

Letters to the Editor

Go To Statement Considered Harmful

Key Words and Phrases: go to statement, jump instruction, branch instruction, conditional clause, alternative clause, repetitive clause, program intelligibility, program sequencing

CR Categories: 4.22, 5.23, 5.24

EDITOR:

For a number of years I have been familiar with the observation that the quality of programmers is a decreasing function of the density of **go to** statements in the programs they produce. More recently I discovered why the use of the **go to** statement has such disastrous effects, and I became convinced that the **go to** statement should be abolished from all "higher level" programming languages (i.e. everything except, perhaps, plain machine code). At that time I did not attach too much importance to this discovery; I now submit my considerations for publication because in very recent discussions in which the subject turned up, I have been urged to do so.

My first remark is that, although the programmer's activity ends when he has constructed a correct program, the process taking place under control of his program is the true subject matter of his activity, for it is this process that has to accomplish the desired effect; it is this process that in its dynamic behavior has to satisfy the desired specifications. Yet, once the program has been made, the "making" of the corresponding process is delegated to the machine.

My second remark is that our intellectual powers are rather geared to master static relations and that our powers to visualize processes evolving in time are relatively poorly developed. For that reason we should do (as wise programmers aware of our limitations) our utmost to shorten the conceptual gap between the static program and the dynamic process, to make the correspondence between the program (spread out in text space) and the process (spread out in time) as trivial as possible.

Let us now consider how we can characterize the progress of a process. (You may think about this question in a very concrete manner: suppose that a process, considered as a time succession of actions, is stopped after an arbitrary action, what data do we have to fix in order that we can redo the process until the very same point?) If the program text is a pure concatenation of, say, assignment statements (for the purpose of this discussion regarded as the descriptions of single actions) it is sufficient to point in the program text to a point between two successive action descriptions. (In the absence of **go to** statements I can permit myself the syntactic ambiguity in the last three words of the previous sentence: if we parse them as "successive (action descriptions)" we mean successive in text space; if we parse as "(successive action) descriptions" we mean successive in time.) Let us call such a pointer to a suitable place in the text a "textual index."

When we include conditional clauses (if B then A), alternative clauses (if B then A_1 else A_2), choice clauses as introduced by C. A. R. Hoare (case[i] of (A_1, A_2, \dots, A_n)), or conditional expressions as introduced by J. McCarthy ($B_1 \rightarrow E_1, B_2 \rightarrow E_2, \dots, B_n \rightarrow E_n$), the fact remains that the progress of the process remains characterized by a single textual index.

As soon as we include in our language procedures we must admit that a single textual index is no longer sufficient. In the case that a textual index points to the interior of a procedure body the

dynamic progress is only characterized when we also give to which call of the procedure we refer. With the inclusion of procedures we can characterize the progress of the process via a sequence of textual indices, the length of this sequence being equal to the dynamic depth of procedure calling.

Let us now consider repetition clauses (like, **while** B **repeat** A or **repeat** A **until** B). Logically speaking, such clauses are now superfluous, because we can express repetition with the aid of recursive procedures. For reasons of realism I don't wish to exclude them: on the one hand, repetition clauses can be implemented quite comfortably with present day finite equipment; on the other hand, the reasoning pattern known as "induction" makes us well equipped to retain our intellectual grasp on the processes generated by repetition clauses. With the inclusion of the repetition clauses textual indices are no longer sufficient to describe the dynamic progress of the process. With each entry into a repetition clause, however, we can associate a so-called "dynamic index," inexorably counting the ordinal number of the corresponding current repetition. As repetition clauses (just as procedure calls) may be applied nestedly, we find that now the progress of the process can always be uniquely characterized by a (mixed) sequence of textual and/or dynamic indices.

The main point is that the values of these indices are outside programmer's control; they are generated (either by the write-up of his program or by the dynamic evolution of the process) whether he wishes or not. They provide independent coordinates in which to describe the progress of the process.

Why do we need such independent coordinates? The reason is—and this seems to be inherent to sequential processes—that we can interpret the value of a variable only with respect to the progress of the process. If we wish to count the number, n say, of people in an initially empty room, we can achieve this by increasing n by one whenever we see someone entering the room. In the in-between moment that we have observed someone entering the room but have not yet performed the subsequent increase of n , its value equals the number of people in the room minus one!

The unbridled use of the **go to** statement has an immediate consequence that it becomes terribly hard to find a meaningful set of coordinates in which to describe the process progress. Usually, people take into account as well the values of some well chosen variables, but this is out of the question because it is relative to the progress that the meaning of these values is to be understood! With the **go to** statement one can, of course, still describe the progress uniquely by a counter counting the number of actions performed since program start (viz. a kind of normalized clock). The difficulty is that such a coordinate, although unique, is utterly unhelpful. In such a coordinate system it becomes an extremely complicated affair to define all those points of progress where, say, n equals the number of persons in the room minus one!

The **go to** statement as it stands is just too primitive; it is too much an invitation to make a mess of one's program. One can regard and appreciate the clauses considered as bridling its use. I do not claim that the clauses mentioned are exhaustive in the sense that they will satisfy all needs, but whatever clauses are suggested (e.g. abortion clauses) they should satisfy the requirement that a programmer independent coordinate system can be maintained to describe the process in a helpful and manageable way.

