IAI INSTITUTE
MEXICO, 2004

IAI INSTITUTE ON URBANIZATION AND GLOBAL ENVIRONMENTAL CHANGE IN LATIN AMERICA

HANDS ON URBAN MODELLING

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09/2004

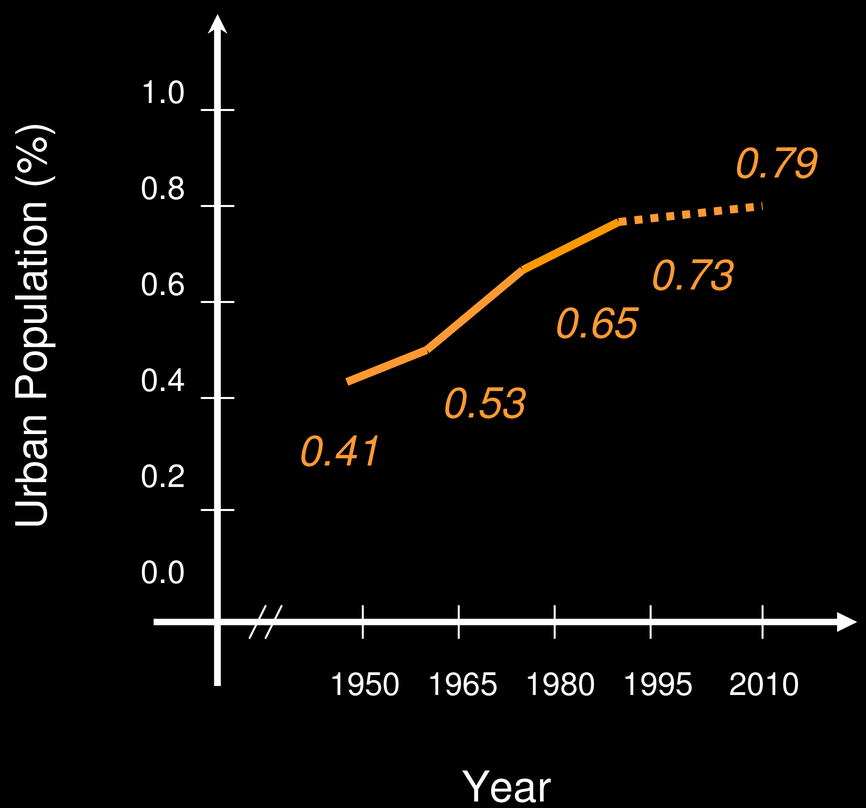
OUTLINE

- *Introduction on Urban Models and Cellular Automata*
- *Some Examples of Urban Modelling*
- *Presentation of a Practical Experiment*
- *Advances and Obstacles in Urban Modelling*
- *Final Considerations*

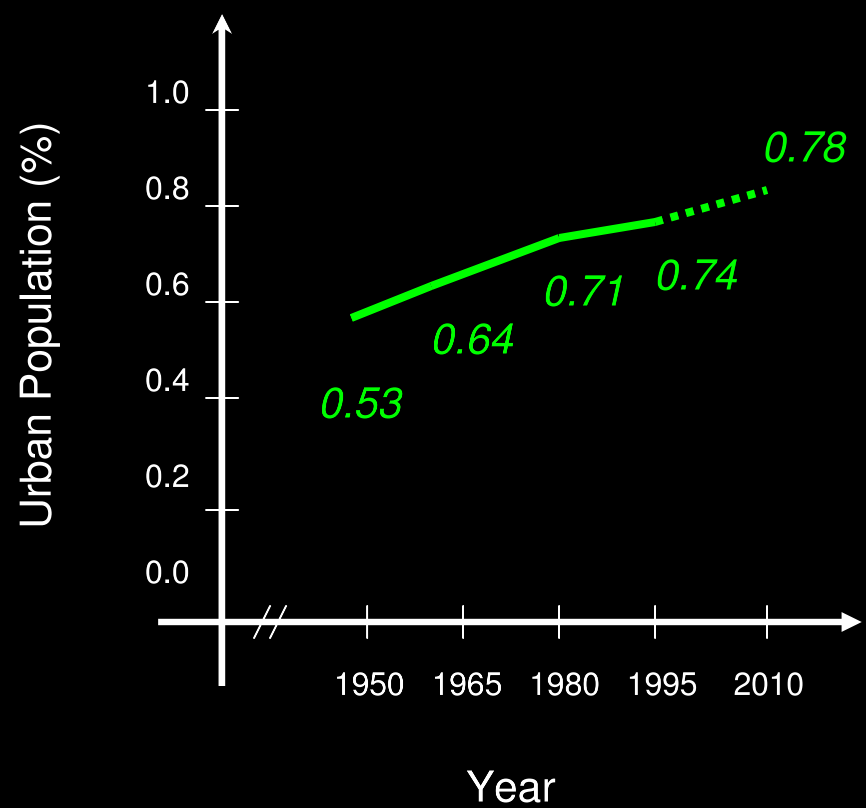
INTRODUCTION

- *Urban areas are bound to shelter the greatest part of the world´s population*

URBAN POPULATION *(UNO, 1998)*



Latin America and the Caribbean



Developed Countries

INTRODUCTION

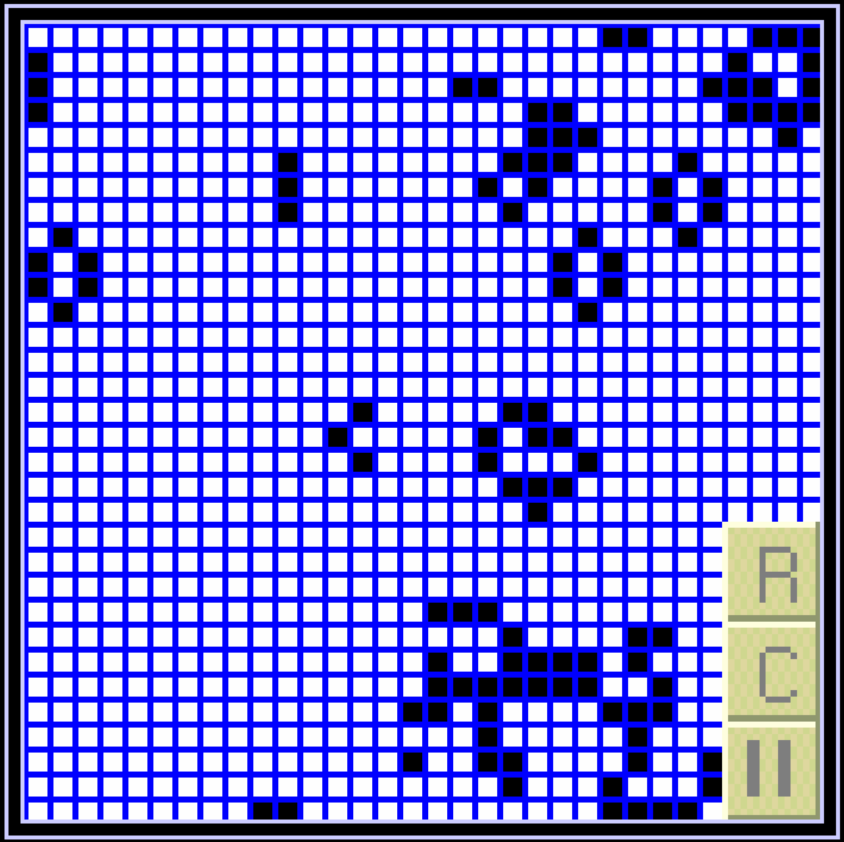
- *Urban areas are bound to shelter the greatest part of the world´s population*
- *Manage the flows of financial resources, man-made and natural assets, human capital, information, technical and scientific knowledge and decision power.*
- *On a proper management of their financial, institutional and physical frameworks will the majority of mankind´s achievements depend.*

