It is a commonplace that computer programming is hard, especially when one aims at creating a program that is correct. What kind of methods should be used to reach that goal is the subject of heated debates. Our thesis is a contribution to these discussions: To understand what computer programming is, and how it should be done, we propose to study how it is actually done — that is, to induce elements of method from factual observation. Our thesis takes the form of a detailed analysis, based on a careful reconstruction, of a particular well-crafted computer program: the first ALGOL 60 system, designed and implemented at the Mathematical Center (now CWI) by E. W. Dijkstra and J. A. Zonneveld, with the assistance of S. J. Christen and M. J. H. Römgens, on an Electrologica X1 computer. It is divided into three main chapters. Chapter I presents the two elements of the problem the Mathematical Center team was facing, namely the ALGOL 60 language and the X1 computer. Chapter II discusses the principles of its solution, explains the implementation choices made by the Mathematical Center team, and compares them to other possible choices. Chapter III presents the details of the Mathematical Center ALGOL 60 system, on an ISO C version of that system, reverse engineered from its X1 assembler source. This program is about 3000 lines long, and is composed of 173 subroutines working on 57 global variables. Finally, our conclusion, in the form of 17 theses and 4 hypotheses, indicates some lessons, in particular on computer programming methods, that we believe can be drawn from the analysis of that particular computer program.

New Insights from Old Programs — The Structure of The First ALGOL 60 System

Gauthier van den Hove

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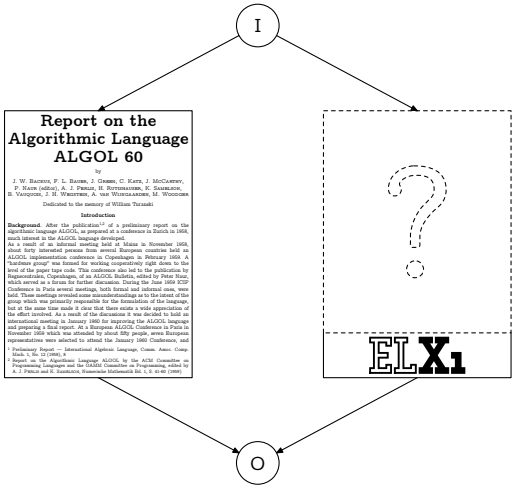
New Insights from Old Programs

The Structure of The First ALGOL 60 System

With a Foreword by Donald E. Knuth



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Algorithm index: A, 94; C_1, 53; C_2, 55; C_3, 56; C_4, 57; C_5, 65; C_6, 71; C_7, 72; C_8, 73; C_9, 79; C_{10}, 88; C_{11}, 89; C, 96; D_1, 63; D_2, 74; D_3, 76; D_4, 89; D, 97; E_1, 59; E_2, 60; E_3, 75; E_4, 75; E, 98; I, 96; J_1, 77; J, 98; R_1, 53; R_2, 55; R_3, 56; R_4, 57; R_5, 66; R_6, 71; R_7, 72; R_8, 73; R_9, 79; R_{10}, 88; R_{11}, 89; R, 97; X, 61; Y_1, 106; Y_2, 111; Y_3, 113; Y_4, 115; Y_5, 118; Y_6, 124; Y, 128.

