

- 1) $\langle \text{mainFunction} \rangle \rightarrow \text{MAIN SQO SQC } \langle \text{stmt And funcDef} \rangle \text{ END}$
 $\langle \text{mainFunction} \rangle.\text{addr} = \langle \text{stmt And funcDef} \rangle.\text{addr}$
- 2) $\langle \text{stmt And funcDef} \rangle \rightarrow \langle \text{stmt Or FunctionDef} \rangle \langle \text{N1} \rangle$
 $\langle \text{stmt And funcDef} \rangle.\text{addr} = \text{new node}(\text{stmt And funcDef}, \langle \text{stmt Or funcDef} \rangle.\text{addr}, \langle \text{N1} \rangle.\text{addr})$
- 3) $\langle \text{N1} \rangle \rightarrow \langle \text{stmt And FunctionDef} \rangle.\text{addr}$
 $\langle \text{N1} \rangle.\text{addr} = \langle \text{stmt And FunctionDef} \rangle.\text{addr}$
- 4) $\langle \text{N1} \rangle \rightarrow \text{epsilon}$
 $\langle \text{N1} \rangle.\text{addr} = \text{NULL}$
- 5) $\langle \text{stmt Or funcDef} \rangle \rightarrow \langle \text{stmt} \rangle$
 $\langle \text{stmt Or funcDef} \rangle.\text{addr} = \langle \text{stmt} \rangle.\text{addr}$
- 6) $\langle \text{stmt Or funcDef} \rangle \rightarrow \langle \text{functionDef} \rangle$
 $\langle \text{stmt Or funcDef} \rangle.\text{addr} = \langle \text{functionDef} \rangle.\text{addr}$
- 7) $\langle \text{stmt} \rangle \rightarrow \langle \text{declaration stmt} \rangle$
 $\langle \text{stmt} \rangle.\text{addr} = \langle \text{declaration stmt} \rangle.\text{addr}$
- 8) $\langle \text{stmt} \rangle \rightarrow \langle \text{assignment - type1} \rangle$
 $\langle \text{stmt} \rangle.\text{addr} = \langle \text{assignment - type1} \rangle.\text{addr}$
- 9) $\langle \text{stmt} \rangle \rightarrow \langle \text{assign - type2} \rangle$
 $\langle \text{stmt} \rangle.\text{addr} = \langle \text{assign - type2} \rangle.\text{addr}$
- 10) $\langle \text{stmt} \rangle \rightarrow \langle \text{if stmt} \rangle$
 $\langle \text{stmt} \rangle.\text{addr} = \langle \text{if stmt} \rangle.\text{addr}$
- 11) $\langle \text{stmt} \rangle \rightarrow \langle \text{io stmt} \rangle$
 $\langle \text{stmt} \rangle.\text{addr} = \langle \text{io stmt} \rangle.\text{addr}$
- 12) $\langle \text{stmt} \rangle \rightarrow \langle \text{fun call stmt} \rangle \text{ SEMICOLON}$
 $\langle \text{stmt} \rangle.\text{addr} = \langle \text{fun call stmt} \rangle.\text{addr}$
- 13) $\langle \text{functionDef} \rangle \rightarrow \text{FUNCTION SQO } \langle \text{parameter - list1} \rangle \text{ SQC ASSIGN NOP}$
 $\text{FUNID SQO } \langle \text{parameter - list2} \rangle \text{ SQC } \langle \text{stmt And funcDef} \rangle$
 END SEMICOLON
 $\langle \text{functionDef} \rangle.\text{addr} \rightarrow \text{new node}(\text{functionDef}, \langle \text{par-list1} \rangle.\text{addr}, \text{FUNID}.\text{addr}, \langle \text{par-list2} \rangle.\text{addr}, \langle \text{stmt And funcDef} \rangle.\text{addr})$
- 14) $\langle \text{par-list} \rangle \rightarrow \langle \text{type} \rangle \text{ ID } \langle \text{remainingList} \rangle$