URBAN MODELS

- *Non-dynamic models of urban land use change (Von Thünen, 1826; Weber, 1909; Christaller, 1933; Clark, 1951; Alonso, 1960; Lowry, 1964; Lakshmanan, 1964, 1968; Seidman, 1969).*
- *Early dynamic models of urban land use change (Czamanski, 1965; Hill, 1965; Forrester, 1969; Paelinck, 1970; Batty, 1971, 1976 ; Allen et al., 1981; Beaumont et al., 1981; Wegener et al., 1986)*
- *Spatially explicit dynamic models of urban land use change (Batty and Xie, 1997; Couclelis and Takeyama, 1997; Clarke et al., 1998; Papini et al., 1998; Portugali et al., 1999; White et al., 1998; O´Sullivan, 2001)*

CELLULAR AUTOMATA - CA

- CA are composed by four elements:
- **Cells** ➡ different shapes and dimensions;
- **State** ➡ discrete
- **Neighborhood** ➡ different forms/ influence the states
- **Transition rules** ➡ uniform and of local action



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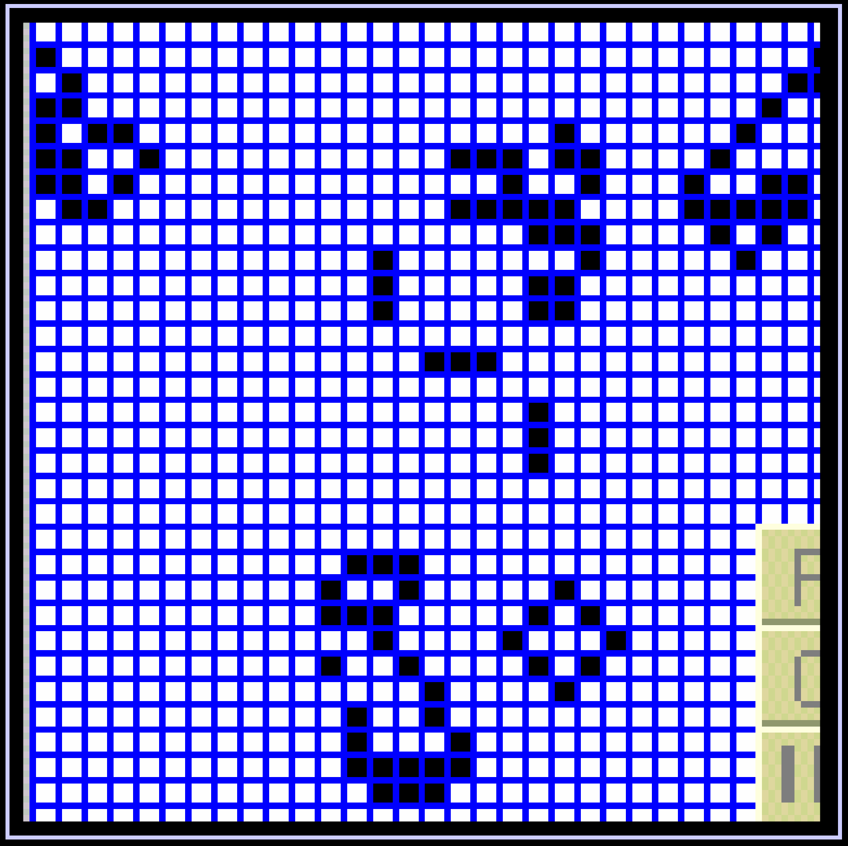

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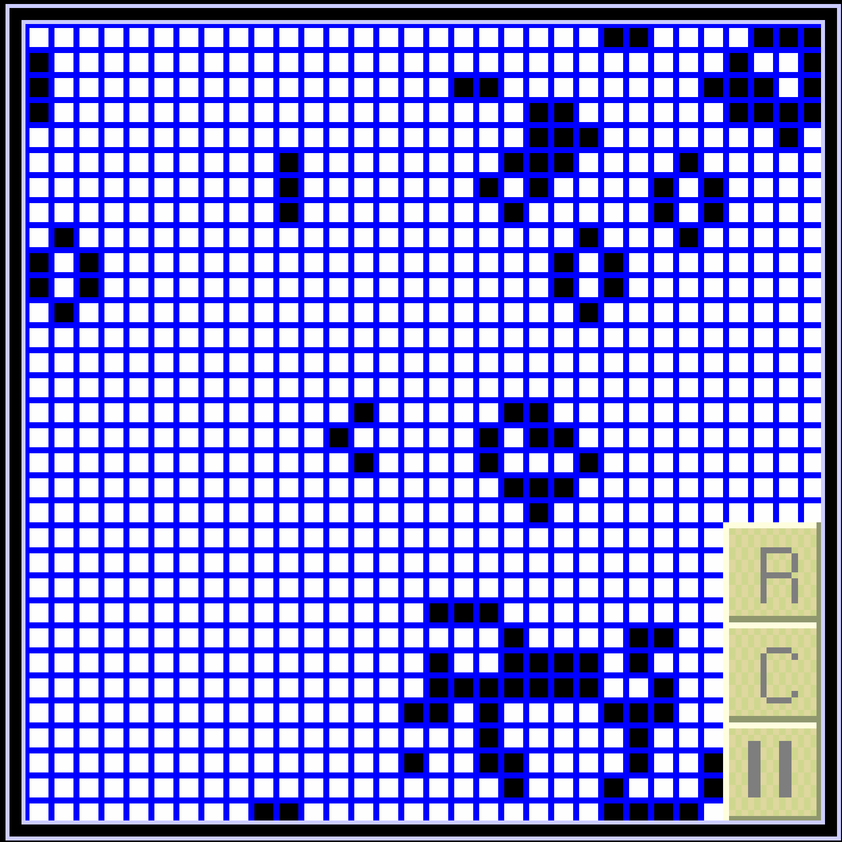