1. ⟨ *empty* $_{24,40,77,101,103,105}$ ⟩ ::=
2. ⟨ *basic symbol* $_{(24)}$ ⟩ ::= ⟨ *letter* $_3$ ⟩ | ⟨ *digit* $_4$ ⟩ | ⟨ *logical value* $_5$ ⟩ | ⟨ *delimiter* $_6$ ⟩
3. ⟨ *letter* $_{2,16,37}$ ⟩ ::= *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *j* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* | *x* | *y* | *z*
| *A* | *B* | *C* | *D* | *E* | *F* | *G* | *H* | *I* | *J* | *K* | *L* | *M* | *N* | *O* | *P* | *Q* | *R* | *S* | *T* | *U* | *V* | *W* | *X* | *Y* | *Z*
4. ⟨ *digit* $_{2,16,17}$ ⟩ ::= *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9*
5. ⟨ *logical value* $_{2,51}$ ⟩ ::= **true** | **false**
6. ⟨ *delimiter* $_2$ ⟩ ::= ⟨ *operator* $_7$ ⟩ | ⟨ *separator* $_{12}$ ⟩ | ⟨ *bracket* $_{13}$ ⟩ | ⟨ *declarator* $_{14}$ ⟩ | ⟨ *specificator* $_{15}$ ⟩
7. ⟨ *operator* $_6$ ⟩ ::= ⟨ *arithmetic operator* $_8$ ⟩ | ⟨ *relational operator* $_9$ ⟩ | ⟨ *logical operator* $_{10}$ ⟩ | ⟨ *sequential operator* $_{11}$ ⟩
8. ⟨ *arithmetic operator* $_7$ ⟩ ::= + | − | × | / | ÷ | ↑
9. ⟨ *relational operator* $_{7,50}$ ⟩ ::= < | ≦ | = | ≧ | > | ≠
10. ⟨ *logical operator* $_7$ ⟩ ::= ≡ | ⊃ | ∨ | ∧ | ¬
11. ⟨ *sequential operator* $_7$ ⟩ ::= **go to** | **if** | **then** | **else** | **for** | **do**
12. ⟨ *separator* $_6$ ⟩ ::= , | . | 10 | : | ; | := | ␣ | **step** | **until** | **while** | **comment**
13. ⟨ *bracket* $_6$ ⟩ ::= (|) | [|] | ‘ | ’ | **begin** | **end**
14. ⟨ *declarator* $_6$ ⟩ ::= **own** | **Boolean** | **integer** | **real** | **array** | **switch** | **procedure**
15. ⟨ *specificator* $_6$ ⟩ ::= **string** | **label** | **value**
16. ⟨ *identifier* $_{16,28,32,35,58,59,99,102}$ ⟩ ::= ⟨ *letter* $_3$ ⟩ | ⟨ *identifier* $_{16}$ ⟩ ⟨ *letter* $_3$ ⟩ | ⟨ *identifier* $_{16}$ ⟩ ⟨ *digit* $_4$ ⟩
17. ⟨ *unsigned integer* $_{17,18,19,21,58}$ ⟩ ::= ⟨ *digit* $_4$ ⟩ | ⟨ *unsigned integer* $_{17}$ ⟩ ⟨ *digit* $_4$ ⟩
18. ⟨ *integer* $_{20}$ ⟩ ::= ⟨ *unsigned integer* $_{17}$ ⟩ | + ⟨ *unsigned integer* $_{17}$ ⟩ | − ⟨ *unsigned integer* $_{17}$ ⟩
19. ⟨ *decimal fraction* $_{21}$ ⟩ ::= . ⟨ *unsigned integer* $_{17}$ ⟩
20. ⟨ *exponent part* $_{22}$ ⟩ ::= 10 ⟨ *integer* $_{18}$ ⟩
21. ⟨ *decimal number* $_{22}$ ⟩ ::= ⟨ *unsigned integer* $_{17}$ ⟩ | ⟨ *decimal fraction* $_{19}$ ⟩ | ⟨ *unsigned integer* $_{17}$ ⟩ ⟨ *decimal fraction* $_{19}$ ⟩
22. ⟨ *unsigned number* $_{23,44}$ ⟩ ::= ⟨ *decimal number* $_{21}$ ⟩ | ⟨ *exponent part* $_{20}$ ⟩ | ⟨ *decimal number* $_{21}$ ⟩ ⟨ *exponent part* $_{20}$ ⟩
23. ⟨ *number* ⟩ ::= ⟨ *unsigned number* $_{22}$ ⟩ | + ⟨ *unsigned number* $_{22}$ ⟩ | − ⟨ *unsigned number* $_{22}$ ⟩