- 15) $\langle \text{type} \rangle \rightarrow \text{INT}$
 $\langle \text{type} \rangle.\text{addr} = \text{INT}.\text{addr}$
- 16) $\langle \text{type} \rangle \rightarrow \text{REAL}$
 $\langle \text{type} \rangle.\text{addr} = \text{REAL}.\text{addr}$
- 17) $\langle \text{type} \rangle \rightarrow \text{STRING}$
 $\langle \text{type} \rangle.\text{addr} = \text{STRING}.\text{addr}$
- 18) $\langle \text{type} \rangle \rightarrow \text{MATRIX}$
 $\langle \text{type} \rangle.\text{addr} = \text{MATRIX}.\text{addr}$
- 19) $\langle \text{remaining List} \rangle \rightarrow \text{COMMA} \langle \text{parameter_list} \rangle$
- 20) $\langle \text{remaining List} \rangle \rightarrow \epsilon$
 $\langle \text{remaining List} \rangle.\text{addr} = \text{NULL}$
- 21) $\langle \text{declaration stmt} \rangle \rightarrow \langle \text{type} \rangle \langle \text{varlist} \rangle \text{ SEMICOLON}$
 $\langle \text{declaration stmt} \rangle.\text{addr} = \text{new node}(\text{declstmt}, \langle \text{type} \rangle.\text{addr}, \langle \text{varlist} \rangle.\text{addr})$
- 22) $\langle \text{varlist} \rangle \rightarrow \text{ID} \langle \text{more_ids} \rangle$
 $\langle \text{varlist} \rangle.\text{addr} = \text{ID}.\text{addr}$
 $\text{ID}.\text{link} = \langle \text{more_ids} \rangle.\text{addr}$
- 23) $\langle \text{more_ids} \rangle \rightarrow \text{COMMA} \langle \text{varlist} \rangle$
 $\langle \text{more_ids} \rangle.\text{addr} = \langle \text{varlist} \rangle.\text{addr}$
- 24) $\langle \text{more_ids} \rangle \rightarrow \epsilon$
 $\langle \text{more_ids} \rangle.\text{addr} = \text{NULL}$
- 25) $\langle \text{assign_type1} \rangle \rightarrow \langle \text{lhs_single var} \rangle \text{ ASSIGNOP} \langle \text{right Handside_type1} \rangle \text{ SEMICOLON}$
 $\langle \text{assign_type1} \rangle.\text{addr} = \text{new node}(\text{assign_type1}, \langle \text{lhs_single var} \rangle.\text{addr}, \langle \text{right Handside_type1} \rangle.\text{addr})$
- 26) $\langle \text{assign_type2} \rangle \rightarrow \langle \text{lhs_list var} \rangle \text{ ASSIGNOP} \langle \text{rhs_type2} \rangle \text{ SEMICOLON}$
 $\langle \text{assign_type2} \rangle.\text{addr} = \text{new node}(\text{assign_type2}, \langle \text{lhs_list vars} \rangle.\text{addr}, \langle \text{rhs_type2} \rangle.\text{addr})$
- 27) $\langle \text{lhs_single var} \rangle \rightarrow \text{ID}$
 $\langle \text{lhs_single var} \rangle.\text{addr} = \text{ID}.\text{addr}$
- 28) $\langle \text{lhs_list var} \rangle \rightarrow \text{SQO} \langle \text{var_list} \rangle \text{ SQC}$
 $\langle \text{lhs_list var} \rangle.\text{addr} = \langle \text{varlist} \rangle.\text{addr}$

