Análisis Matemático de un Programa en C

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Resumen Ejecutivo

Este documento presenta la traducción completa de un programa de software escrito en C a un objeto matemático puro: un sistema de ecuaciones diofánticas. El proceso demuestra la equivalencia fundamental entre la computación (algoritmos) y la teoría de números (polinomios), como lo postula el Teorema de Matiyasevich (MRDP).

El compilador ha analizado el código fuente y ha extraído las siguientes componentes clave para describir una única transición de estado (un ”fotograma”):

- **Variables de Estado (S_t):** Las variables que definen el estado del sistema en un instante t. Para este programa, son: b, c, d, e, f, g, p, q.
- **Variables de Entrada (I_t):** Las variables que representan la interacción con el exterior en el instante t. Para este programa, son: getch, kbhit.

El documento se divide en dos partes principales, que corresponden a las dos grandes fases de la traducción:

1. **La Función de Transición de Estado:** Muestra cómo la lógica procedural del programa (bucles, condicionales) se ”aplana” en un sistema de ecuaciones de asignación $S_{t+1} = F(S_t, I_t)$, y cómo este sistema se optimiza para revelar su estructura.
2. **La Conversión a Polinomio Puro:** Muestra cómo el sistema de asignación, que aún contiene operadores lógicos, se convierte en un sistema de ecuaciones diofánticas puras (solo usando suma, resta y multiplicación), cumpliendo con el objetivo teórico final del proyecto.

Part I
La Función de Transición de Estado

1 Aplanamiento y Optimización

El primer paso consiste en convertir la lógica imperativa del bucle principal del programa en una función matemática estática, F. Esto se logra mediante un proceso de ”aplanamiento” que transforma construcciones como ‘if-else‘ en expresiones aritméticas y sustituye todas las variables temporales hasta que cada ecuación solo dependa del estado anterior (S_t) y las entradas (I_t).

Ecuaciones de Estado (Forma Pura, Sin Optimizar)

Esta es la forma ”pura” de la función de transición. Cada ecuación es matemáticamente autocontenida y muestra la dependencia total del estado anterior. Su complejidad y repetición visual reflejan la necesidad de optimización.

$$
\begin{aligned}
b[t+1] = {} & (((\mathrm{b\ +\ d})\ \text{¡}\ 1)\ \cdot(40) + (1-((b+d)<1))\cdot((((b+d)>78)\cdot(40)+(1- \\
& ((b+d)>78))\cdot((b+d)))))
\end{aligned}
$$

$$
\begin{aligned}
c[t+1] = {} & (((\mathrm{b\ +\ d})\ \text{¡}\ 1)\ \cdot(12) + (1-((b+d)<1))\cdot((((b+d)>78)\cdot(12)+(1- \\
& ((b+d)>78))\cdot((c+e)))))
\end{aligned}
$$