24. ⟨ *proper string* $_{25}$ ⟩ ::= ⟨ *any sequence of basic symbols not containing ‘ or ’* $_{(2)}$ ⟩ | ⟨ *empty* $_1$ ⟩
25. ⟨ *open string* $_{25,26}$ ⟩ ::= ⟨ *proper string* $_{24}$ ⟩ | ‘ ⟨ *open string* $_{25}$ ⟩ ’ | ⟨ *open string* $_{25}$ ⟩ ⟨ *open string* $_{25}$ ⟩
26. ⟨ *string* $_{36}$ ⟩ ::= ‘ ⟨ *open string* $_{25}$ ⟩ ’
27. ⟨ *expression* $_{36}$ ⟩ ::= ⟨ *arithmetic expression* $_{49}$ ⟩ | ⟨ *Boolean expression* $_{57}$ ⟩ | ⟨ *designational expression* $_{62}$ ⟩
28. ⟨ *variable identifier* $_{29}$ ⟩ ::= ⟨ *identifier* $_{16}$ ⟩
29. ⟨ *simple variable* $_{34,86}$ ⟩ ::= ⟨ *variable identifier* $_{28}$ ⟩
30. ⟨ *subscript expression* $_{31,60}$ ⟩ ::= ⟨ *arithmetic expression* $_{49}$ ⟩
31. ⟨ *subscript list* $_{31,33}$ ⟩ ::= ⟨ *subscript expression* $_{30}$ ⟩ | ⟨ *subscript list* $_{31}$ ⟩ , ⟨ *subscript expression* $_{30}$ ⟩
32. ⟨ *array identifier* $_{33,36,94}$ ⟩ ::= ⟨ *identifier* $_{16}$ ⟩
33. ⟨ *subscripted variable* $_{34}$ ⟩ ::= ⟨ *array identifier* $_{32}$ ⟩ [⟨ *subscript list* $_{31}$ ⟩]
34. ⟨ *variable* $_{44,51,73,82}$ ⟩ ::= ⟨ *simple variable* $_{29}$ ⟩ | ⟨ *subscripted variable* $_{33}$ ⟩
35. ⟨ *procedure identifier* $_{36,41,84,106}$ ⟩ ::= ⟨ *identifier* $_{16}$ ⟩
36. ⟨ *actual parameter* $_{39}$ ⟩ ::= ⟨ *string* $_{26}$ ⟩ | ⟨ *expression* $_{27}$ ⟩ | ⟨ *array identifier* $_{32}$ ⟩ | ⟨ *switch identifier* $_{59}$ ⟩
| ⟨ *procedure identifier* $_{35}$ ⟩
37. ⟨ *letter string* $_{37,38}$ ⟩ ::= ⟨ *letter* $_3$ ⟩ | ⟨ *letter string* $_{37}$ ⟩ ⟨ *letter* $_3$ ⟩
38. ⟨ *parameter delimiter* $_{39,100}$ ⟩ ::= , |) ⟨ *letter string* $_{37}$ ⟩ : (
39. ⟨ *actual parameter list* $_{39,40}$ ⟩ ::= ⟨ *actual parameter* $_{36}$ ⟩
| ⟨ *actual parameter list* $_{39}$ ⟩ ⟨ *parameter delimiter* $_{38}$ ⟩ ⟨ *actual parameter* $_{36}$ ⟩
40. ⟨ *actual parameter part* $_{41,84}$ ⟩ ::= ⟨ *empty* $_1$ ⟩ | (⟨ *actual parameter list* $_{39}$ ⟩)
41. ⟨ *function designator* $_{44,51}$ ⟩ ::= ⟨ *procedure identifier* $_{35}$ ⟩ ⟨ *actual parameter part* $_{40}$ ⟩
42. ⟨ *adding operator* $_{47}$ ⟩ ::= + | −
43. ⟨ *multiplying operator* $_{46}$ ⟩ ::= × | / | ÷
44. ⟨ *primary* $_{45}$ ⟩ ::= ⟨ *unsigned number* $_{22}$ ⟩ | ⟨ *variable* $_{34}$ ⟩ | ⟨ *function designator* $_{41}$ ⟩ | (⟨ *arithmetic expression* $_{49}$ ⟩)
45. ⟨ *factor* $_{45,46}$ ⟩ ::= ⟨ *primary* $_{44}$ ⟩ | ⟨ *factor* $_{45}$ ⟩ ↑ ⟨ *primary* $_{44}$ ⟩
46. ⟨ *term* $_{46,47}$ ⟩ ::= ⟨ *factor* $_{45}$ ⟩ | ⟨ *term* $_{46}$ ⟩ ⟨ *multiplying operator* $_{43}$ ⟩ ⟨ *factor* $_{45}$ ⟩