- 29) $\langle \text{rhs_type1} \rangle \rightarrow \langle \text{arithmetic Expression} \rangle$
 $\langle \text{rhs_type1} \rangle.\text{addr} = \langle \text{arithmetic Expression} \rangle.\text{addr}$
- 30) $\langle \text{rhs_type1} \rangle \rightarrow \langle \text{size Expression} \rangle$
 $\langle \text{rhs_type1} \rangle.\text{addr} = \langle \text{size Expression} \rangle.\text{addr}$
- 31) $\langle \text{rhs_type1} \rangle \rightarrow \langle \text{funCall Stmt} \rangle$
 $\langle \text{rhs_type1} \rangle.\text{addr} = \langle \text{funCall Stmt} \rangle.\text{addr}$
- 32) $\langle \text{rhs_type2} \rangle \rightarrow \langle \text{size Expression} \rangle$
 $\langle \text{rhs_type2} \rangle.\text{addr} = \langle \text{size Expression} \rangle.\text{addr}$
- 33) $\langle \text{rhs_type2} \rangle \rightarrow \langle \text{funCall Stmt} \rangle$
 $\langle \text{rhs_type2} \rangle.\text{addr} = \langle \text{funCall Stmt} \rangle.\text{addr}$
- 34) $\langle \text{size Expression} \rangle \rightarrow \text{SIZE ID}$
 $\langle \text{size Expression} \rangle.\text{addr} = \text{new node}(\text{sizeExp}, \text{SIZE.addr}, \text{ID.addr})$
- 35) $\langle \text{if Stmt} \rangle \rightarrow \text{IF OP} \langle \text{boolean Exp} \rangle \text{ CL} \langle \text{Stmt} \rangle \langle \text{otherStmts} \rangle \langle \text{N2} \rangle$
 $\langle \text{if Stmt} \rangle.\text{addr} = \text{new node}(\text{if}, \langle \text{boolean Exp} \rangle.\text{addr}, \langle \text{Stmt} \rangle.\text{addr}, \langle \text{otherStmts} \rangle.\text{addr}, \langle \text{N2} \rangle.\text{addr})$
- 36) $\langle \text{N2} \rangle \rightarrow \text{ELSE} \langle \text{Stmt} \rangle \langle \text{otherStmt} \rangle \text{ENDIF SEMICOLON}$
 $\langle \text{N2} \rangle.\text{addr} = \text{new node}(\text{N2}, \langle \text{Stmt} \rangle.\text{addr}, \langle \text{otherStmt} \rangle.\text{addr})$
- 37) $\langle \text{N2} \rangle \rightarrow \text{ENDIF SEMICOLON}$
 $\langle \text{N2} \rangle.\text{addr} = \text{NULL}$
- 38) $\langle \text{otherStmts} \rangle \rightarrow \langle \text{Stmt} \rangle \langle \text{otherStmts2} \rangle$ // I & L to distinguish
 $\langle \text{otherStmts} \rangle.\text{addr} = \langle \text{Stmt} \rangle.\text{addr}$
 $\langle \text{Stmt} \rangle.\text{link} = \langle \text{otherStmts2} \rangle.\text{addr}$
- 39) $\langle \text{otherStmts} \rangle \rightarrow \text{epsilon}$
 $\langle \text{otherStmts} \rangle.\text{addr} = \text{NULL}$
- 40) $\langle \text{io Stmt} \rangle \rightarrow \text{READ OP ID CL SEMICOLON}$
 $\langle \text{io Stmt} \rangle.\text{addr} = \text{new node}(\text{io}, \text{READ.addr}, \text{ID.addr})$
- 41) $\langle \text{io Stmt} \rangle \rightarrow \text{PRINT OP ID CL SEMICOLON}$
 $\langle \text{io Stmt} \rangle.\text{addr} = \text{new node}(\text{io}, \text{PRINT.addr}, \text{ID.addr})$
- 42) $\langle \text{funCall Stmt} \rangle \rightarrow \text{FUNID OP} \langle \text{inputParameterList} \rangle \text{ CL}$
 $\langle \text{funCall Stmt} \rangle.\text{addr} = \text{new node}(\text{funCall}, \text{FUNID.addr}, \langle \text{inputParameterList} \rangle.\text{addr})$
- 43) $\langle \text{inputParameterList} \rangle \rightarrow \langle \text{Var} \rangle \langle \text{listVar} \rangle$
 $\langle \text{inputParameterList} \rangle.\text{addr} = \langle \text{Var} \rangle.\text{addr}$
 $\langle \text{Var} \rangle.\text{link} = \langle \text{listVar} \rangle.\text{addr}$
- 44) $\langle \text{listVar} \rangle \rightarrow \text{COMMA} \langle \text{inputParameterList} \rangle$
 $\langle \text{listVar} \rangle.\text{addr} = \langle \text{inputParameterList} \rangle.\text{addr}$
- 45) $\langle \text{listVar} \rangle \rightarrow \text{epsilon}$
 $\langle \text{listVar} \rangle.\text{addr} = \text{NULL}$
- 46) $\langle \text{inputParameterList} \rangle \rightarrow \text{epsilon}$
 $\langle \text{inputParameterList} \rangle.\text{addr} = \text{NULL}$

