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题目. P_9 1.3.6 对程序:

$$
\begin{aligned}
&\mathscr{P}_2: \\
&\quad \text{IF} \quad X \neq 0 \quad \text{GOTO} \quad A \\
&\quad Y \leftarrow Y+1 \\
&\quad Z \leftarrow Z+1 \\
&\quad \text{IF} \quad Z \neq 0 \quad \text{GOTO} \quad E \\
&[A] X \leftarrow X-1 \\
&[B] \text{IF} \quad X \neq 0 \quad \text{GOTO} \quad B
\end{aligned}
$$

给出它从输入变量X分别等于$0,1,5$的初始状态开始的计算.

解答. (1) 思路: $X=0$, 不跳转到$[A]$, 之后$Y=1, Z=1$, 此时$Z \neq 0$, 跳转到$[E]$, 结束程序. 程序结束时, 输出变量$Y=1$.
计算:

$$
\begin{aligned}
&(1, \quad \{X=0, Y=0, Z=0\}) \\
&(2, \quad \{X=0, Y=0, Z=0\}) \\
&(3, \quad \{X=0, Y=1, Z=0\}) \\
&(4, \quad \{X=0, Y=1, Z=1\}) \\
&(7, \quad \{X=0, Y=1, Z=1\}) \quad \text{(终点快相)}
\end{aligned}
$$

(2) 思路： $X=1$, 跳转到$[A]$, 执行$X \leftarrow X-1$后, $X=0$, 不执行$[B]$, 结束程序. 程序结束时, 输出变量$Y=0$.
计算:

$$
\begin{aligned}
&(1, \quad \{X=1, Y=0, Z=0\}) \\
&(5, \quad \{X=1, Y=0, Z=0\}) \\
&(6, \quad \{X=0, Y=0, Z=0\}) \\
&(7, \quad \{X=0, Y=0, Z=0\})
\end{aligned}
$$

(3) 思路: $X=5$, 跳转到$[A]$, 执行$X \leftarrow X-1$后, $X=4$, 执行$[B]$, 进入死循环. 程序结束时, 输出变量$Y=0$.
计算:

$$
\begin{aligned}
&(1, \quad \{X=5, Y=0, Z=0\}) \\
&(5, \quad \{X=5, Y=0, Z=0\}) \\
&(6, \quad \{X=4, Y=0, Z=0\}) \\
&(6, \quad \{X=4, Y=0, Z=0\}) \\
&\cdots \quad \text{(死循环)}
\end{aligned}
$$

□

题目. P_9 1.3.7 对程序

$$
\begin{aligned}
&\mathscr{P}_3:\\
&\quad X_1 \leftarrow X_1+1\\
&\quad X_1 \leftarrow X_1+1\\
&[A]X_1 \leftarrow X_1-1\\
&\quad \text{IF}\quad X_1\neq 0\quad \text{GOTO}\quad C\\
&[B]Z \leftarrow Z+1\\
&\quad \text{IF}\quad Z\neq 0\quad \text{GOTO}\quad B\\
&[C]X_1 \leftarrow X_1-1\\
&\quad \text{IF}\quad X_1\neq 0\quad \text{GOTO}\quad A\\
&\quad \text{IF}\quad X_2\neq 0\quad \text{GOTO}\quad D\\
&\quad Y \leftarrow Y+1\\
&[D]Y \leftarrow Y
\end{aligned}
$$

设输入变量的初始状态的值如下:
(1) $X_1=2, X_2=0$
(1) $X_1=4, X_2=3$
(1) $X_1=1, X_2=4$
写出计算

解答. (1) 分析: 执行了$[A]$后, $X_1=3$, 跳转到C, 之后$X_1=2$, 跳转回$[A]$, $X_1=1$, 再跳转到$[C]$, $X_1=0$, 而$X_2=0$, 执行$Y \leftarrow Y+1$, 之后进入空指令$[D]$. 最后输出变量$Y=1$.
计算:

$$
\begin{aligned}
&(1,\quad \{X_1=2, X_2=0, Y=0, Z=0\})\\
&(2,\quad \{X_1=3, X_2=0, Y=0, Z=0\})\\
&(3,\quad \{X_1=4, X_2=0, Y=0, Z=0\})\\
&(4,\quad \{X_1=3, X_2=0, Y=0, Z=0\})\\
&(7,\quad \{X_1=3, X_2=0, Y=0, Z=0\})\\
&(8,\quad \{X_1=2, X_2=0, Y=0, Z=0\})\\
&(3,\quad \{X_1=2, X_2=0, Y=0, Z=0\})\\
&(4,\quad \{X_1=1, X_2=0, Y=0, Z=0\})\\
&(7,\quad \{X_1=1, X_2=0, Y=0, Z=0\})\\
&(8,\quad \{X_1=0, X_2=0, Y=0, Z=0\})\\
&(9,\quad \{X_1=0, X_2=0, Y=0, Z=0\})\\
&(10,\quad \{X_1=0, X_2=0, Y=0, Z=0\})\\
&(11,\quad \{X_1=0, X_2=0, Y=1, Z=0\})\\
&(12,\quad \{X_1=0, X_2=0, Y=1, Z=0\})
\end{aligned}
$$

(2) 思路: 执行$[A]$之后, $X_1=5$, 跳转$[C]$, 之后$X_1=4$, 跳转回$[A]$, 在$[C]$, $[A]$间来回跳转, 根据X_1的奇偶性, 最后在执行$[C]$的第一步之后$X_1=0$, $X_2=3\neq 0$, 跳转到空指令D. 最后输出变量$Y=0$.

计算:

$$
\begin{aligned}
&(1, \quad \{X_1 = 4, X_2 = 3, Y = 0, Z = 0\})\\
&(2, \quad \{X_1 = 5, X_2 = 3, Y = 0, Z = 0\})\\
&(3, \quad \{X_1 = 6, X_2 = 3, Y = 0, Z = 0\})\\
&(4, \quad \{X_1 = 5, X_2 = 3, Y = 0, Z = 0\})\\
&(7, \quad \{X_1 = 5, X_2 = 3, Y = 0, Z = 0\})\\
&(8, \quad \{X_1 = 4, X_2 = 3, Y = 0, Z = 0\})\\
&(3, \quad \{X_1 = 4, X_2 = 3, Y = 0, Z = 0\})\\
&(4, \quad \{X_1 = 3, X_2 = 3, Y = 0, Z = 0\})\\
&(7, \quad \{X_1 = 3, X_2 = 3, Y = 0, Z = 0\})\\
&(8, \quad \{X_1 = 2, X_2 = 3, Y = 0, Z = 0\})\\
&(3, \quad \{X_1 = 2, X_2 = 3, Y = 0, Z = 0\})\\
&(4, \quad \{X_1 = 1, X_2 = 3, Y = 0, Z = 0\})\\
&(7, \quad \{X_1 = 1, X_2 = 3, Y = 0, Z = 0\})\\
&(8, \quad \{X_1 = 0, X_2 = 3, Y = 0, Z = 0\})\\
&(9, \quad \{X_1 = 0, X_2 = 3, Y = 0, Z = 0\})\\
&(11, \quad \{X_1 = 0, X_2 = 3, Y = 0, Z = 0\})\\
&(12, \quad \{X_1 = 0, X_2 = 3, Y = 0, Z = 0\})
\end{aligned}
$$

(3) 思路: 执行$[A]$之后, $X_1 = 2$, 跳转$[C]$, 之后$X_1 = 1$, 跳转回$[A]$, $X_1 = 0$, 执行$[B]$, $Z = 1$, 在$[B]$中进入死循环. 最后输出变量$Y = 0$.
计算:

$$
\begin{aligned}
&(1, \quad \{X_1 = 1, X_2 = 4, Y = 0, Z = 0\})\\
&(2, \quad \{X_1 = 2, X_2 = 4, Y = 0, Z = 0\})\\
&(3, \quad \{X_1 = 3, X_2 = 4, Y = 0, Z = 0\})\\
&(4, \quad \{X_1 = 2, X_2 = 4, Y = 0, Z = 0\})\\
&(7, \quad \{X_1 = 2, X_2 = 4, Y = 0, Z = 0\})\\
&(8, \quad \{X_1 = 1, X_2 = 4, Y = 0, Z = 0\})\\
&(3, \quad \{X_1 = 1, X_2 = 4, Y = 0, Z = 0\})\\
&(4, \quad \{X_1 = 0, X_2 = 4, Y = 0, Z = 0\})\\
&(5, \quad \{X_1 = 0, X_2 = 4, Y = 0, Z = 0\})\\
&(6, \quad \{X_1 = 0, X_2 = 4, Y = 0, Z = 1\})\\
&(5, \quad \{X_1 = 0, X_2 = 4, Y = 0, Z = 1\})\\
&(6, \quad \{X_1 = 0, X_2 = 4, Y = 0, Z = 2\})\\
&\cdots \quad \text{(进入死循环)}
\end{aligned}
$$

□

题目. P_{12} 1.1 写出计算下述函数的$\mathscr{S}$程序(允许使用宏指令):
(1) $f(x) = \lfloor x/2 \rfloor$(向下取整)
(2) x偶数, $f(x) = 1$; x奇数, $f(x)$无定义.