47. ⟨ *simple arithmetic expression* $_{47,49}$ ⟩ ::= ⟨ *term* $_{46}$ ⟩ | ⟨ *adding operator* $_{42}$ ⟩ ⟨ *term* $_{46}$ ⟩
| ⟨ *simple arithmetic expression* $_{47}$ ⟩ ⟨ *adding operator* $_{42}$ ⟩ ⟨ *term* $_{46}$ ⟩
48. ⟨ *if clause* $_{49,57,62,78}$ ⟩ ::= **if** ⟨ *Boolean expression* $_{57}$ ⟩ **then**
49. ⟨ *arithmetic expression* $_{27,30,44,49,50,75,80,90,91}$ ⟩ ::= ⟨ *simple arithmetic expression* $_{47}$ ⟩
| ⟨ *if clause* $_{48}$ ⟩ ⟨ *simple arithmetic expression* $_{47}$ ⟩ **else** ⟨ *arithmetic expression* $_{49}$ ⟩
50. ⟨ *relation* $_{51}$ ⟩ ::= ⟨ *arithmetic expression* $_{49}$ ⟩ ⟨ *relational operator* $_9$ ⟩ ⟨ *arithmetic expression* $_{49}$ ⟩
51. ⟨ *Boolean primary* $_{52}$ ⟩ ::= ⟨ *logical value* $_5$ ⟩ | ⟨ *variable* $_{34}$ ⟩ | ⟨ *function designator* $_{41}$ ⟩ | ⟨ *relation* $_{50}$ ⟩
| (⟨ *Boolean expression* $_{57}$ ⟩)
52. ⟨ *Boolean secondary* $_{53}$ ⟩ ::= ⟨ *Boolean primary* $_{51}$ ⟩ | ¬ ⟨ *Boolean primary* $_{51}$ ⟩
53. ⟨ *Boolean factor* $_{53,54}$ ⟩ ::= ⟨ *Boolean secondary* $_{52}$ ⟩ | ⟨ *Boolean factor* $_{53}$ ⟩ ∧ ⟨ *Boolean secondary* $_{52}$ ⟩
54. ⟨ *Boolean term* $_{54,55}$ ⟩ ::= ⟨ *Boolean factor* $_{53}$ ⟩ | ⟨ *Boolean term* $_{54}$ ⟩ ∨ ⟨ *Boolean factor* $_{53}$ ⟩
55. ⟨ *implication* $_{55,56}$ ⟩ ::= ⟨ *Boolean term* $_{54}$ ⟩ | ⟨ *implication* $_{55}$ ⟩ ⊃ ⟨ *Boolean term* $_{54}$ ⟩

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56. ⟨*simple Boolean*$_{56,57}$⟩ ::= ⟨*implication*$_{55}$⟩ | ⟨*simple Boolean*$_{56}$⟩ ≡ ⟨*implication*$_{55}$⟩
57. ⟨*Boolean expression*$_{27,48,51,57,75,80}$⟩ ::= ⟨*simple Boolean*$_{56}$⟩
| ⟨*if clause*$_{48}$⟩ ⟨*simple Boolean*$_{56}$⟩ **else** ⟨*Boolean expression*$_{57}$⟩
58. ⟨*label*$_{61,64,71,72,78,83}$⟩ ::= ⟨*identifier*$_{16}$⟩ | ⟨*unsigned integer*$_{17}$⟩
59. ⟨*switch identifier*$_{36,60,98}$⟩ ::= ⟨*identifier*$_{16}$⟩
60. ⟨*switch designator*$_{61}$⟩ ::= ⟨*switch identifier*$_{59}$⟩ [⟨*subscript expression*$_{30}$⟩]
61. ⟨*simple designational expression*$_{62}$⟩ ::= ⟨*label*$_{58}$⟩ | ⟨*switch designator*$_{60}$⟩ | (⟨*designational expression*$_{62}$⟩)
62. ⟨*designational expression*$_{27,61,62,76,97}$⟩ ::= ⟨*simple designational expression*$_{61}$⟩
| ⟨*if clause*$_{48}$⟩ ⟨*simple designational expression*$_{61}$⟩ | **else** ⟨*designational expression*$_{62}$⟩
63. ⟨*unlabeled basic statement*$_{64}$⟩ ::= ⟨*assignment statement*$_{75}$⟩ | ⟨*go to statement*$_{76}$⟩ | ⟨*dummy statement*$_{77}$⟩
| ⟨*procedure statement*$_{84}$⟩
64. ⟨*basic statement*$_{64,65}$⟩ ::= ⟨*unlabeled basic statement*$_{63}$⟩ | ⟨*label*$_{58}$⟩ : ⟨*basic statement*$_{64}$⟩