- 47) $\langle \text{operator_lowprec} \rangle \rightarrow \text{PLUS}$
 $\langle \text{operator_lowprec} \rangle.\text{addr} = \text{PLUS}.\text{addr}$
- 48) $\langle \text{operator_lowprec} \rangle \rightarrow \text{MINUS}$
 $\langle \text{operator_lowprec} \rangle.\text{addr} = \text{MINUS}.\text{addr}$
- 49) $\langle \text{op_highprec} \rangle \rightarrow \text{MUL}$
 $\langle \text{op_highprec} \rangle.\text{addr} = \text{MUL}.\text{addr}$
- 50) $\langle \text{op_highprec} \rangle \rightarrow \text{DIV}$
 $\langle \text{op_highprec} \rangle.\text{addr} = \text{DIV}.\text{addr}$
- 51) $\langle \text{boolean Exp} \rangle \rightarrow \text{OP} \langle \text{boolean Exp} \rangle \text{CL} \langle \text{logical Op} \rangle \text{OP} \langle \text{boolean Exp} \rangle \text{CL}$
 $\langle \text{boolean Exp} \rangle.\text{addr} = \text{new node}(\text{boolean Exp}, \langle \text{logical Op} \rangle.\text{addr}, \langle \text{boolean Exp} \rangle.\text{addr})$
- 52) $\langle \text{boolean Exp} \rangle.\text{addr} = \text{new node}(\text{boolean Exp}, \langle \text{constrained Vars} \rangle.\text{addr}, \langle \text{relational Op} \rangle.\text{addr}, \langle \text{constrained Vars} \rangle.\text{addr})$
- 53) $\langle \text{constrained Vars} \rangle \rightarrow \text{ID}$
 $\langle \text{constrained Vars} \rangle.\text{addr} = \text{ID}.\text{addr}$
- 54) $\langle \text{constrained Vars} \rangle \rightarrow \text{NUM}$
 $\langle \text{constrained Vars} \rangle.\text{addr} = \text{NUM}.\text{addr}$
- 55) $\langle \text{constrained Vars} \rangle \rightarrow \text{RNUM}$
 $\langle \text{constrained Vars} \rangle.\text{addr} = \text{RNUM}.\text{addr}$
- 56) $\langle \text{var} \rangle \rightarrow \text{ID} \langle \text{NS} \rangle$
 $\langle \text{var} \rangle.\text{addr} = \text{new node}(\text{var}, \text{ID}.\text{addr}, \langle \text{NS} \rangle.\text{addr})$
- 57) $\langle \text{var} \rangle \rightarrow \text{NUM}$
 $\langle \text{var} \rangle.\text{addr} = \text{NUM}.\text{addr}$
- 58) $\langle \text{var} \rangle \rightarrow \text{RNUM}$
 $\langle \text{var} \rangle.\text{addr} = \text{RNUM}.\text{addr}$
- 59) $\langle \text{var} \rangle \rightarrow \text{STR}$
 $\langle \text{var} \rangle.\text{addr} = \text{STR}.\text{addr}$
- 60) $\langle \text{var} \rangle \rightarrow \langle \text{matrix} \rangle$
 $\langle \text{var} \rangle.\text{addr} = \langle \text{matrix} \rangle.\text{addr}$
- 61) $\langle \text{NS} \rangle \rightarrow \langle \text{matrix Element} \rangle$
 $\langle \text{NS} \rangle.\text{addr} = \langle \text{matrix Element} \rangle.\text{addr}$
- 62) $\langle \text{NS} \rangle \rightarrow \text{epsilon}$
 $\langle \text{NS} \rangle.\text{addr} = \text{NULL}$
- 63) $\langle \text{matrix} \rangle \rightarrow \text{SQO} \langle \text{rows} \rangle \text{SQL}$
 $\langle \text{matrix} \rangle.\text{addr} = \langle \text{rows} \rangle.\text{addr}$