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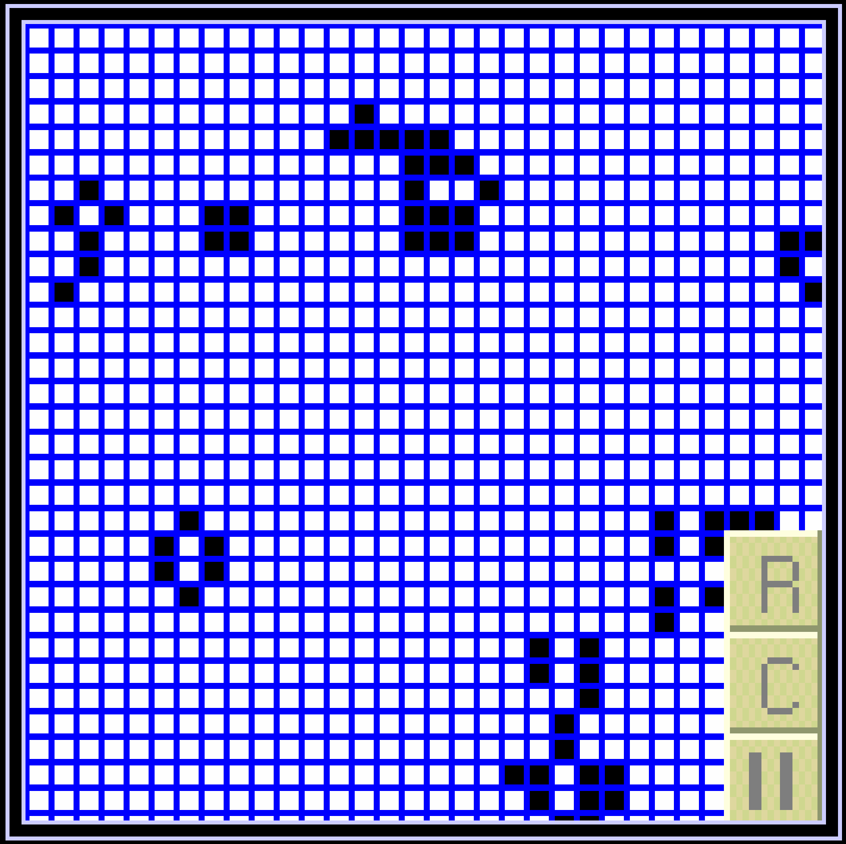

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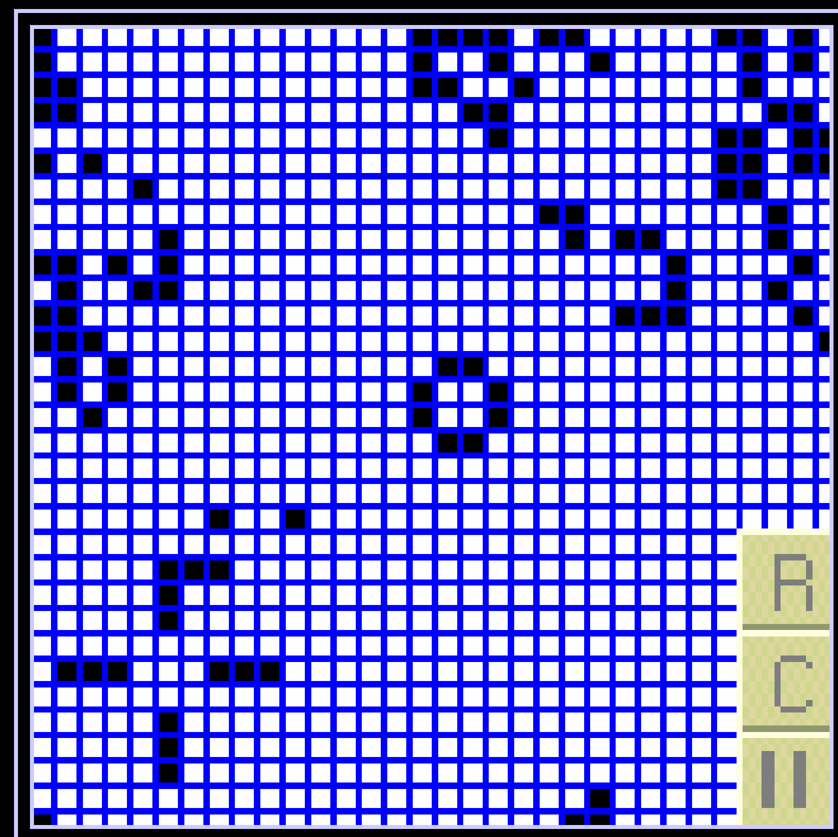

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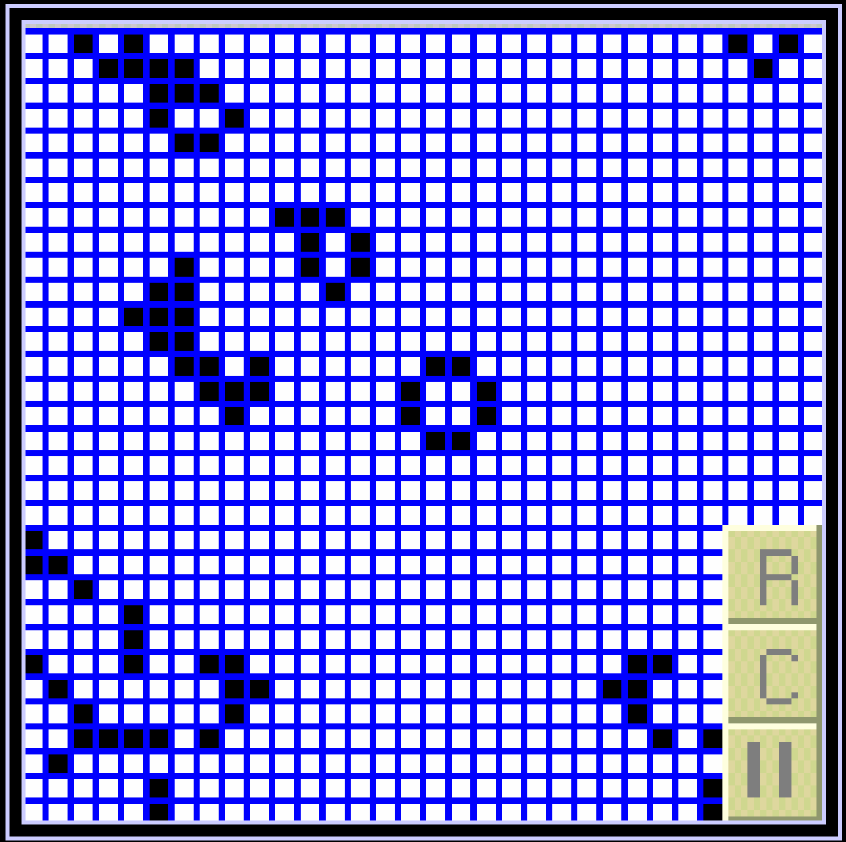

