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6673
Memorandum M-2074

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

SUBJECT: BI-WEEKLY, PROJECT 6673, OCTOBER 27, 1950

1. ANALYSIS

(W. G. Welchman)

C. H. Gaudette has joined the Analysis Group of Project 6673.

The 6673 meeting on Monday, October 16th was largely concerned with alternative methods of handling guidance and interception and with the approximations that are required. Further discussion with Professor Franklin showed that his formula for arc tan will give accuracy to a fifth of a degree. It was also realized that, when a small difference between angles is being computed from the tangents of the angles, the simpler formula might give good results. Consideration of methods of approximating to a lead angle for a collision course led to several alternative ideas that seem worth study. A manuscript chart was drawn up to coordinate further investigation.

The meeting on Monday October 23rd was mainly concerned with tracking programs and with the shortage of computer time that has been encountered. This shortage of time is largely the result of doing all the computations when contact is made with each aircraft instead of spreading the work evenly. After the meeting some simple calculations were made to examine the effect of the number of false signals per revolution, the frequency of double recordings and the width of the search sector on the maximum number of aircraft that the computer can track.

In connection with Course 6.535 the examination of the error curve for Professor Franklin's arc tan formula has been used as the basis of a homework problem. As part of their training for work in Project 6673 Saxenian and Gaudette will prepare a program that will display the error curve and the maximum error for different values of the adjustable constant that occurs in the formula. This program will illustrate a number of coding techniques and will provide a good demonstration when the students of Course 6.535 visit the computer.

(J. M. Salzer)

I have started to collect a set of subroutines basic in (r, θ) and (x, y) conversions and exerted an effort to make these programs as efficient as can be. Although the major tendency is to reduce the storage requirements keeping the necessary precision, some attention is also given to the minimization of time duration

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1. ANALYSIS (continued)

(J. M. Salzer) (continued)

of the routines. Saxenian and Gaudette helped in working out the details for optimizing numerical formulas and coded programs. When the minimal set of subroutines reach some form of finality, they will be issued in a note. For the time being it will be helpful to summarize the status quo. In the table below the ta and sp orders that refer the program out of the subroutine are charged against the subroutine; the storage tally includes everything (i.e. temporary registers and universal constants also); the duration is computed as the average number of orders performed in sequence.

Subroutine for	Originator	Precision (Max.Error)	Storage Requirement			Duration (in orders)
			Orders	Other	Total	
arctan	Walquist, Salzer	0.235 deg.	34	9	43	27
	Welchman	4 deg.	16	3	19	15
	Franklin	0.20 deg.	26	8	34	26
sine & cosine	Israel		36	9	45	55
	Dodd		34	9	43	34
	[illegible]	[illegible]	[illegible]5 [illegible]3)*	9	33 (+3)	40 1/4 (+3)
$\sqrt{x^2 + y^2}$	Franklin (Salzer)	0.0013	23	6	29	23
$\sqrt{a}$	Israel	variable	17	3	20	40+ (iterative)

* The coded program is designed for $-\pi \leq \theta \leq \pi$, but 3 additional orders allow the range $0 \leq \theta < 2\pi$.

Work is continuing on these and other subroutines (such as arcsin and exponential functions).

1. ANALYSIS (continued)

(D. R. Israel)

Radar Tracking Program II (RTP-II), to be used for the tracking of a single aircraft, has been completed. A flow diagram of the program is available as Drawing SC-45107; a written description of the program and actual orders are available for duplication by Ozalid.

Radar Tracking Program IV (RTP-IV) is an extension of the method of RTP-II to the two-aircraft case. This program permits specification of the target and the interceptor, initiation of tracking being governed either by the joystick or by the light gun. Provision is made in RTP-IV for the inclusion of a sub-program to compute the heading, etc, needed for a collision course. The present version of RTP-IV uses 205 ES registers. A description of the program together with the orders and a flow diagram will be available next week.

Inasmuch as a program for finding the square root will be required for the calculation of the collision course, etc, an effort has been made at obtaining a short program for that purpose. The best effort at the present seems to result from the use of Newton's formula with a cyclic iteration. Although the program will require only 15 orders, 12n operations are involved, where n is the number of iterations. For most purposes n should not exceed 4 or 5.