64) $\langle rows \rangle \rightarrow \langle row \rangle \langle NG \rangle$
 $\langle rows \rangle.addr = \langle row \rangle.addr$
 $\langle row \rangle.link = \langle NG \rangle.addr$

65) $\langle NG \rangle \rightarrow \text{SEMICOLON } \langle rows \rangle$
 $\langle NG \rangle.addr = \langle rows \rangle.addr$

66) $\langle NG \rangle \rightarrow \text{epsilon}$
 $\langle NG \rangle.addr = \text{NULL}$

67) $\langle row \rangle \rightarrow \text{NUM } \langle \text{remaining Col Elements} \rangle$
 $\langle row \rangle.addr = \text{NUM}.addr$
 $\text{NUM}.link = \langle \text{remaining Col Elements} \rangle.addr$

68) $\langle \text{remaining Col Elements} \rangle \rightarrow \text{COMMA NUM } \langle \text{remaining Col Elements} \rangle$
 $\langle \text{remaining Col Elements} \rangle.addr = \text{NUM}.addr$
 $\text{NUM}.link = \langle \text{remaining Col Elements} \rangle_2.addr$

69) $\langle \text{remaining Col Elements} \rangle \rightarrow \text{epsilon}$
 $\langle \text{remaining Col Elements} \rangle.addr = \text{NULL}$

70) $\langle \text{matrix Element} \rangle \rightarrow \text{SQO NUM COMMA NUM SQC}$
 $\langle \text{matrix Element} \rangle.addr = \text{new node}(\text{matrix Element}, \text{NUM}.addr, \text{NUM}.addr)$

71) $\langle \text{logical Op} \rangle \rightarrow \text{AND}$
 $\langle \text{logical Op} \rangle.addr = \text{AND}.addr$

72) $\langle \text{logical Op} \rangle \rightarrow \text{OR}$
 $\langle \text{logical Op} \rangle.addr = \text{OR}.addr$

73) $\langle \text{boolean Exp} \rangle \rightarrow \text{NOT OP } \langle \text{boolean Exp} \rangle$
 $\langle \text{boolean Exp} \rangle_1.addr = \text{new node}(\text{boolean Exp}, \langle \text{boolean Exp} \rangle_2.addr)$

74) $\langle \text{relational Op} \rangle \rightarrow \text{LT}$
 $\langle \text{relational Op} \rangle.addr = \text{LT}.addr$

75) $\langle \text{relational Op} \rangle \rightarrow \text{LE}$
 $\langle \text{relational Op} \rangle.addr = \text{LE}.addr$

76) $\langle \text{relational Op} \rangle \rightarrow \text{EQ}$
 $\langle \text{relational Op} \rangle.addr = \text{EQ}.addr$

77) $\langle \text{relational Op} \rangle \rightarrow \text{GT}$
 $\langle \text{relational Op} \rangle.addr = \text{GT}.addr$

78) $\langle \text{relational Op} \rangle \rightarrow \text{GE}$
 $\langle \text{relational Op} \rangle.addr = \text{GE}.addr$

79) $\langle \text{relationalOp} \rangle \rightarrow \text{NE}$
 $\langle \text{relationalOp} \rangle.\text{addr} = \text{NE}.\text{addr}$

80) $\langle \text{arithmeticExpression} \rangle \rightarrow \langle \text{arithmeticTerm} \rangle \langle \text{N3} \rangle$
 $\langle \text{arithmeticExpression} \rangle.\text{addr} = \langle \text{arithmeticTerm} \rangle.\text{addr}$

81) $\langle \text{N3} \rangle$