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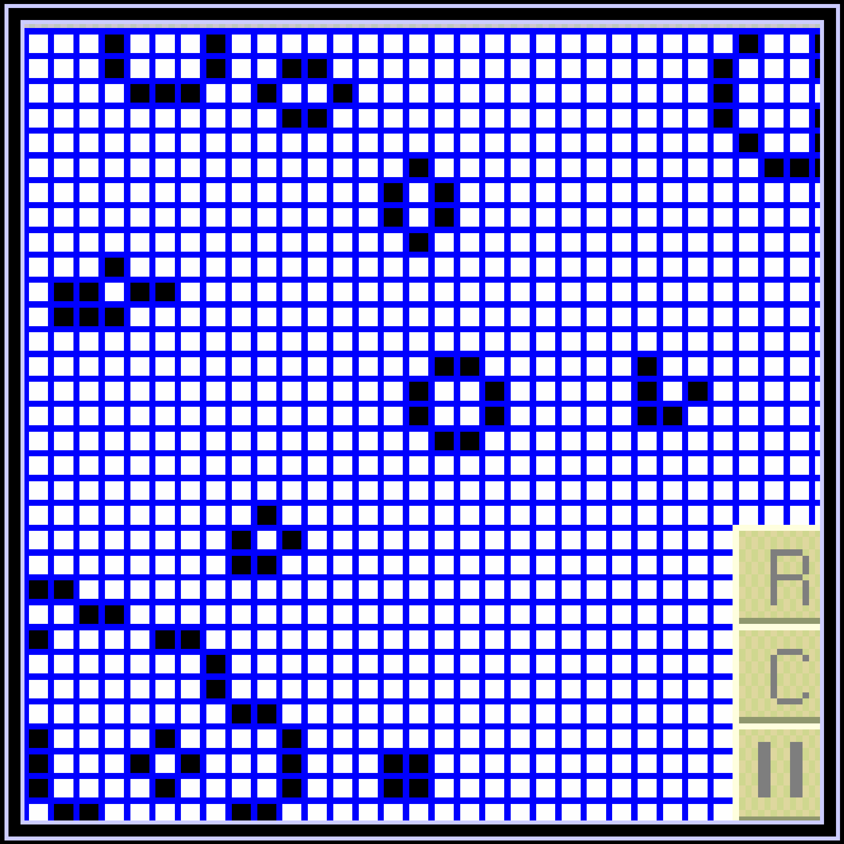

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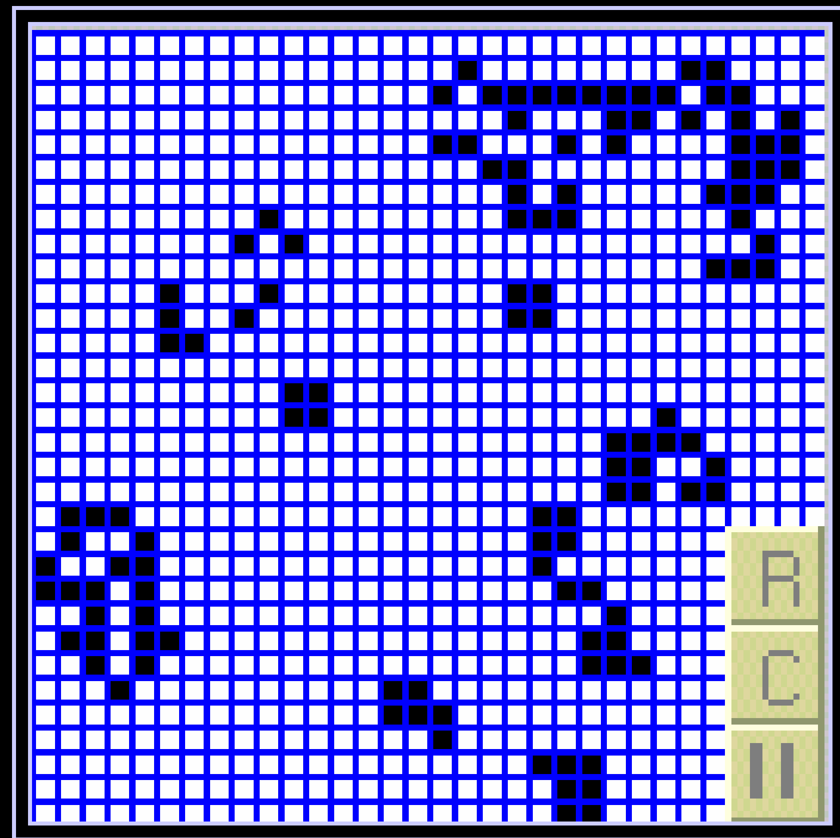

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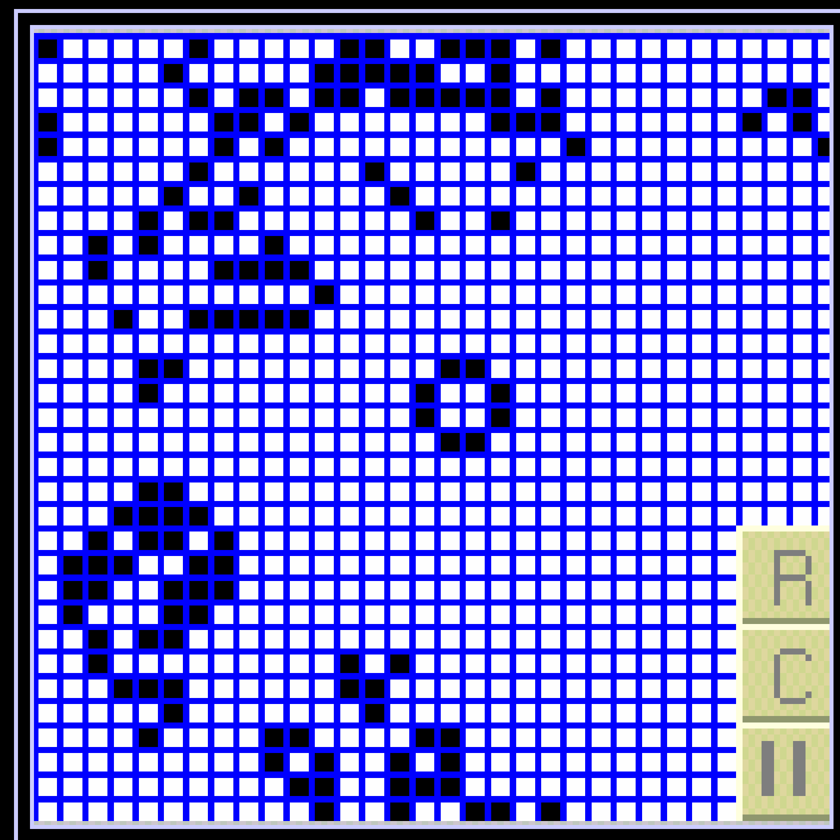

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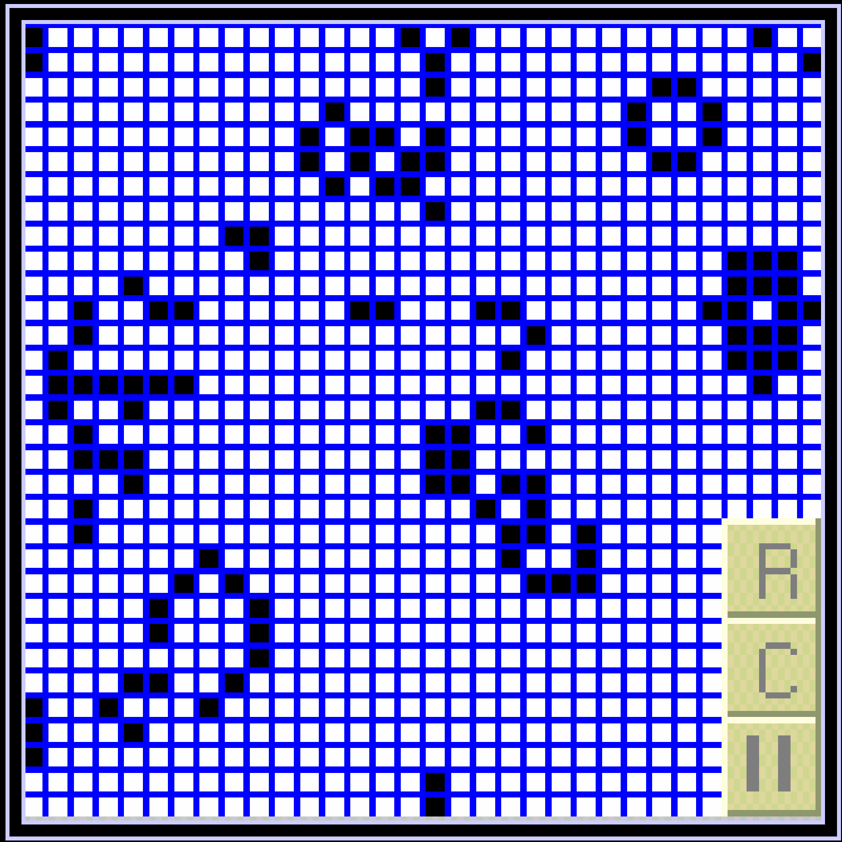