$$
\begin{aligned}
d[t+1] = {} & ((((((\mathrm{b\ +\ d}) = 2)\ \wedge((c+e) \geq ((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 119)\wedge(p>1))\cdot((p-1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 119)\wedge(p>1)))\cdot(((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 115)\wedge(p< \\
& 18))\cdot((p+1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 115)\wedge(p< \\
& 18)))\cdot(p))))))\wedge((c+e) < (((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 119)\wedge(p>1))\cdot((p-1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 119)\wedge(p>1)))\cdot(((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 115)\wedge(p< \\
& 18))\cdot((p+1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 115)\wedge(p< \\
& 18)))\cdot(p))))+5)))\vee((((b+d) = 77)\wedge((c+e)\geq((((kbhit\cdot(getch)+(1- \\
& kbhit)\cdot(0)) = 105)\wedge(q>1))\cdot((q-1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot \\
& (0)) = 105)\wedge(q>1)))\cdot(((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 107)\wedge(q< \\
& 18))\cdot((q+1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 107)\wedge(q< \\
& 18)))\cdot(q))))))\wedge((c+e) < (((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 105)\wedge \\
& (q>1))\cdot((q-1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 105)\wedge(q> \\
& 1)))\cdot(((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 107)\wedge(q<18))\cdot((q+1))+(1- \\
& (((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 107)\wedge(q<18)))\cdot(q))))+5))))\cdot((0- \\
& d))+(1-(((((b+d) = 2)\wedge((c+e)\geq((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 119)\wedge(p>1))\cdot((p-1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 119)\wedge(p>1)))\cdot(((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 115)\wedge(p< \\
& 18))\cdot((p+1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 115)\wedge(p< \\
& 18)))\cdot(p))))))\wedge((c+e) < (((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 119)\wedge(p>1))\cdot((p-1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 119)\wedge(p>1)))\cdot(((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 115)\wedge(p< \\
& 18))\cdot((p+1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 115)\wedge(p< \\
& 18)))\cdot(p))))+5)))\vee((((b+d) = 77)\wedge((c+e)\geq((((kbhit\cdot(getch)+(1- \\
& kbhit)\cdot(0)) = 105)\wedge(q>1))\cdot((q-1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot \\
& (0)) = 105)\wedge(q>1)))\cdot(((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 107)\wedge(q< \\
& 18))\cdot((q+1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 107)\wedge(q< \\
& 18)))\cdot(q))))))\wedge((c+e) < (((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 105)\wedge(q>1))\cdot((q-1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = \\
& 105)\wedge(q>1)))\cdot(((((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 107)\wedge(q< \\
& 18))\cdot((q+1))+(1-(((kbhit\cdot(getch)+(1-kbhit)\cdot(0)) = 107)\wedge(q< \\
& 18)))\cdot(q))))+5)))))\cdot(d))
\end{aligned}
$$

$$
e[t+1] = ((((c+e) = 1)\vee((c+e) = 22))\cdot((0-e))+(1-(((c+e) = 1)\vee((c+e) = 22)))\cdot(e))
$$

$$
f[t+1] = (((b+d)<1)\cdot((f+1))+(1-((b+d)<1))\cdot(f))
$$

$$
\begin{aligned}
g[t+1] = {} & (((\mathrm{b\ +\ d})\ \text{¡}\ 1)\ \cdot(g) + (1-((b+d)<1))\cdot((((b+d)>78)\cdot((g+1))+ \\
& (1-((b+d)>78))\cdot(g))))
\end{aligned}
$$

$$
\begin{aligned}
p[t+1] = {} & ((((\text{kbhit } \cdot (getch) + (1 - kbhit) \cdot (0)) = 119) \wedge (p > 1)) \cdot ((p-1)) + \\
& (1 - (((kbhit \cdot (getch) + (1 - kbhit) \cdot (0)) = 119) \wedge (p > 1))) \cdot (((((kbhit \cdot \\
& (getch) + (1 - kbhit) \cdot (0)) = 115) \wedge (p < 18)) \cdot ((p+1)) + (1 - (((kbhit \cdot \\
& (getch) + (1 - kbhit) \cdot (0)) = 115) \wedge (p < 18))) \cdot (p))))
\end{aligned}
$$

$$
\begin{aligned}
q[t+1] = {} & ((((\text{kbhit } \cdot (getch) + (1 - kbhit) \cdot (0)) = 105) \wedge (q > 1)) \cdot ((q-1)) + \\
& (1 - (((kbhit \cdot (getch) + (1 - kbhit) \cdot (0)) = 105) \wedge (q > 1))) \cdot (((((kbhit \cdot \\
& (getch) + (1 - kbhit) \cdot (0)) = 107) \wedge (q < 18)) \cdot ((q+1)) + (1 - (((kbhit \cdot \\
& (getch) + (1 - kbhit) \cdot (0)) = 107) \wedge (q < 18))) \cdot (q))))
\end{aligned}
$$

Definiciones de Cálculos Comunes (CSE)

Para simplificar y hacer las ecuaciones manejables, el sistema busca expresiones que se repiten (ej. la lógica de movimiento de una pala), les asigna un nombre simbólico (ej. $C_0, C_1, \ldots$) y las calcula una sola vez. Estas definiciones representan los bloques de construcción lógicos del programa.