解答. (1) 思路: 除以2可以用一直减2表示.

$$
\begin{aligned}
&\mathscr{P}_1: \\
&\quad Z \leftarrow Z+1 \\
&\quad X \leftarrow X+1 \quad (+1\text{的目的是为了保证2的输出是1, 以此类推}) \\
&[A]X \leftarrow X-1 \\
&\quad X \leftarrow X-1 \\
&\quad \text{IF} \quad X \neq 0 \quad \text{GOTO} \quad B \\
&\quad \text{IF} \quad Z \neq 0 \quad \text{GOTO} \quad E \\
&[B]Y \leftarrow Y+1 \\
&\quad \text{IF} \quad Y \neq 0 \quad \text{GOTO} \quad A
\end{aligned}
$$

使用宏指令的版本:

$$
\begin{aligned}
&\mathscr{P}_1^*: \\
&\quad X \leftarrow X+1 \\
&[A]X \leftarrow X-2 \\
&\quad \text{IF} \quad X \neq 0 \quad \text{GOTO} \quad B \\
&\quad \text{GOTO} \quad E \\
&[B]Y \leftarrow Y+1 \\
&\quad \text{GOTO} \quad A
\end{aligned}
$$

(2) 思路: 对输入的X, 循环减两次1, 但每次都检查X是否是0, 来判断奇偶性, 为了兼容0, 首先加上1. 简单来说, 就是看减去的是奇数个还是偶数个1来进行出口的分类.

$$
\begin{aligned}
&\mathscr{P}_2^*: \\
&\quad X \leftarrow X+1 \\
&[A]X \leftarrow X-1 \\
&\quad \text{IF} \quad X = 0 \quad \text{GOTO} \quad B \\
&\quad X \leftarrow X-1 \\
&\quad \text{IF} \quad X \neq 0 \quad \text{GOTO} \quad A \\
&\quad \text{GOTO} \quad C \\
&[B]Y \leftarrow Y+1 \\
&\quad \text{GOTO} \quad E \\
&[C]Z \leftarrow Z+1 \\
&\quad \text{IF} \quad Z \neq 0 \quad \text{GOTO} \quad C
\end{aligned}
$$

如果不允许判断$X=0$, 可以这么写:

$$
\begin{aligned}
&\mathscr{P}_2^*: \\
&\quad X \leftarrow X+1 \\
&[A]X \leftarrow X-1 \\
&\quad \text{IF} \quad X \neq 0 \quad \text{GOTO} \quad B \\
&\quad \text{GOTO} \quad C \quad (\text{偶数出口})
\end{aligned}
$$

$[B]X \leftarrow X - 1$
IF $X \neq 0$ GOTO A
GOTO D (奇数出口)
$[C]Y \leftarrow Y + 1$
GOTO E
$[D]Z \leftarrow Z + 1$
IF $Z \neq 0$ GOTO D (死循环)

□

题目的注记. 可供使用的宏指令:

- GOTO A
- $V \leftarrow V'$
- 判断 $X = 0$ 和跳转

题目. P_{12} 1.2 给出下列程序$\mathscr{P}$计算的函数$\psi^{(1)}_{\mathscr{P}}(x)$:

(1)$[A]X \leftarrow X + 1$
$X \leftarrow X - 1$
IF $X \neq 0$ GOTO A
(2)$[A]X \leftarrow X - 1$
IF $X = 0$ GOTO A
$X \leftarrow X - 1$
IF $X \neq 0$ GOTO A
(3)空程序

解答. (1) $\psi^{(1)}_{\mathscr{P}_1}(x) = \begin{cases} \uparrow (\text{未定义}) & \text{if } x \in \mathbb{N}^*, \\ 0 & \text{if } x = 0. \end{cases}$
(2) $\psi^{(1)}_{\mathscr{P}_1}(x) = \begin{cases} 0, & x\text{是正偶数} \\ \uparrow, & x = 0\text{或}x\text{是奇数} \end{cases}$
(3) $\psi^{(1)}_{\mathscr{P}_1}(x) = 0, \forall x \in \mathbb{N}$ □