This square root program can be used in conjunction with a program for the sine to give the cosine ($\cos x = \sqrt{1 - \sin^2 x}$). (Note: the sine and cosine of incoming azimuths must be found for display purposes). Salzer has written a sine program requiring about 12 orders, and a sine and cosine program using about 27. It would seem that Salzer's program for the sine and cosine (which represents a saving over the previously considered program) should be utilized whenever the square root is not required, as in RTP-III. However, by using Salzer's program for only the sine and with the program for the square root, both the sine and cosine are obtained for about 32 orders, with the square root being available as a subprogram for use in other parts of the program. RTP-IV is an example of a situation where a saving of orders would result from the use of the sine and the square root. The time requirement for the square root (12 n operations, $n \sim 4$) does not appear to present any difficulties in such applications.

1. ANALYSIS (continued)

(D. R. Israel) (continued)

The matter of time requirements has revealed itself to be of some importance in the longer programs of RTP-III and RTP-IV. Although the total time required for the programs is only a very small fraction of each antenna revolution, inasmuch as the computer storage is limited the computer is required to operate whenever it has data. Because of this fact, the bunching of aircraft in a small sector of the sweep may tend to overload the computer for a short time. The situation, in fact, results only from a highly inefficient use of the computer and is a situation which might be remedied by an increased storage capacity or by the reduction of program operating time. Consideration of the present programs has revealed the greatest user of time to be the provision for selecting the best piece of data (minimum $|\Delta x| + |\Delta y|$ criterion). For this reason, plans are now being made to test RTP-II without this feature.

(R. L. Walquist)

Radar Tracking Program-III (tracking "n" targets, where "n" is greater than 2) is rapidly nearing completion. Completion of the program is at present awaiting the final version of a shorter sine-cosine program being written by J. M. Salzer. This new program should reduce the number of storage registers needed in the conversion from R-O to X-Y by around 8. Such a reduction should allow for the tracking of one additional target in Program-III.

Consideration of the timing problem (as mentioned in the last bi-weekly) has led to some significant changes in the present program. The indexing or aircraft box selection section of the program had to be completely revised. (This section of the program sets the remainder of Program-III to progressively deal with each of the aircraft being tracked). Although the previous form of indexing program required a minimum of storage registers, the total number of operations per tracked aircraft was around 75. The new form, while occupying a larger number of storage registers, reduces the number of operations to around 30 per aircraft. Further consideration indicated that if each tracked target was first checked to see if it was time to search for the best fit of incoming data before entering the indexing program, the number of tracked targets could further be increased. This process cannot be continued indefinitely, however, since the limited storage must also be considered.

The use of a light gun for initiating tracking appears to be advantageous, and the present program has been written assuming its use. While the light gun saves only 10 to 12 storage registers over the joystick method of initiating tracking, its real value for

1. ANALYSIS (continued)

(R. L. Walquist) (continued)

Radar Tracking Program-III comes from the ease with which one can selectively cease tracking. Any one of the targets being tracked may be eliminated in much the same manner in which tracking is initiated.

A simplified form of the Manual Intervention Program has been written by J. A. Arnow. This program is to fit into Test Storage along with a read-in program, thus leaving all of electrostatic storage available for Program-III. With shorter sine-cosine and manual intervention programs, the limitations on the number of targets which can be tracked are as follows: from time considerations -- 5 targets;
from storage considerations -- 8 targets.
Program-III has been written so as to provide for all 8 targets, assuming that search must be made for no more than 5 of these targets at any one time.

A flow diagram and written explanation of this program are in the process of being prepared and will be issued as a memorandum shortly.

(J. A. Arnow)

Three programs for visual display of heading instructions were written. One will display numbers from 000-359. This program takes a total of 54 registers, which would indicate that it can be used only in conjunction with very simple guidance schemes.

An alternative method is one which would display dots on three vertical lines, the number of dots on each line representing the value of the integer in the three digit number. This program requires only 24 registers, but it might prove somewhat difficult to count 8 or 9 dots. There is also the question of what to do in the case of the digit 0. (As the program now stands, no dot will be displayed). A slight modification of the former will display dots whose heights correspond to the value of the digit. This program would presuppose calibration of the oscilloscope.

Another program for simulation of radar data was written. This program requires a few more storage registers, but has an advantage in that it generates a target with approximately constant velocity.

2. ENGINEERING

(C. R. Wieser)

The Bedford radar has been modified to operate at an antenna speed of 2 rpm. This change includes modification of the video storage system to integrate 23 radar pulses and read out on the 24th. (Formerly, at 4 rpm, 11 pulses were integrated with read-out on the 12th.) The moving target indicator (MTI) is now operating, and it appears to do a good job of removing ground clutter. With the MTI operative, the range below which targets are gated out has been reduced from 40 nautical miles to about 25 nautical miles.