$$
\begin{aligned}
C_0 &= (C_1 \cdot C_5 + (1 - C_1) \cdot C_6) \\
C_1 &= (C_2 \wedge C_4) \\
C_2 &= (C_3 = 105) \\
C_3 &= (kbhit \cdot getch + (1 - kbhit) \cdot 0) \\
C_4 &= (q > 1) \\
C_5 &= (q - 1) \\
C_6 &= (C_7 \cdot C_10 + (1 - C_7) \cdot q) \\
C_7 &= (C_8 \wedge C_9) \\
C_8 &= (C_3 = 107) \\
C_9 &= (q < 18) \\
C_10 &= (q + 1) \\
C_11 &= (C_12 \cdot C_15 + (1 - C_12) \cdot C_16) \\
C_12 &= (C_13 \wedge C_14) \\
C_13 &= (C_3 = 119) \\
C_14 &= (p > 1) \\
C_15 &= (p - 1) \\
C_16 &= (C_17 \cdot C_20 + (1 - C_17) \cdot p) \\
C_17 &= (C_18 \wedge C_19) \\
C_18 &= (C_3 = 115) \\
C_19 &= (p < 18) \\
C_20 &= (p + 1) \\
C_21 &= (c + e) \\
C_22 &= (C_23 < 1) \\
C_23 &= (b + d) \\
C_24 &= (C_23 > 78)
\end{aligned}
$$

Ecuaciones de Estado Finales (Optimizadas con CSE)

Esta es la versión final y simplificada de la función de transición. Utiliza las definiciones de C_n para ser más compacta, legible y eficiente. Esta forma es la que más se asemeja a cómo un humano estructuraría los cálculos.

$$
\begin{aligned}
b[t+1] &= (C_2 2 \cdot 40 + (1 - C_2 2) \cdot (C_2 4 \cdot 40 + (1 - C_2 4) \cdot C_2 3)) \\
c[t+1] &= (C_2 2 \cdot 12 + (1 - C_2 2) \cdot (C_2 4 \cdot 12 + (1 - C_2 4) \cdot C_2 1)) \\
d[t+1] &= (((((\mathrm{C}_2 3 = 2) \wedge (C_2 1 \geq C_1 1)) \wedge (C_2 1 < (C_1 1 + 5))) \vee (((C_2 3 = 77) \wedge (C_2 1 \geq \\
&\quad C_0)) \wedge (C_2 1 < (C_0 + 5)))) \cdot (0 - d) + (1 - ((((C_2 3 = 2) \wedge (C_2 1 \geq C_1 1)) \wedge \\
&\quad (C_2 1 < (C_1 1 + 5))) \vee (((C_2 3 = 77) \wedge (C_2 1 \geq C_0)) \wedge (C_2 1 < (C_0 + 5))))) \cdot d) \\
e[t+1] &= (((C_2 1 = 1) \vee (C_2 1 = 22)) \cdot (0 - e) + (1 - ((C_2 1 = 1) \vee (C_2 1 = 22))) \cdot e) \\
f[t+1] &= (C_2 2 \cdot (f + 1) + (1 - C_2 2) \cdot f) \\
g[t+1] &= (C_2 2 \cdot g + (1 - C_2 2) \cdot (C_2 4 \cdot (g + 1) + (1 - C_2 4) \cdot g)) \\
p[t+1] &= C_1 1 \\
q[t+1] &= C_0
\end{aligned}
$$

Part II
Conversión a Polinomio Puro

2 Traducción a Ecuaciones Diofánticas

El paso final y más profundo es convertir la función de transición (que aún contiene operadores lógicos como '==', '¡', etc.) en un sistema que solo utiliza aritmética entera (suma, resta, multiplicación). Esto se logra introduciendo variables existenciales (e_n) y aplicando trucos de la teoría de números, como el Teorema de los Cuatro Cuadrados de Lagrange para manejar las desigualdades.

El proceso ha introducido **134 variables existenciales** para producir un sistema de **102 ecuaciones puras**.

