LGP-30 USERS' ORGANIZATION - POOL

"SEARCH FOR ROOT"

Program No. C2-37

PROGRAM DESCRIPTION

Program Title: "Search For Root"

Author: Arthur I. Larky and Jerry Rayna

Installation: Lehigh University

Purpose:

To solve for the real roots of equations of the form

$$f(x) = 0$$

by an iteration process. (The method of false position*).

The program may be used either as a keyboard routine to print X and f (x) or as a subroutine within a program.

Input:

Two distinct initial guesses for each root must be stored in L_o + 0051 and L_o + 0052.

A constant ϵ stored in L_o + 0062 indicating the tolerance allowed in f (x).

An accelerating factor may be required (optional). (See also Procedure).

Output:

When used as a subroutine only: X_o in the accumulator at a q determined by the subroutine used to calculate f(x). (See below).

When used as a keyboard routine:

Decimal printout of X and f(x). With transfer control depressed, the above is printed for each iteration. If the control button is up, printout will occur only for those values of f(x) which are less than ϵ in absolute value.

Calling Sequence:

As a subroutine:

R L_o + 0110
U L_o } if X_1, X_2 and ϵ are to be inputed.

R L_o + 0110
U L_o + 0002 } if X_1, X_2 and ϵ are already in memory

The routine will exit with X_o in the accumulator.

* Hartree, "Numerical Analysis," Oxford University Press, Second Edition (1958) Page 214.

As a keyboard routine:

Transfer to L_o
Type in X_1, X_2, and ϵ
into $L_o + 0051$, $L_o + 0052$, and $L_o + 0062$ using the proper data input identification words.

Depress transfer control if every iteration is to be printed. Routine will continue iteration until X_o is printed twice after which an overflow stop will occur.

Subroutines Required:

1) A properly scaled subroutine capable of calculating f(x) for the X values most likely to be encountered must be in memory. The R-U calling sequence for this subroutine must be placed into $L_o + 0003 - L_o + 0004$ and $L_o + 0009 - L_o + 0010$.

2) A data input subrcutine with calling sequence in L_o and $L_o + 0001$ (optional).

3) A data output subroutine with calling sequences in $L_o + 0118 - 0120$ and $L_o + 0127 - 0129$. (optional).

4) A test quadratic $[2x^2 + 5x + 1 = f(x)]$ is included in the coding and is called by the sequence R0113, U0101 in locations 0003-4 and 0009-10. x_1, x_2, and ϵ must be entered @ q = 4 as usual.

Procedure:

1) The iteration uses the formula:

$$X_{i+1} = X_{i-1} + \frac{X_{i-1} - X_i}{[f(x_i) - f(x_{i-1})] / \phi} \cdot \frac{f(x_{i-1})}{\phi}$$

where $\phi = |f(x_i)| + |f(x_{i-1})| + 1$ at 30

and is repeated until $|f(x)| \leq \epsilon$

2) For use as a subroutine in a general program: The general program must provide X_1, X_2, and ϵ in the proper memory locations or read them from tape. The transfer control button may be depressed during program check-out to print X and f(x) for each iteration (except the final one). Routine exits with X_o in accumulator.

3) For use as a keyboard routine:

Change $L_o + 0027$ to U0028. Then X and f(x) will be printed (at q's determined by the data output calling sequence) when $|f(x)| \leq \epsilon$ or for each iteration when the transfer control is depressed.

4) An accelerating factor to aid in convergence may be included by changing $L_o + 0155$ to M0113. The accelerating factor (at q = 0) should be stored in $L_o + 0113$. (OPTIONAL).

5) Break Points 16 and 32 should be depressed.

Programmed Stops:

Two break point 32 stops and one break point 16 stop are included. The breakpoint 32 stops follow the f(x) print and the X_{i+1} calculation. Their purpose is to permit the iteration to be halted and new values for X_1, X_2, and ϵ to be read in. This is done by skipping the execution of the next program step. To do so release the Break Point 32 button. When the computer stops, perform the following steps:

a) depress One Operation button
b) depress Manual Input button (on console)
c) depress Start button
d) return to Normal Operation and Start.

The break point 16 stop enables the programmer to look at the size of the correction factor for the iteration.

Limitations:

When used as a keyboard routine, the program will over flow stop after the second printout of the root. To search for additional roots, release the Break Point 32 button, and restart and when a break point 32 stop occurs, return to data input as outlined under Programmed Stops above.