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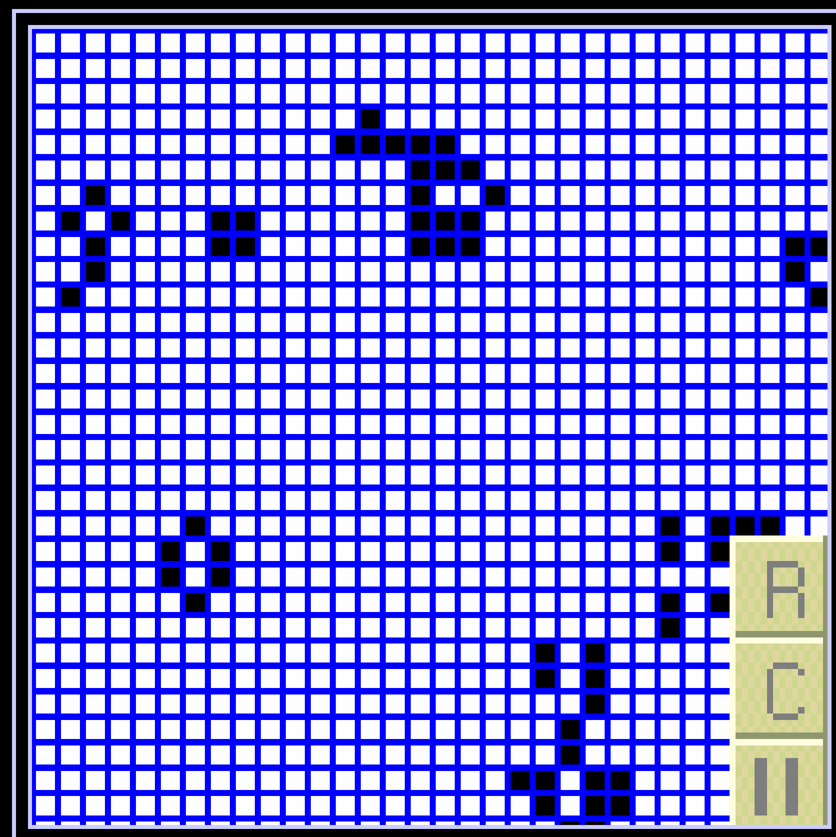

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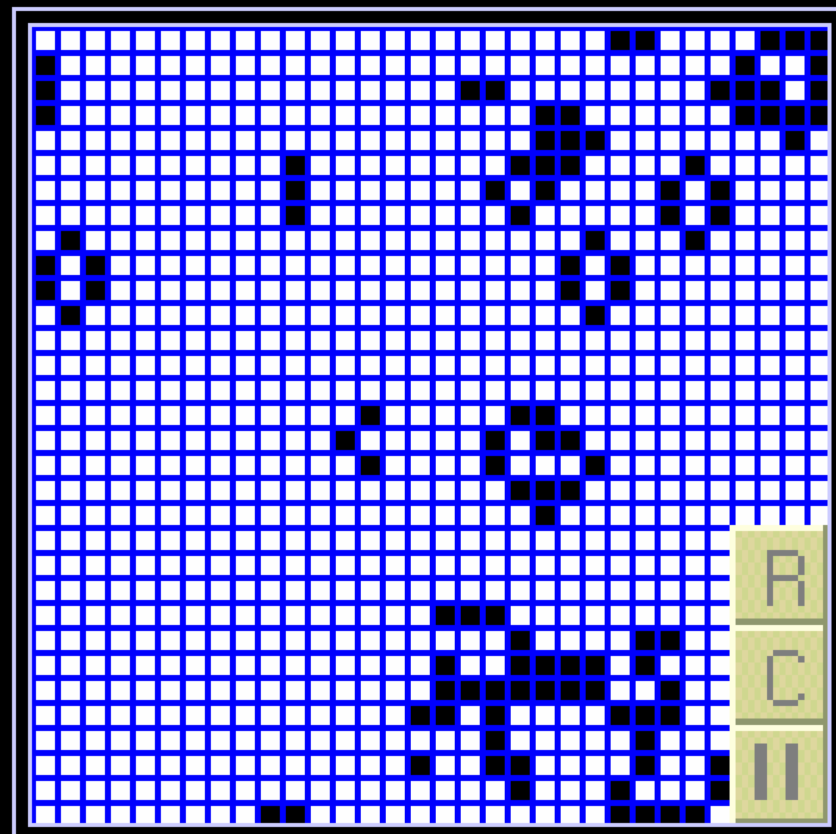

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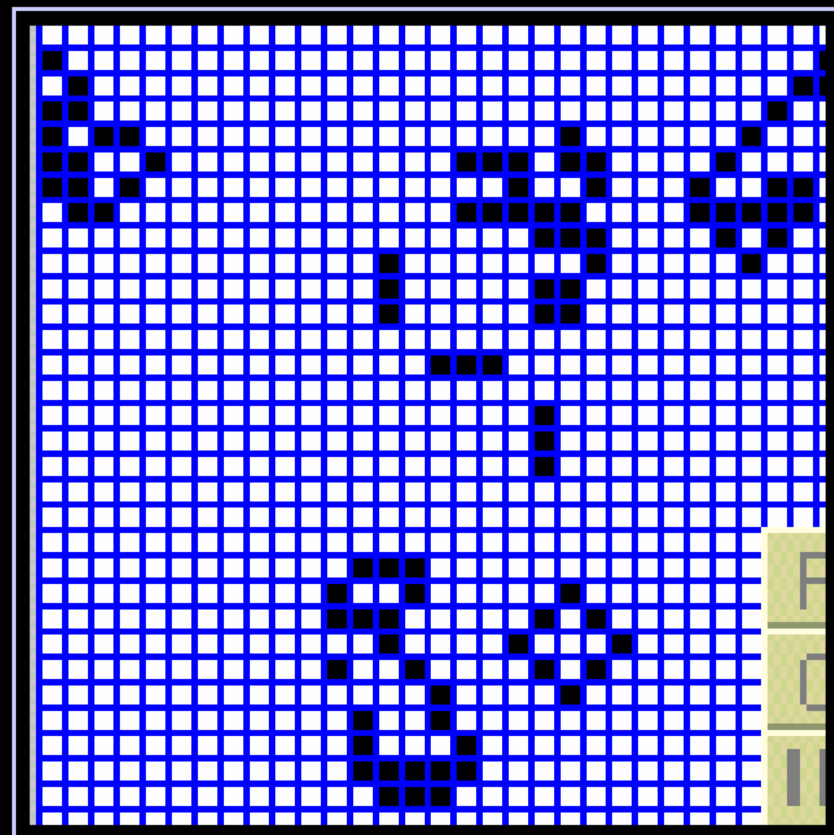