Sistema de Ecuaciones Diofánticas Puras (Forma Práctica)

Esta es la representación más útil para aplicaciones de ingeniería, como la simulación o la síntesis de hardware. Es un sistema de ecuaciones interdependientes que deben satisfacerse simultáneamente. Cada línea representa un cálculo simple o una restricción lógica.

$$
\begin{aligned}
C_0 - ((C_1) \cdot (C_5) + (1 - C_1) \cdot (C_6)) = 0 \\
C_1 - (C_2 \cdot C_4) = 0 \\
C_2 \cdot (1 - C_2) = 0 \\
C_2 \cdot ((C_3) - (105)) = 0 \\
((C_3) - (105)) \cdot e_0 - (1 - C_2) = 0 \\
C_3 - ((kbhit) \cdot (getch) + (1 - kbhit) \cdot (0)) = 0 \\
e_3 - (q - 1) = 0
\end{aligned}
$$

$$C_4 \cdot (1 - C_4) = 0$$
$$C_4 \cdot ((e_3) - (1) - (e_4^2 + e_5^2 + e_6^2 + e_7^2)) = 0$$
$$(1 - C_4) \cdot ((1) - (e_3) - 1 - (e_8^2 + e_9^2 + e_{10}^2 + e_{11}^2)) = 0$$
$$C_5 - (q - 1) = 0$$
$$C_6 - ((C_7) \cdot (C_{10}) + (1 - C_7) \cdot (q)) = 0$$
$$C_7 - (C_8 \cdot C_9) = 0$$
$$C_8 \cdot (1 - C_8) = 0$$
$$C_8 \cdot ((C_3) - (107)) = 0$$
$$((C_3) - (107)) \cdot e_{12} - (1 - C_8) = 0$$
$$e_{14} - (18 - 1) = 0$$
$$C_9 \cdot (1 - C_9) = 0$$
$$C_9 \cdot ((e_{14}) - (q) - (e_{15}^2 + e_{16}^2 + e_{17}^2 + e_{18}^2)) = 0$$
$$(1 - C_9) \cdot ((q) - (e_{14}) - 1 - (e_{19}^2 + e_{20}^2 + e_{21}^2 + e_{22}^2)) = 0$$
$$C_{10} - (q + 1) = 0$$
$$C_{11} - ((C_{12}) \cdot (C_{15}) + (1 - C_{12}) \cdot (C_{16})) = 0$$
$$C_{12} - (C_{13} \cdot C_{14}) = 0$$
$$C_{13} \cdot (1 - C_{13}) = 0$$
$$C_{13} \cdot ((C_3) - (119)) = 0$$
$$((C_3) - (119)) \cdot e_{23} - (1 - C_{13}) = 0$$
$$e_{26} - (p - 1) = 0$$
$$C_{14} \cdot (1 - C_{14}) = 0$$
$$C_{14} \cdot ((e_{26}) - (1) - (e_{27}^2 + e_{28}^2 + e_{29}^2 + e_{30}^2)) = 0$$
$$(1 - C_{14}) \cdot ((1) - (e_{26}) - 1 - (e_{31}^2 + e_{32}^2 + e_{33}^2 + e_{34}^2)) = 0$$
$$C_{15} - (p - 1) = 0$$
$$C_{16} - ((C_{17}) \cdot (C_{20}) + (1 - C_{17}) \cdot (p)) = 0$$
$$C_{17} - (C_{18} \cdot C_{19}) = 0$$
$$C_{18} \cdot (1 - C_{18}) = 0$$
$$C_{18} \cdot ((C_3) - (115)) = 0$$
$$((C_3) - (115)) \cdot e_{35} - (1 - C_{18}) = 0$$
$$e_{37} - (18 - 1) = 0$$
$$C_{19} \cdot (1 - C_{19}) = 0$$
$$C_{19} \cdot ((e_{37}) - (p) - (e_{38}^2 + e_{39}^2 + e_{40}^2 + e_{41}^2)) = 0$$
$$(1 - C_{19}) \cdot ((p) - (e_{37}) - 1 - (e_{42}^2 + e_{43}^2 + e_{44}^2 + e_{45}^2)) = 0$$
$$C_{20} - (p + 1) = 0$$
$$C_{21} - (c + e) = 0$$
$$e_{47} - (1 - 1) = 0$$
$$C_{22} \cdot (1 - C_{22}) = 0$$
$$C_{22} \cdot ((e_{47}) - (C_{23}) - (e_{48}^2 + e_{49}^2 + e_{50}^2 + e_{51}^2)) = 0$$
$$(1 - C_{22}) \cdot ((C_{23}) - (e_{47}) - 1 - (e_{52}^2 + e_{53}^2 + e_{54}^2 + e_{55}^2)) = 0$$
$$C_{23} - (b + d) = 0$$