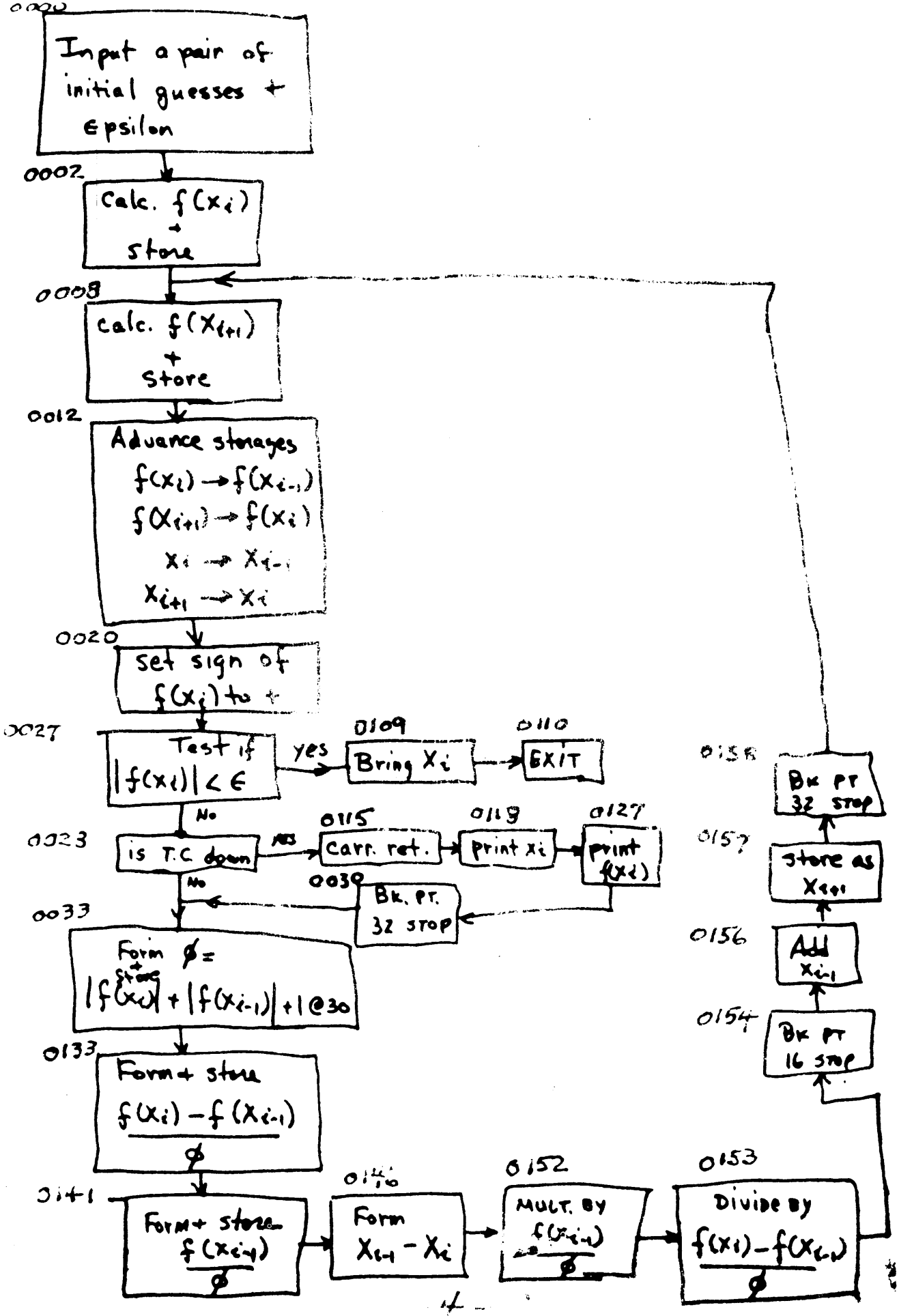
It is likely that, if the initial guesses for X_1 and X_2 are too far away from X_o, overflow stops may occur. In this case merely depress the start button as often as necessary. Regardless of the presence of an overflow, some correction to X_i will be effected and ultimately values within scale will be obtained and the search continued. The function calculation subroutine must, of course, be able to handle X values reasonably near its root without overflow. The method causes looping at a point of inflection.

Storage:

127 locations, no temporary storage.

Author: A.I. Larky & G.Rayl... "Search for Root" Program No. 02-...

Installation: Lehigh University



Root Search Example Problem

$2X^2 + 5X + 1 = f(X)$.

PDP Program No. 02-[illegible] "Search for Root"
by [illegible].I. Larky and [illegible]. Rayna
[illegible] University

1. With transfer control button up:

.0000800'

0+040851' 3' -0000003' .000000'
4+040862' 1' -0000000'

Transfer to [illegible].