It is hard to end this with a fair acknowledgment. Am I to

judge by whom my thinking has been influenced? It is fairly obvious that I am not uninfluenced by Peter Landin and Christopher Strachey. Finally I should like to record (as I remember it quite distinctly) how Heinz Zemanek at the pre-ALGOL meeting in early 1959 in Copenhagen quite explicitly expressed his doubts whether the **go to** statement should be treated on equal syntactic footing with the assignment statement. To a modest extent I blame myself for not having then drawn the consequences of his remark.

The remark about the undesirability of the **go to** statement is far from new. I remember having read the explicit recommendation to restrict the use of the **go to** statement to alarm exits, but I have not been able to trace it; presumably, it has been made by C. A. R. Hoare. In [1, Sec. 3.2.1.] Wirth and Hoare together make a remark in the same direction in motivating the case construction: "Like the conditional, it mirrors the dynamic structure of a program more clearly than **go to** statements and switches, and it eliminates the need for introducing a large number of labels in the program."

In [2] Guiseppe Jacopini seems to have proved the (logical) superfluosity of the **go to** statement. The exercise to translate an arbitrary flow diagram more or less mechanically into a jumpless one, however, is not to be recommended. Then the resulting flow diagram cannot be expected to be more transparent than the original one.

REFERENCES:

1. WIRTH, NIKLAUS, AND HOARE, C. A. R. A contribution to the development of ALGOL. *Comm. ACM* 9 (June 1966), 413-432.
2. BÖHM, CORRADO, AND JACOPINI, GUISEPPE. Flow diagrams, Turing machines and languages with only two formation rules. *Comm. ACM* 9 (May 1966), 366-371.

EDSGER W. DIJKSTRA
*Technological University
Eindhoven, The Netherlands*

Language Protection by Trademark Ill-advised

Key Words and Phrases: TRAC languages, procedure-oriented language, proprietary software, protection of software, trademarks, copyright protection, patent protection, standardization, licensing, Mooers doctrine

CR Categories: 2.12, 2.2, 4.0, 4.2

EDITOR:

I would like to comment on a policy published 25 August 1967 by the Rockford Research Institute Inc., for trademark control of the TRAC language "originated by Calvin N. Mooers of that corporation": "It is the belief at Rockford Research that an aggressive course of action can and should be taken to protect the integrity of its carefully designed languages." Mr. Mooers believes that "well-drawn standards are not enough to prevent irresponsible deviations in computer languages," and that therefore "Rockford Research shall insist that all software and supporting services for its TRAC languages and related services be furnished for a price by Rockford, or by sources licensed and authorized by Rockford in a contract arrangement." Mooers' policy, which applies to academic institutions as well as commercial users, includes "authorized use of the algorithm and primitives of a specific TRAC language; authorization for experimentation with the language . . ."

I think that this attempt to protect a language and its software by controlling the name is very ill-advised. One is reminded of the COMIT language, whose developers (under V. Yngve) restricted

its source-level distribution. As a result, that effort was bypassed by the people at Bell Laboratories who developed SNOBOL. This latter language and its software were inevitably superior, and were immediately available to everyone, including the right to make extensions. Later versions benefitted from "meritorious extensions" by "irrepressible young people" at universities, with the result that SNOBOL today is an important and prominent language, while COMIT enjoys relative obscurity.

Mr. Mooers will find that new TRAC-like languages will appear whose documentation, because of the trademark restriction, cannot mention TRAC. Textbook references will be similarly inhibited. It is unfortunate.

BERNARD A. GALLER
*University of Michigan
Ann Arbor, Mich. 48104*

Mr. Mooer's Reply

EDITOR:

Professor Galler's letter, commenting on our Rockford Research policy statement on software protection of 25 August 1967, opens the discussion of what may be a very significant development to our computing profession. This policy statement applies to our TRAC (TM) computer-controlling languages. The statement includes a new doctrine of software protection which may be generally applicable to a variety of different kinds of complex computer systems, computer services, languages, and software. Already it is evident that this doctrine has a number of interesting legal and commercial implications. It is accordingly appropriate that it be subject to critical discussion.

The doctrine is very simple. For specificity, I shall describe it in regard to the TRAC languages which we have developed: (1) Rockford Research has designated itself as the sole authority for the development and publication of authentic standards and specifications for our TRAC languages; and (2) we have adopted TRAC as our commercial trademark (and service mark) for use in connection with our computer-controlling languages, our publications providing standards for the languages and any other related goods or services.

The power of this doctrine derives from the unique manner in which it serves the interests of the consuming public—the people who will be using computer services. The visible and recognized TRAC trademark informs this public—the engineers, the sociology professors, the business systems people, and the nonprogrammers everywhere—that the language or computer capability identified by this trademark adheres authentically and exactly to a carefully drawn Rockford Research standard for one of our TRAC languages or some related service. This is in accord with a long commercial and legal tradition.

The evils of the present situation and the need to find a suitable remedy are well known. An adequate basis for proprietary software development and marketing is urgently needed, particularly in view of the doubtful capabilities of copyright, patent, or "trade secret" methods when applied to software. Developers of valuable systems—including languages—deserve to have some vehicle to give them a return. On the user side the nonexistence of standards in the computer systems area is a continuing nuisance. The proliferation of dialects on valuable languages (e.g. SNOBOL or FORTRAN) is sheer madness. The layman user (read "nonprogrammer") who now has access to any of several dozen computer facilities (each with incompatible systems and dialects) needs relief. It is my opinion that this new doctrine of autonomous standardization coupled with resort to commercial trademark can provide a substantial contribution to remedying a variety of our problems in this area.

Several points of Professor Galler's letter deserve specific comment. The full impact of our Rockford Research policy (and