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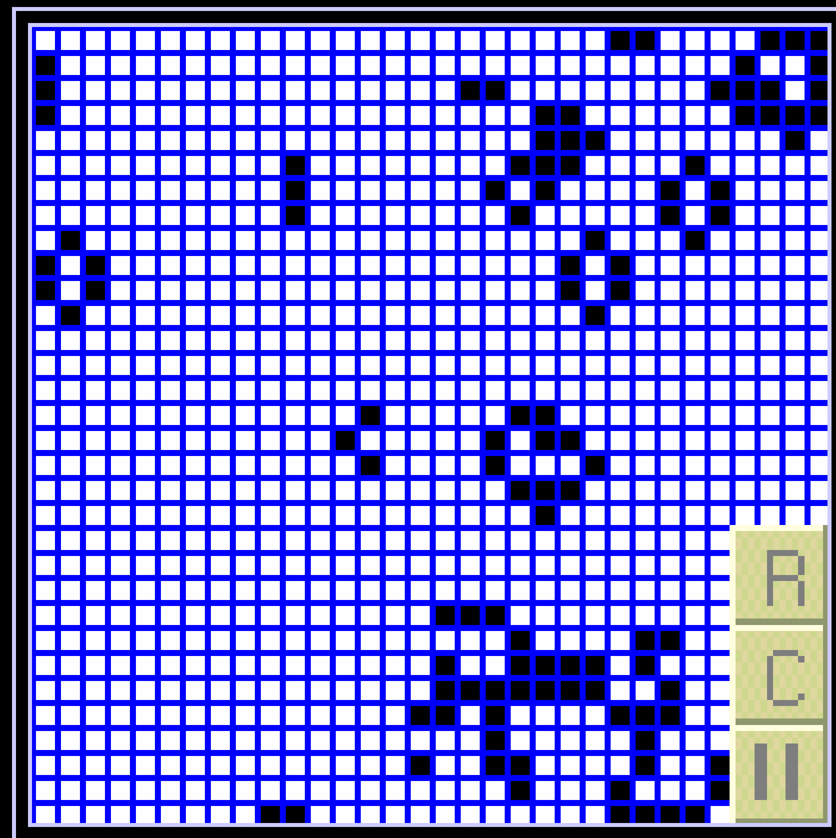

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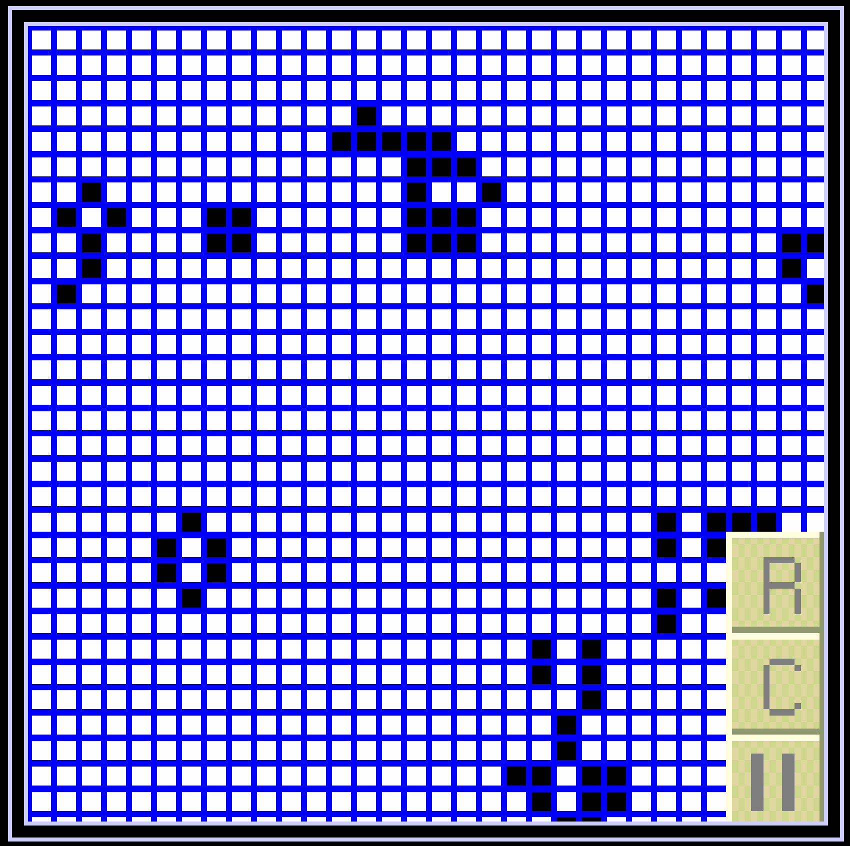

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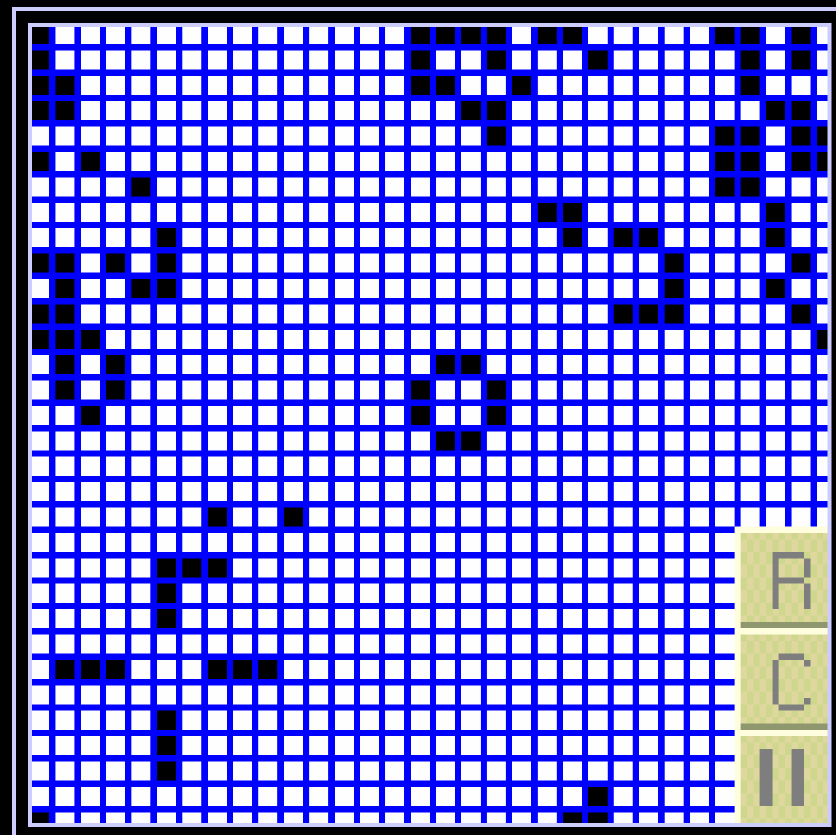

