ) and (x, y) coordinates was used. Continuous difficulties with ES prevented proper operation and no data was taken.

1-15-51
16 20 - 17 40 Three tapes were converted from sexadecimal to the 6-6-4 inverted mode.

17 40 - 18 30 A program to measure the accuracy of the sine-cosine calculations used in (r, θ) to (x, y) conversion was operated. The results were unsatisfactory due to at least one programming error which could not be corrected at that time.

18 35 - 19 00 The program to test the computation of the arctangent (see 1-10-51) was again tested. Following the correction of two errors -- one due to tape preparation, the other due to programming -- satisfactory operation ensued.

1-17-51
15 15 - 16 08 The program to follow an aircraft and print the (r, θ) and (x, y) coordinates was again tested. Unsatisfactory ES operation prevented the taking of data.

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1.1 (continued)

COMPUTER OPERATIONS

(D. R. Israel)

1-17-51 (continued)

16 10 - 18 30 A program to test the collision course calculation formulae was operated. Data was taken and constants were chosen for optimum operation of the program. Initial difficulties with ES delayed the proceedings.

18 30 - 19 00 A program to test the equations used for the smoothing of the velocities of a tracked aircraft was operated. ES difficulties prevented satisfactory operation.

1-18-51

15 15 - 18 30 The program for testing the smoothing of velocities was operated again. ES difficulties prevented continuous operation, but sufficient data was taken to permit a choice of optimum coefficients for the formulae.

18 30 - 19 00 ES difficulties prevented the satisfactory conversion of tape 60 from sexadecimal to 6-6-4 inverted mode.

1-19-51

16 30 - 16 50 Tape 60 converted to 6-6-4 inverted mode.

17 00 - 19 05 A program for measuring the rate of input of information to WWI from the phone line or the Magnecorder was operated. Following a good deal of initial difficulties with ES, satisfactory operation was achieved and data was taken.

19 10 - 20 35 The program to test the accuracy of the sine-cosine conversion(see 1-10-51 and 1-15-51) was again tested. The program operated satisfactorily. Certain difficulties which seemed to arise in the conversion were checked order by order. A good deal of data was printed out by means of the Flexowriter equipment

20 30 - 23 35 Radar Tracking Program II (1 a/c, velocity tracking) was tested with internally-generated data. A good deal of difficulty with ES was encountered, however the omission of several orders was discovered and some observations concerning operation of the program were made. These indicated the need for a preparation of a new and revised tape.

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1.1 (continued)

COMPUTER OPERATIONS

(D. R. Israel)

1-22-51
17 05 - 18 55 An effort was made at operating a revised version of RTP II. Due to ES difficulties the program at no time operated successfully.

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2. ENGINEERING

(C. R. Wieser)

When the relay link from Bedford was returned to operation after the holidays, considerable trouble with bad tubes was experienced. The equipment has been repaired and operated with both radars.

On January 19 a test flight was arranged using a C-45 as the target. The new radar was connected to the relay link and the data fed to both WWI and the tape recorder. Operation was poor, and the aircraft position was not coded except over a very small portion of the flight. The trouble is believed to be in the radar set.

Further flight tests are scheduled for next week. We are in the process of making arrangements with AFCRL and the MIT Instrumentation Laboratory to facilitate the assignment of aircraft and pilots to flights for WWI. A definite procedure for arranging flights will be even more important for experiments in interception.

Two indicator-light panels have been installed in Room 224, and one has been connected to FPSR3 of WWI as requested by Israel.

The digital PPI scope has been completed and is being tested at AFCRL. Delivery is promised for January 22. The necessary wiring from Room 138 to Room 224 is being held up until the wireways arrive. In the meantime, the scope will be operated in Room 138.

(D. A. Buck)

Difficulties in special display were traced to faulty operation of the sign-digit multivibrator in the vertical decoder. Intensification gate length is now 80 μsec.

Satisfactory test operation of the modulation and demodulation equipment for recording instructions and voice conversations has been achieved. A balanced demodulator has been completed, and at present, the suppressor-grid modulated amplifier is being converted to a balanced modulator so as to cancel out some of the voice components which are in the same frequency range as the lower sideband of the modulated waveform.

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2. ENGINEERING (continued)

(H. J. Kirshner)

1. Construction of the second light gun is near completion. This unit and its associated amplifier should be ready for use within the next bi-weekly period.

2. Components for a device to enable sector recording of radar data have been selected and will be procured soon.

(R. L. Best)

A master's thesis has been written on the subject: "A Direct-Coupled Amplifier for Magnetically Deflecting an Oscillograph Tube". and handed in.

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