$$e_{58} - (C_{23} - 1) = 0$$
$$C_{24} \cdot (1 - C_{24}) = 0$$
$$C_{24} \cdot ((e_{58}) - (78) - (e_{59}^2 + e_{60}^2 + e_{61}^2 + e_{62}^2)) = 0$$
$$(1 - C_{24}) \cdot ((78) - (e_{58}) - 1 - (e_{63}^2 + e_{64}^2 + e_{65}^2 + e_{66}^2)) = 0$$
$$e_{67} - ((C_{24}) \cdot (40) + (1 - C_{24}) \cdot (C_{23})) = 0$$
$$b[t+1] - ((C_{22}) \cdot (40) + (1 - C_{22}) \cdot (e_{67})) = 0$$
$$e_{68} - ((C_{24}) \cdot (12) + (1 - C_{24}) \cdot (C_{21})) = 0$$
$$c[t+1] - ((C_{22}) \cdot (12) + (1 - C_{22}) \cdot (e_{68})) = 0$$
$$e_{72} \cdot (1 - e_{72}) = 0$$
$$e_{72} \cdot ((C_{23}) - (2)) = 0$$
$$((C_{23}) - (2)) \cdot e_{73} - (1 - e_{72}) = 0$$
$$e_{74} \cdot (1 - e_{74}) = 0$$
$$e_{74} \cdot ((C_{21}) - (C_{11}) - (e_{76}^2 + e_{77}^2 + e_{78}^2 + e_{79}^2)) = 0$$
$$(1 - e_{74}) \cdot ((C_{11}) - (C_{21}) - 1 - (e_{80}^2 + e_{81}^2 + e_{82}^2 + e_{83}^2)) = 0$$
$$e_{71} - (e_{72} \cdot e_{74}) = 0$$
$$e_{85} - (C_{11} + 5) = 0$$
$$e_{88} - (C_{11} + 5) = 0$$
$$e_{87} - (e_{88} - 1) = 0$$
$$e_{84} \cdot (1 - e_{84}) = 0$$
$$e_{84} \cdot ((e_{87}) - (C_{21}) - (e_{89}^2 + e_{90}^2 + e_{91}^2 + e_{92}^2)) = 0$$
$$(1 - e_{84}) \cdot ((C_{21}) - (e_{87}) - 1 - (e_{93}^2 + e_{94}^2 + e_{95}^2 + e_{96}^2)) = 0$$
$$e_{70} - (e_{71} \cdot e_{84}) = 0$$
$$e_{99} \cdot (1 - e_{99}) = 0$$
$$e_{99} \cdot ((C_{23}) - (77)) = 0$$
$$((C_{23}) - (77)) \cdot e_{100} - (1 - e_{99}) = 0$$
$$e_{101} \cdot (1 - e_{101}) = 0$$
$$e_{101} \cdot ((C_{21}) - (C_0) - (e_{103}^2 + e_{104}^2 + e_{105}^2 + e_{106}^2)) = 0$$
$$(1 - e_{101}) \cdot ((C_0) - (C_{21}) - 1 - (e_{107}^2 + e_{108}^2 + e_{109}^2 + e_{110}^2)) = 0$$
$$e_{98} - (e_{99} \cdot e_{101}) = 0$$
$$e_{112} - (C_0 + 5) = 0$$
$$e_{115} - (C_0 + 5) = 0$$
$$e_{114} - (e_{115} - 1) = 0$$
$$e_{111} \cdot (1 - e_{111}) = 0$$
$$e_{111} \cdot ((e_{114}) - (C_{21}) - (e_{116}^2 + e_{117}^2 + e_{118}^2 + e_{119}^2)) = 0$$
$$(1 - e_{111}) \cdot ((C_{21}) - (e_{114}) - 1 - (e_{120}^2 + e_{121}^2 + e_{122}^2 + e_{123}^2)) = 0$$
$$e_{97} - (e_{98} \cdot e_{111}) = 0$$
$$e_{69} - (e_{70} + e_{97} - e_{70} \cdot e_{97}) = 0$$
$$e_{124} - (0 - d) = 0$$
$$d[t+1] - ((e_{69}) \cdot (e_{124}) + (1 - e_{69}) \cdot (d)) = 0$$
$$e_{126} \cdot (1 - e_{126}) = 0$$