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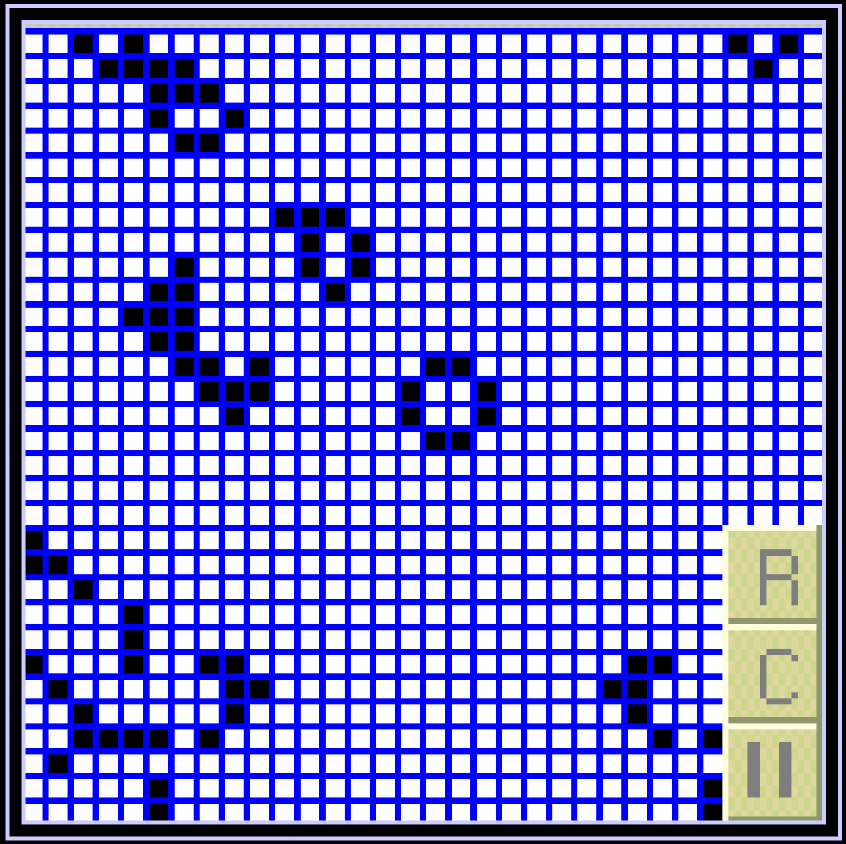

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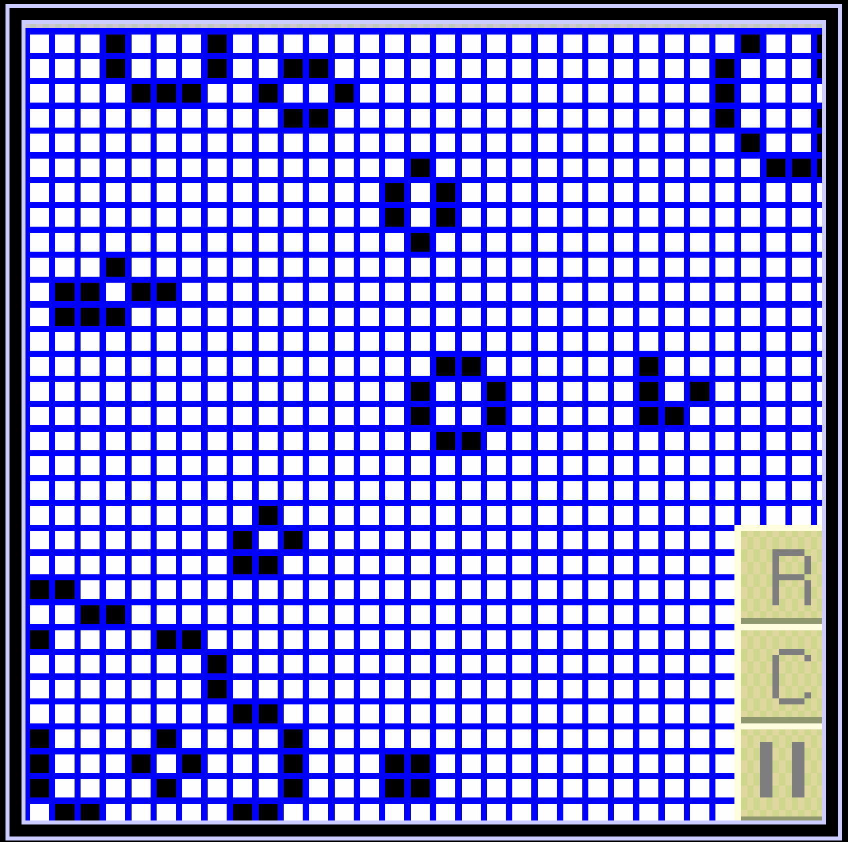

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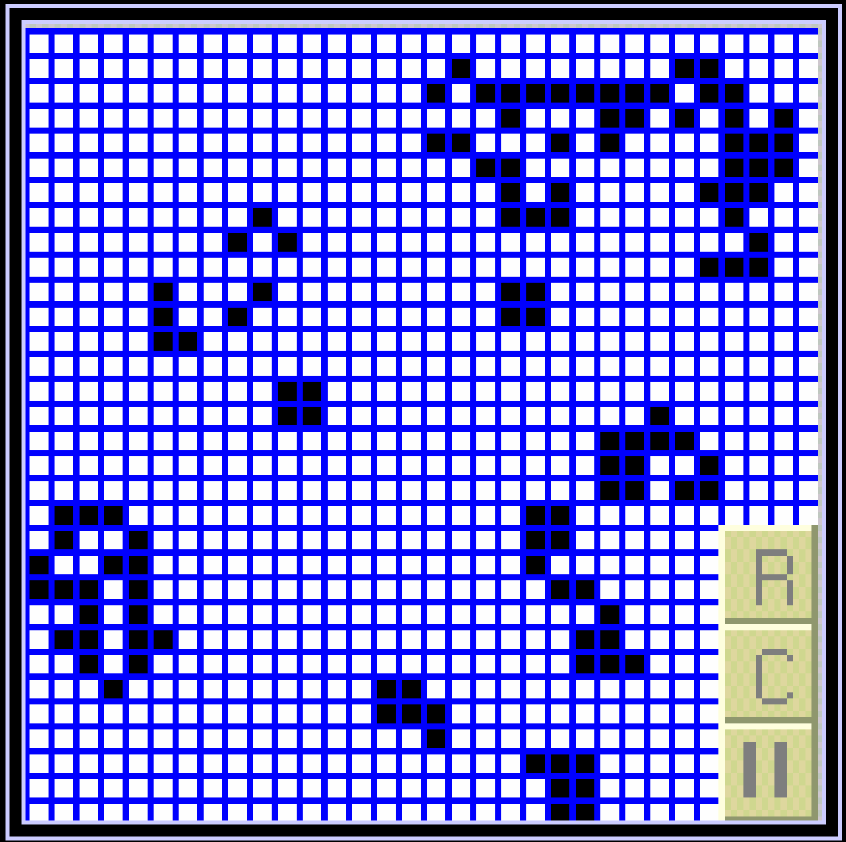