The two guesses for X.
The epsilon.

X	f(X)	
-2.28079589	.000080	
-2.28077645	.000000	
-2.28077645	.000000	Final Solution.

0+040851' 0' -0000001' .000000'

New guesses for X.

X	f(X)	
-.21854294	.002807	
-.21922728	-.000014	
-.21922357	.000000	Final Solution
-.21922357	.000000	

2. With transfer control button down:
(Note effect, if any, of depression of transfer control button on other subroutines in use; in particular, the data input routine.

.0000800'

Transfer to [illegible].

0+040851' 3' -0000003' .000000'
4+040862' 1' -0000000'

The two guesses for X.
The epsilon.

X	f(X)	
2.999999	033.9999	Solution after first iteration.
-3.800000	010.8799	Solution after second iteration.
-7.000000	064.0000	.
-3.144578	005.0538	.
-2.814026	002.7673	.
-2.413957	000.5845	
-2.306810	000.1086	
-2.282337	000.0064	
-2.280795	000.0000	
-2.280776	000.0000	Final Solution
-2.280776	000.0000	

0+040851' 0' -0000001' -0000000'

New guesses for X.

0.000000	001.0000	Solution after first iteration.
-0.333333	-000.4444	
-0.230769	-000.0473	.
-0.219542	000.0028	.
-0.219227	-000.0000	.
-0.219223	000.0000	
-0.219223	000.0000	Final solution.

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JOB NO.	PROGRAM NO. C2-37	PROGRAM PREPARED BY: A.I.Larky and G. Rayna	PROGRAM CHECKED BY: POOL Review	DATE 2/4/60
PROBLEM: "SEARCH FOR ROOT"				TRACK

PROGRAM INPUT CODES	STOP	LOCATION	INSTRUCTION OPERATION	INSTRUCTION ADDRESS	STOP	CONTENTS OF ADDRESS	NOTES
3 0 0 0 L_b	/						
1 0 0 0 L_b	/	☒					
		0 0 0 0	X R	2 7 0 8	/		Data Input Routine
		0 0 0 1	X U	2 7 0 0	/		for X_1, X_2, ϵ
		0 0 1 2	B	0 0 5 2	/	Xi	
		0 0 1 3	R	0 1 1 3	/	☒	calc. f(xi)
		0 0 1 4	U	0 1 0 1	/		
		0 0 1 5	H	0 0 5 5	/	f(xi)	
		0 0 1 6	U	0 0 0 8	/		
		0 0 1 7			/	☒	
		0 0 1 8	B	0 0 5 1	/	Xi + 1	
		0 0 1 9	R	0 1 1 3	/		calc. f(xi+1)
		0 0 1 10	U	0 1 0 1	/		
		0 0 1 11	H	0 0 6 1	/	☒ f(xi+1)	
		0 0 1 12	B	0 0 5 5	/	f(xi)	
		0 0 1 13	H	0 0 5 6	/		new f(xi-1)
		0 0 1 14	U	0 0 2 3	/		
		0 0 1 15	B	0 0 5 1	/	☒ Xi+1	
		0 0 1 16	H	0 0 5 2	/		new Xi
		0 0 1 17	U	0 0 1 8	/		
		0 0 1 18	B	0 0 6 1	/	f(xi+1)	
		0 0 1 19	H	0 0 5 5	/	☒	new f(xi)
		0 0 2 10	T	0 1 4 9	/		change sign
		0 0 2 11	U	0 0 2 6	/		
		0 0 2 12			/		
		0 0 2 13	B	0 0 5 2	/	☒ Xi	
		0 0 2 14	H	0 0 5 3	/		new Xi-1
		0 0 2 15	U	0 0 1 5	/		
		0 0 2 16	S	0 0 6 2	/	ϵ	
		0 0 2 17	T	0 1 0 9	/	☒	search over
		8 0 0 0	T	0 1 1 5	/		print Xi, f(xi) on button
		0 0 2 19	U	0 0 3 3	/		
1 0 0 0 0 0 0 0		0 0 3 0			/		
		0 0 3 1			/	☒	f(xi-1) / 0

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PROBLEM: "SEARCH FOR ROOT"				TRACK