$$e_{126} \cdot ((C_{21}) - (1)) = 0$$
$$((C_{21}) - (1)) \cdot e_{127} - (1 - e_{126}) = 0$$
$$e_{128} \cdot (1 - e_{128}) = 0$$
$$e_{128} \cdot ((C_{21}) - (22)) = 0$$
$$((C_{21}) - (22)) \cdot e_{129} - (1 - e_{128}) = 0$$
$$e_{125} - (e_{126} + e_{128} - e_{126} \cdot e_{128}) = 0$$
$$e_{130} - (0 - e) = 0$$
$$e[t+1] - ((e_{125}) \cdot (e_{130}) + (1 - e_{125}) \cdot (e)) = 0$$
$$e_{131} - (f + 1) = 0$$
$$f[t+1] - ((C_{22}) \cdot (e_{131}) + (1 - C_{22}) \cdot (f)) = 0$$
$$e_{133} - (g + 1) = 0$$
$$e_{132} - ((C_{24}) \cdot (e_{133}) + (1 - C_{24}) \cdot (g)) = 0$$
$$g[t+1] - ((C_{22}) \cdot (g) + (1 - C_{22}) \cdot (e_{132})) = 0$$
$$p[t+1] - (C_{11}) = 0$$
$$q[t+1] - (C_0) = 0$$

Ecuación Polinómica Única (Forma Teórica P=0)

Por completitud teórica, el sistema anterior puede ser combinado en una única ecuación mediante la suma de los cuadrados de cada ecuación. Una solución entera a esta única y masiva ecuación corresponde a una transición de estado válida del programa original. Esta es la forma final que demuestra el Teorema MRDP.

$$\begin{aligned}
&(C_0 - ((C_1) \cdot (C_5) + (1 - C_1) \cdot (C_6)))^2 \\
&+ (C_1 - (C_2 \cdot C_4))^2 + (C_2 \cdot (1 - C_2))^2 \\
&+ (C_2 \cdot ((C_3) - (105)))^2 \\
&+ (((C_3) - (105)) \cdot e_0 - (1 - C_2))^2 + (C_3 - ((kbhit) \cdot (getch) \\
&+ (1 - kbhit) \cdot (0)))^2 + (e_3 - (q - 1))^2 + (C_4 \cdot (1 - C_4))^2 \\
&+ (C_4 \cdot ((e_3) - (1) - (e_4^2 + e_5^2 + e_6^2 + e_7^2)))^2 \\
&+ ((1 - C_4) \cdot ((1) - (e_3) - 1 - (e_8^2 + e_9^2 + e_{10}^2 \\
&+ e_{11}^2)))^2 + (C_5 - (q - 1))^2 + (C_6 - ((C_7) \cdot (C_{10}) \\
&+ (1 - C_7) \cdot (q)))^2 + (C_7 - (C_8 \cdot C_9))^2 \\
&+ (C_8 \cdot (1 - C_8))^2 + (C_8 \cdot ((C_3) - (107)))^2 \\
&+ (((C_3) - (107)) \cdot e_{12} - (1 - C_8))^2 + (e_{14} - (18 - 1))^2 \\
&+ (C_9 \cdot (1 - C_9))^2 + (C_9 \cdot ((e_{14}) - (q) - (e_{15}^2 \\
&+ e_{16}^2 + e_{17}^2 + e_{18}^2)))^2 \\
&+ ((1 - C_9) \cdot ((q) - (e_{14}) - 1 - (e_{19}^2 + e_{20}^2 + e_{21}^2 \\
&+ e_{22}^2)))^2 + (C_{10} - (q + 1))^2 + (C_{11} - ((C_{12}) \cdot (C_{15}) \\
&+ (1 - C_{12}) \cdot (C_{16})))^2 + (C_{12} - (C_{13} \cdot C_{14}))^2 \\
&+ (C_{13} \cdot (1 - C_{13}))^2 + (C_{13} \cdot ((C_3) - (119)))^2 \\
&+ (((C_3) - (119)) \cdot e_{23} - (1 - C_{13}))^2 + (e_{26} - (p - 1))^2 \\
&+ (C_{14} \cdot (1 - C_{14}))^2 + (C_{14} \cdot ((e_{26}) - (1) - (e_{27}^2
\end{aligned}$$