65. ⟨*unconditional statement*$_{66,78}$⟩ ::= ⟨*basic statement*$_{64}$⟩ | ⟨*for statement*$_{83}$⟩ | ⟨*compound statement*$_{72}$⟩
| ⟨*block*$_{71}$⟩
66. ⟨*statement*$_{67,79,83,107}$⟩ ::= ⟨*unconditional statement*$_{65}$⟩ | ⟨*conditional statement*$_{79}$⟩
67. ⟨*compound tail*$_{67,69,70}$⟩ ::= ⟨*statement*$_{66}$⟩ **end** | ⟨*statement*$_{66}$⟩ ; ⟨*compound tail*$_{67}$⟩
68. ⟨*block head*$_{68,70}$⟩ ::= **begin** ⟨*declaration*$_{85}$⟩ | ⟨*block head*$_{68}$⟩ ; ⟨*declaration*$_{85}$⟩
69. ⟨*unlabeled compound*$_{72}$⟩ ::= **begin** ⟨*compound tail*$_{67}$⟩
70. ⟨*unlabeled block*$_{71}$⟩ ::= ⟨*block head*$_{68}$⟩ ; ⟨*compound tail*$_{67}$⟩
71. ⟨*block*$_{65,71}$⟩ ::= ⟨*unlabeled block*$_{70}$⟩ | ⟨*label*$_{58}$⟩ : ⟨*block*$_{71}$⟩
72. ⟨*compound statement*$_{65,72}$⟩ ::= ⟨*unlabeled compound*$_{69}$⟩ | ⟨*label*$_{58}$⟩ : ⟨*compound statement*$_{72}$⟩
73. ⟨*left part*$_{74}$⟩ ::= ⟨*variable*$_{34}$⟩ :=
74. ⟨*left part list*$_{74,75}$⟩ ::= ⟨*left part*$_{73}$⟩ | ⟨*left part list*$_{74}$⟩ ⟨*left part*$_{73}$⟩
75. ⟨*assignment statement*$_{63}$⟩ ::= ⟨*left part list*$_{74}$⟩ ⟨*arithmetic expression*$_{49}$⟩
| ⟨*left part list*$_{74}$⟩ ⟨*Boolean expression*$_{57}$⟩
76. ⟨*go to statement*$_{63}$⟩ ::= **go to** ⟨*designational expression*$_{62}$⟩
77. ⟨*dummy statement*$_{63}$⟩ ::= ⟨*empty*$_{1}$⟩
78. ⟨*if statement*$_{78,79}$⟩ ::= ⟨*if clause*$_{48}$⟩ ⟨*unconditional statement*$_{65}$⟩ | ⟨*label*$_{58}$⟩ : ⟨*if statement*$_{78}$⟩
79. ⟨*conditional statement*$_{66}$⟩ ::= ⟨*if statement*$_{78}$⟩ | ⟨*if statement*$_{78}$⟩ **else** ⟨*statement*$_{66}$⟩
80. ⟨*for list element*$_{81}$⟩ ::= ⟨*arithmetic expression*$_{49}$⟩
| ⟨*arithmetic expression*$_{49}$⟩ **step** ⟨*arithmetic expression*$_{49}$⟩ **until** ⟨*arithmetic expression*$_{49}$⟩
| ⟨*arithmetic expression*$_{49}$⟩ **while** ⟨*Boolean expression*$_{57}$⟩
81. ⟨*for list*$_{81,82}$⟩ ::= ⟨*for list element*$_{80}$⟩ | ⟨*for list*$_{81}$⟩ , ⟨*for list element*$_{80}$⟩
82. ⟨*for clause*$_{83}$⟩ ::= **for** ⟨*variable*$_{34}$⟩ := ⟨*for list*$_{81}$⟩ **do**
83. ⟨*for statement*$_{65,83}$⟩ ::= ⟨*for clause*$_{82}$⟩ ⟨*statement*$_{66}$⟩ | ⟨*label*$_{58}$⟩ : ⟨*for statement*$_{83}$⟩
84. ⟨*procedure statement*$_{63}$⟩ ::= ⟨*procedure identifier*$_{35}$⟩ ⟨*actual parameter part*$_{40}$⟩
85. ⟨*declaration*$_{68}$⟩ ::= ⟨*type declaration*$_{89}$⟩ | ⟨*array declaration*$_{96}$⟩ | ⟨*switch declaration*$_{98}$⟩
| ⟨*procedure declaration*$_{108}$⟩
86. ⟨*type list*$_{86,89}$⟩ ::= ⟨*simple variable*$_{29}$⟩ | ⟨*simple variable*$_{29}$⟩ , ⟨*type list*$_{86}$⟩