PROGRAM INPUT CODES	STOP	LOCATION	INSTRUCTION OPERATION	INSTRUCTION ADDRESS	STOP	CONTENTS OF ADDRESS	NOTES
	/						
	/	☒					
		0 0 3 2	F	0 0 0 0 0	/		5 @ 6
		3 3	B	0 0 5 5	/	f(xi)	
		3 4	T	0 1 0 6	/		compl.
		3 5	U	0 0 3 6	/	☒	
		3 6	H	0 0 5 8	/	f(xi)	
		3 7	B	0 0 5 6	/	f(xi-1)	
		3 8	T	0 0 4 0	/		compl,
		3 9	U	0 0 4 2	/	☒	
		4 0	C	0 1 0 5	/		clear accumulator
		4 1	S	0 0 5 6	/	f(xi-1)	
		4 2	A	0 1 0 0	/	1 @ 30	
		4 3	A	0 0 5 8	/	☒ f(xi)	
		4 4	H	0 1 2 3	/		∅
		4 5	U	0 1 3 3	/		
1 0 0 0 0 1 9	!	4 6			/		
		4 7			/	☒	
		4 8			/		
		4 9	8	0 0 0 0 0	/	(0106)	-1 @ 0
		5 0			/		
		5 1	[	]	/	☒	Xi+1
		5 2	[	]	/		Xi
		5 3	[	]	/		Xi-1
		5 4			/		
		5 5	[	]	/	☒	f(xi)
		5 6	[	]	/		f(xi-1)
		5 7			/		
		5 8	[	]	/		f (xi)
		5 9			/	☒	
		6 0			/		
		6 1	[	]	/		f(xi+1)
		6 2	[	]	/		∈
		6 3			/	☒	

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PROBLEM:	"SEARCH FOR ROOT"			TRACK

PROGRAM INPUT CODES	STOP	LOCATION	INSTRUCTION OPERATION	INSTRUCTION ADDRESS	STOP	CONTENTS OF ADDRESS	NOTES
	/						
	/	☒					
		01 00		2	/		1 @ 30
		10 01	H	0151	/	x @ 4	
		10 02	M	0124	/	2 @ 2	
		10 03	A	0032	/	☒ 5 @ 6	
		10 04	U	0111	/		
		10 05	[	]	/	(0040)	dump
		10 06	M	0049	/	-1 @ 0	
		10 07	U	0036	/	☒	
		10 08			/		
		10 09	B	0052	/	Xi	
		11 10	U	[0000]	/		"R" to here for search
		11 11	M	0151	/	☒ X @ 4	
		11 12	A	0162	/	1 @ 10	
		11 13	U	[0000]	/		
		11 14	80 XF	0000	/		-1 @ 0
		11 15	X	P1644	/	☒	C.R.
		11 16	B	0052	/	Xi	
		11 17	XF	0003	/		delay
		11 18	XR	3012	/		Data Output
		11 19	XU	3000	/	☒	
		12 20	XF	0001	/		print xi
		12 21	U	0126	/		
10 00 00 00 04	!	12 22			/		
		12 23	[	]	/	☒	
		12 24	40 00	0000	/		2 @ 2
		12 25	[	]	/		A+10
		12 26	B	0055	/	f(xi)	
		12 27	XR	3012	/	☒	Data Output
		12 28	XU	3000	/		
		12 29	XF	0003	/		print f(xi)
		13 30	XF	3261	/		Bk Pt 32 STOP
		13 31	U	0033	/	☒	

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PROBLEM:	"SEARCH FOR ROOT"			TRACK

PROGRAM INPUT CODES	STOP	LOCATION	INSTRUCTION OPERATION	INSTRUCTION ADDRESS	STOP	CONTENTS OF ADDRESS	NOTES
	/						
	/	☒					
		01 32	U	0000	/		read new X, ∈
		33	B	0055	/	f(xi)	
		34	S	0056	/	f(xi-1)	
		35	U	0137	/	☒	
		36			/		
		37	D	0123	/	∅	
		38	U	0139	/		
		39	H	0125	/	☒	
		40	U	0141	/		
		41	B	0056	/	f(xi-1)	
		42	U	0144	/		
		43			/	☒	
		44	D	0123	/	∅	
		45	C	0031	/		
		46	B	0053	/	Xi-1	
		47	S	0052	/	☒ Xi	
		48	U	0152	/		
		49	M	0114	/	-1@0	
		50	U	0026	/		
		51	[	]	/	☒	x @ 2
		52	M	0031	/	f(xi-1) /	∅
		53	D	0125	/		
		54	XF	1626	/		Stop Bk. Pt. 16
		55	U	0156	/	☒	
		56	A	0053	/	Xi-1	
		57	H	0051	/		
		58	XF	3230	/		Stop Bk. Pt. 32
		59	U	0009	/	☒	
		60	U	0000	/		
00000002	!	61			/		
		62	2	0000	/		1 @ 10
		63			/	☒	

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