$$+ e_{28}^2 + e_{29}^2 + e_{30}^2)))^2$$
$$+ ((1 - C_{14}) \cdot ((1) - (e_{26}) - 1 - (e_{31}^2 + e_{32}^2 + e_{33}^2$$
$$+ e_{34}^2)))^2 + (C_{15} - (p - 1))^2 + (C_{16} - ((C_{17}) \cdot (C_{20})$$
$$+ (1 - C_{17}) \cdot (p)))^2 + (C_{17} - (C_{18} \cdot C_{19}))^2$$
$$+ (C_{18} \cdot (1 - C_{18}))^2 + (C_{18} \cdot ((C_3) - (115)))^2$$
$$+ (((C_3) - (115)) \cdot e_{35} - (1 - C_{18}))^2 + (e_{37} - (18 - 1))^2$$
$$+ (C_{19} \cdot (1 - C_{19}))^2 + (C_{19} \cdot ((e_{37}) - (p) - (e_{38}^2$$
$$+ e_{39}^2 + e_{40}^2 + e_{41}^2)))^2$$
$$+ ((1 - C_{19}) \cdot ((p) - (e_{37}) - 1 - (e_{42}^2 + e_{43}^2 + e_{44}^2$$
$$+ e_{45}^2)))^2 + (C_{20} - (p + 1))^2 + (C_{21} - (c + e))^2$$
$$+ (e_{47} - (1 - 1))^2 + (C_{22} \cdot (1 - C_{22}))^2$$
$$+ (C_{22} \cdot ((e_{47}) - (C_{23}) - (e_{48}^2 + e_{49}^2 + e_{50}^2$$
$$+ e_{51}^2)))^2 + ((1 - C_{22}) \cdot ((C_{23}) - (e_{47}) - 1 - (e_{52}^2$$
$$+ e_{53}^2 + e_{54}^2 + e_{55}^2)))^2 + (C_{23} - (b + d))^2$$
$$+ (e_{58} - (C_{23} - 1))^2 + (C_{24} \cdot (1 - C_{24}))^2$$
$$+ (C_{24} \cdot ((e_{58}) - (78) - (e_{59}^2 + e_{60}^2 + e_{61}^2$$
$$+ e_{62}^2)))^2 + ((1 - C_{24}) \cdot ((78) - (e_{58}) - 1 - (e_{63}^2 + e_{64}^2$$
$$+ e_{65}^2 + e_{66}^2)))^2 + (e_{67} - ((C_{24}) \cdot (40)$$
$$+ (1 - C_{24}) \cdot (C_{23})))^2 + (b[t + 1] - ((C_{22}) \cdot (40)$$
$$+ (1 - C_{22}) \cdot (e_{67})))^2 + (e_{68} - ((C_{24}) \cdot (12)$$
$$+ (1 - C_{24}) \cdot (C_{21})))^2 + (c[t + 1] - ((C_{22}) \cdot (12)$$
$$+ (1 - C_{22}) \cdot (e_{68})))^2 + (e_{72} \cdot (1 - e_{72}))^2$$
$$+ (e_{72} \cdot ((C_{23}) - (2)))^2$$
$$+ (((C_{23}) - (2)) \cdot e_{73} - (1 - e_{72}))^2 + (e_{74} \cdot (1 - e_{74}))^2$$
$$+ (e_{74} \cdot ((C_{21}) - (C_{11}) - (e_{76}^2 + e_{77}^2 + e_{78}^2$$
$$+ e_{79}^2)))^2 + ((1 - e_{74}) \cdot ((C_{11}) - (C_{21}) - 1 - (e_{80}^2$$
$$+ e_{81}^2 + e_{82}^2 + e_{83}^2)))^2 + (e_{71} - (e_{72} \cdot e_{74}))^2$$
$$+ (e_{85} - (C_{11} + 5))^2 + (e_{88} - (C_{11} + 5))^2 + (e_{87} - (e_{88} - 1))^2$$
$$+ (e_{84} \cdot (1 - e_{84}))^2 + (e_{84} \cdot ((e_{87}) - (C_{21}) - (e_{89}^2$$
$$+ e_{90}^2 + e_{91}^2 + e_{92}^2)))^2$$
$$+ ((1 - e_{84}) \cdot ((C_{21}) - (e_{87}) - 1 - (e_{93}^2 + e_{94}^2 + e_{95}^2$$
$$+ e_{96}^2)))^2 + (e_{70} - (e_{71} \cdot e_{84}))^2$$
$$+ (e_{99} \cdot (1 - e_{99}))^2 + (e_{99} \cdot ((C_{23}) - (77)))^2$$
$$+ (((C_{23}) - (77)) \cdot e_{100} - (1 - e_{99}))^2$$
$$+ (e_{101} \cdot (1 - e_{101}))^2 + (e_{101} \cdot ((C_{21}) - (C_0) - (e_{103}^2$$
$$+ e_{104}^2 + e_{105}^2 + e_{106}^2)))^2$$
$$+ ((1 - e_{101}) \cdot ((C_0) - (C_{21}) - 1 - (e_{107}^2 + e_{108}^2 + e_{109}^2$$
$$+ e_{110}^2)))^2 + (e_{98} - (e_{99} \cdot e_{101}))^2 + (e_{112} - (C_0 + 5))^2$$
$$+ (e_{115} - (C_0 + 5))^2 + (e_{114} - (e_{115} - 1))^2$$
$$+ (e_{111} \cdot (1 - e_{111}))^2$$