87. ⟨*type*$_{88,104,108}$⟩ ::= **real** | **integer** | **Boolean**
88. ⟨*local or own type*$_{89,96}$⟩ ::= ⟨*type*$_{87}$⟩ | **own** ⟨*type*$_{87}$⟩
89. ⟨*type declaration*$_{85}$⟩ ::= ⟨*local or own type*$_{88}$⟩ ⟨*type list*$_{86}$⟩
90. ⟨*lower bound*$_{92}$⟩ ::= ⟨*arithmetic expression*$_{49}$⟩
91. ⟨*upper bound*$_{92}$⟩ ::= ⟨*arithmetic expression*$_{49}$⟩
92. ⟨*bound pair*$_{93}$⟩ ::= ⟨*lower bound*$_{90}$⟩ : ⟨*upper bound*$_{91}$⟩
93. ⟨*bound pair list*$_{93,94}$⟩ ::= ⟨*bound pair*$_{92}$⟩ | ⟨*bound pair list*$_{93}$⟩ , ⟨*bound pair*$_{92}$⟩
94. ⟨*array segment*$_{94,95}$⟩ ::= ⟨*array identifier*$_{32}$⟩ [⟨*bound pair list*$_{93}$⟩] | ⟨*array identifier*$_{32}$⟩ , ⟨*array segment*$_{94}$⟩
95. ⟨*array list*$_{95,96}$⟩ ::= ⟨*array segment*$_{94}$⟩ | ⟨*array list*$_{95}$⟩ , ⟨*array segment*$_{94}$⟩
96. ⟨*array declaration*$_{85}$⟩ ::= **array** ⟨*array list*$_{95}$⟩ | ⟨*local or own type*$_{88}$⟩ **array** ⟨*array list*$_{95}$⟩
97. ⟨*switch list*$_{97,98}$⟩ ::= ⟨*designational expression*$_{62}$⟩ | ⟨*switch list*$_{97}$⟩ , ⟨*designational expression*$_{62}$⟩
98. ⟨*switch declaration*$_{85}$⟩ ::= **switch** ⟨*switch identifier*$_{59}$⟩ := ⟨*switch list*$_{97}$⟩
99. ⟨*formal parameter*$_{100}$⟩ ::= ⟨*identifier*$_{16}$⟩
100. ⟨*formal parameter list*$_{100,101}$⟩ ::= ⟨*formal parameter*$_{99}$⟩
| ⟨*formal parameter list*$_{100}$⟩ ⟨*parameter delimiter*$_{38}$⟩ ⟨*formal parameter*$_{99}$⟩
101. ⟨*formal parameter part*$_{106}$⟩ ::= ⟨*empty*$_{1}$⟩ | (⟨*formal parameter list*$_{100}$⟩)
102. ⟨*identifier list*$_{102,103,105}$⟩ ::= ⟨*identifier*$_{16}$⟩ | ⟨*identifier list*$_{102}$⟩ , ⟨*identifier*$_{16}$⟩
103. ⟨*value part*$_{106}$⟩ ::= **value** ⟨*identifier list*$_{102}$⟩ ; | ⟨*empty*$_{1}$⟩
104. ⟨*specifier*$_{105}$⟩ ::= **string** | ⟨*type*$_{87}$⟩ | **array** | ⟨*type*$_{87}$⟩ **array** | **label** | **switch** | **procedure** | ⟨*type*$_{87}$⟩ **procedure**
105. ⟨*specification part*$_{105,106}$⟩ ::= ⟨*empty*$_{1}$⟩ | ⟨*specifier*$_{104}$⟩ ⟨*identifier list*$_{102}$⟩ ;
| ⟨*specification part*$_{105}$⟩ ⟨*specifier*$_{104}$⟩ ⟨*identifier list*$_{102}$⟩ ;
106. ⟨*procedure heading*$_{108}$⟩ ::= ⟨*procedure identifier*$_{35}$⟩ ⟨*formal parameter part*$_{101}$⟩ ;
⟨*value part*$_{103}$⟩ ⟨*specification part*$_{105}$⟩
107. ⟨*procedure body*$_{108}$⟩ ::= ⟨*statement*$_{66}$⟩
108. ⟨*procedure declaration*$_{85}$⟩ ::= **procedure** ⟨*procedure heading*$_{106}$⟩ ⟨*procedure body*$_{107}$⟩
| ⟨*type*$_{87}$⟩ **procedure** ⟨*procedure heading*$_{106}$⟩ ⟨*procedure body*$_{107}$⟩

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