Several hours of radar data have been recorded. During one lunch-hour period, some of the data were examined briefly. There appears to be (1) a marked decrease in the total number of signals per antenna revolution, (2) no overloading of the relay link, and (3) several signals per antenna revolution which do not correspond to previous sweeps. The Bedford group have stated that some of these signals which appear to be random are moving targets which are reported only occasionally by the radar. This they attribute to (1) the relatively low altitude at which commercial traffic flies and (2) the poor low-altitude coverage of the radar caused by its site.

In the near future we will meet with the Bedford group during the evening and night to study the data. This will include observing the data on the Bedford PPI display and on the WWI display. This will give (1) a check on the fidelity of recording, playback, and WWI display and (2) a rough estimate of the number of radar misses on a moving target.

A visit was made to the MIT Instrumentation Laboratory facilities at Bedford. Present were Whitaker of the Instrumentation Laboratory and Staples and Nicholsen of AFCRL. The purpose of the meeting was a preliminary discussion of the nature of the aircraft guidance signals which we should furnish, and the nature of the ground-to-air communication system. Work on the autopilot has been going on for some time, and a contract for the communication system is to be let soon. We will cooperate with these groups in planning the equipment which will link the aircraft to WWI.

2. ENGINEERING (continued)

(D. A. Buck)

In conjunction with H. J. Kirshner, preliminary research on light gun design was carried out. An attempt will be made to get a pulse back into WWI in ten microseconds. If every QD or QF order refers to electrostatic storage and never to test storage, the pulse will get back into WWI during the E.S. operation and thus will not have to be synchronized with the restorer pulse generator and carry. Operation of this type will minimize time delay and equipment.

An illuminated grid was added to one of the five-inch display scopes to facilitate range and azimuth estimation in the dark room.

An investigation into Y-axis amplifier drift in the F-scope is being made.

(H. J. Kirshner)

Preliminary investigation of the photomultiplier type light-gun led to the conclusion that direct light-gun output could not be utilized with any standard WWI pulse conversion equipment. This arises from the fact that present pulse output of the light-gun is characterized by a slow rise time. It is felt that if a more sensitive type photomultiplier (e.g. 1P21) were employed, rise time characteristics would be improved. It is anticipated that the next light gun to be built will employ a type 1P21 with a cathode follower stage in the light gun itself. This will feed a blocking oscillator, which in turn will produce a sufficiently sharp pulse. This pulse will then be further shaped by standard WWI test gear so that it may be used in the computer.

Construction of this second photomultiplier type light-gun will commence next week.

A visit was paid to a section of the Cambridge Field Station at Fort Dawes, where a photomultiplier type light-gun is being used successfully. Some ideas on physical shaping of the light gun were obtained and will probably be employed here. The circuits employed by the Cambridge Field Station group in their light-gun are similar to those used in ours.

2. ENGINEERING (continued)

(H. J. Kirshner) (continued)

It was also learned that Airborne Instruments Laboratory is using a light-gun having a miniature type phototube as the light sensitive element.

A second light-gun was constructed here using a miniature phototube. Light pulses from the scope face were detected; however, their amplitude and shape were such to imply that several stages of amplification and at least one stage of pulse shaping would have to be utilized before a useful pulse output would be obtained.

Since it appears that more immediate success may be anticipated with a photomultiplier type light-gun, efforts will be devoted to its development first, and further development of the miniature phototube light-gun made later.

(R. L. Best)

Four 16 inch magnetically deflected cathode ray tubes have been ordered from Dumont, 3 with metallized screens, and one plain. The Radar Lab of the Air Force Cambridge Research Lab has built a deflection yoke for these tubes, and delivery of the yoke is expected this week. Two 20 KV power supplies have been ordered from Techtronix, into which we will build regulators. Regulation of this voltage is necessary, as a result of the random rate at which the load will be pulsed. A master's thesis proposal is being written on the subject of designing and building an amplifier to drive the deflection yoke. It is hoped to achieve a current rise time of 10 microseconds, a linearity of 5%, and a stability of 1%. Technical advisor for the thesis will be C. R. Wieser, and academic advisor will be Prof. T. S. Gray of the E.E. Dept.