$$
\begin{aligned}
&+ (e_{111} \cdot ((e_{114}) - (C_{21}) - (e_{116}^2 + e_{117}^2 + e_{118}^2 \\
&+ e_{119}^2)))^2 + ((1 - e_{111}) \cdot ((C_{21}) - (e_{114}) - 1 - (e_{120}^2 \\
&+ e_{121}^2 + e_{122}^2 + e_{123}^2)))^2 + (e_{97} - (e_{98} \cdot e_{111}))^2 \\
&+ (e_{69} - (e_{70} + e_{97} - e_{70} \cdot e_{97}))^2 + (e_{124} - (0 - d))^2 \\
&+ (d[t+1] - ((e_{69}) \cdot (e_{124}) + (1 - e_{69}) \cdot (d)))^2 \\
&+ (e_{126} \cdot (1 - e_{126}))^2 + (e_{126} \cdot ((C_{21}) - (1)))^2 \\
&+ (((C_{21}) - (1)) \cdot e_{127} - (1 - e_{126}))^2 \\
&+ (e_{128} \cdot (1 - e_{128}))^2 + (e_{128} \cdot ((C_{21}) - (22)))^2 \\
&+ (((C_{21}) - (22)) \cdot e_{129} - (1 - e_{128}))^2 + (e_{125} - (e_{126} \\
&+ e_{128} - e_{126} \cdot e_{128}))^2 + (e_{130} - (0 - e))^2 \\
&+ (e[t+1] - ((e_{125}) \cdot (e_{130}) + (1 - e_{125}) \cdot (e)))^2 + (e_{131} - (f \\
&+ 1))^2 + (f[t+1] - ((C_{22}) \cdot (e_{131}) + (1 - C_{22}) \cdot (f)))^2 \\
&+ (e_{133} - (g+1))^2 + (e_{132} - ((C_{24}) \cdot (e_{133}) \\
&+ (1 - C_{24}) \cdot (g)))^2 + (g[t+1] - ((C_{22}) \cdot (g) \\
&+ (1 - C_{22}) \cdot (e_{132})))^2 + (p[t+1] - (C_{11}))^2 + (q[t+1] - (C_0))^2 = 0
\end{aligned}
$$