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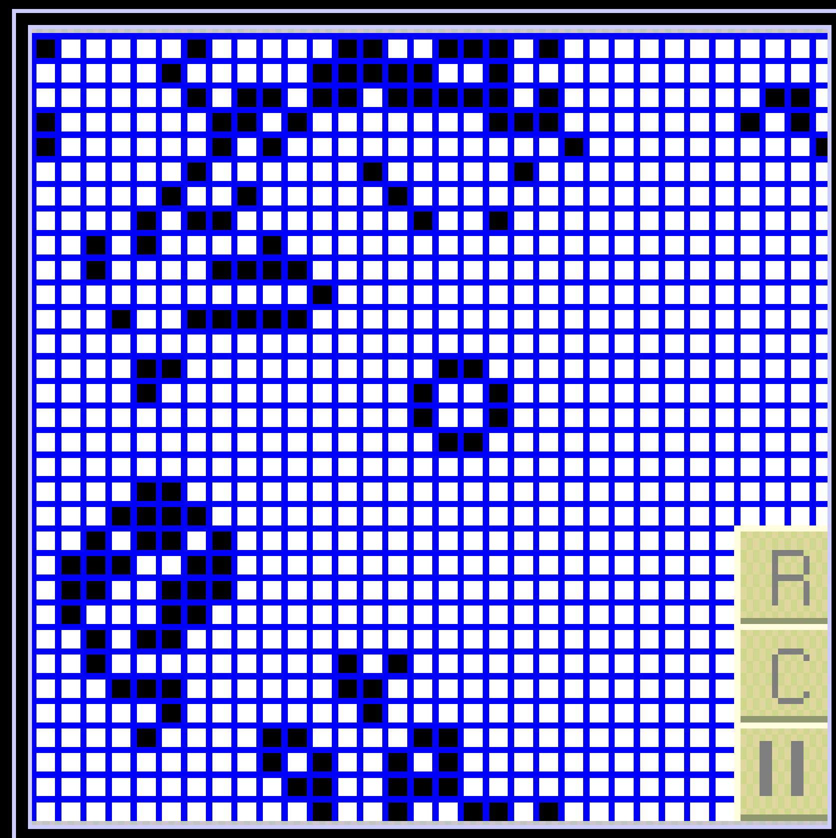

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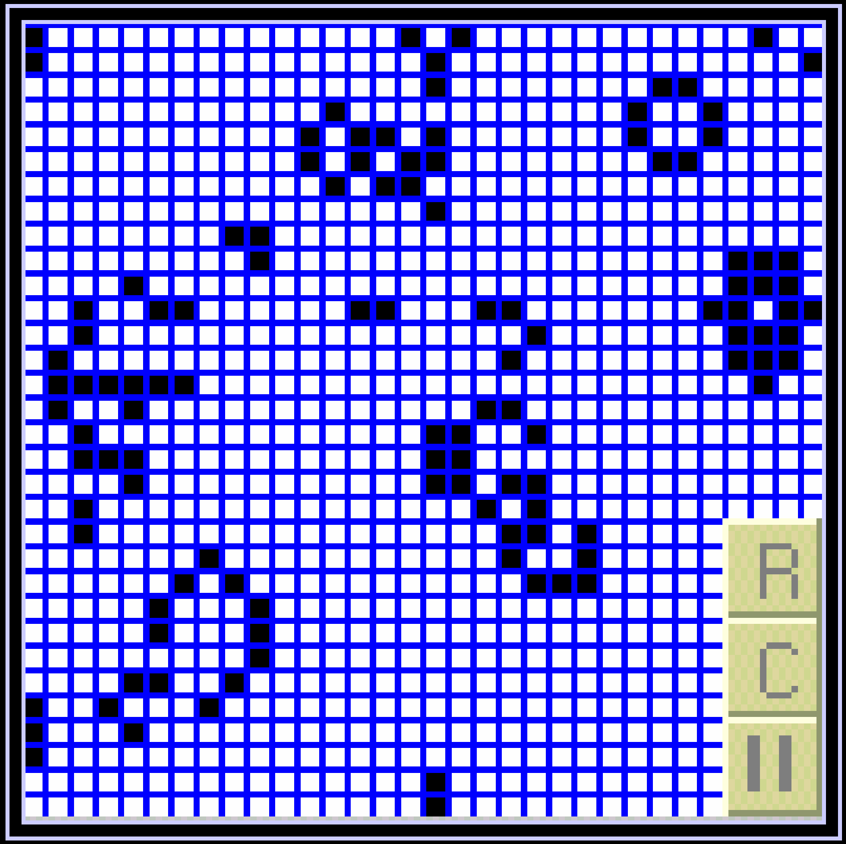

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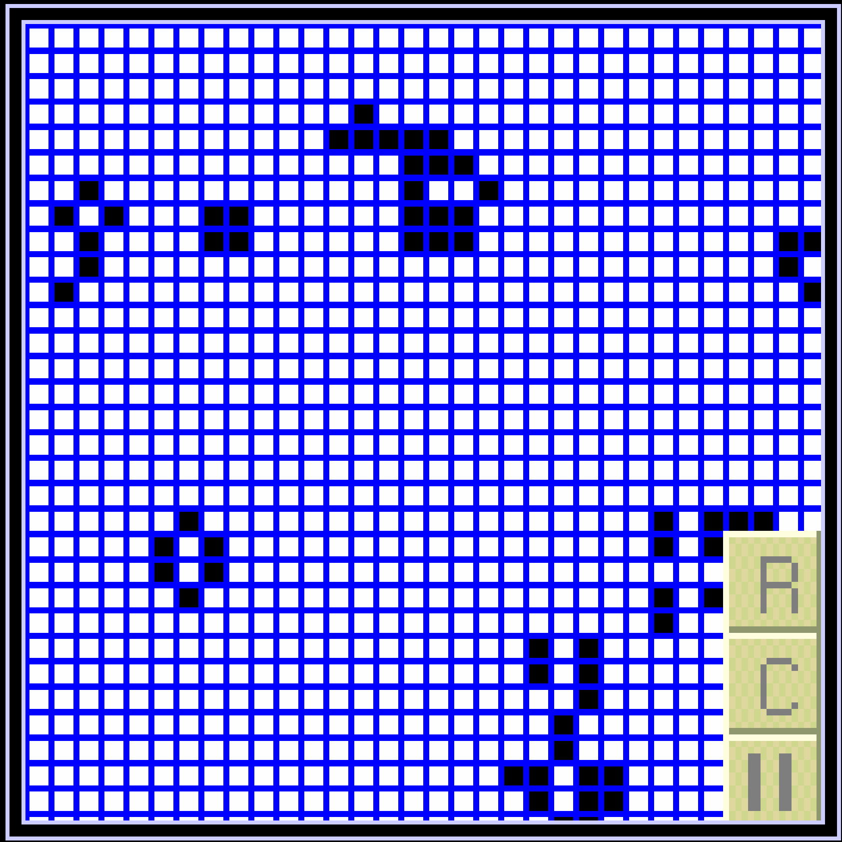

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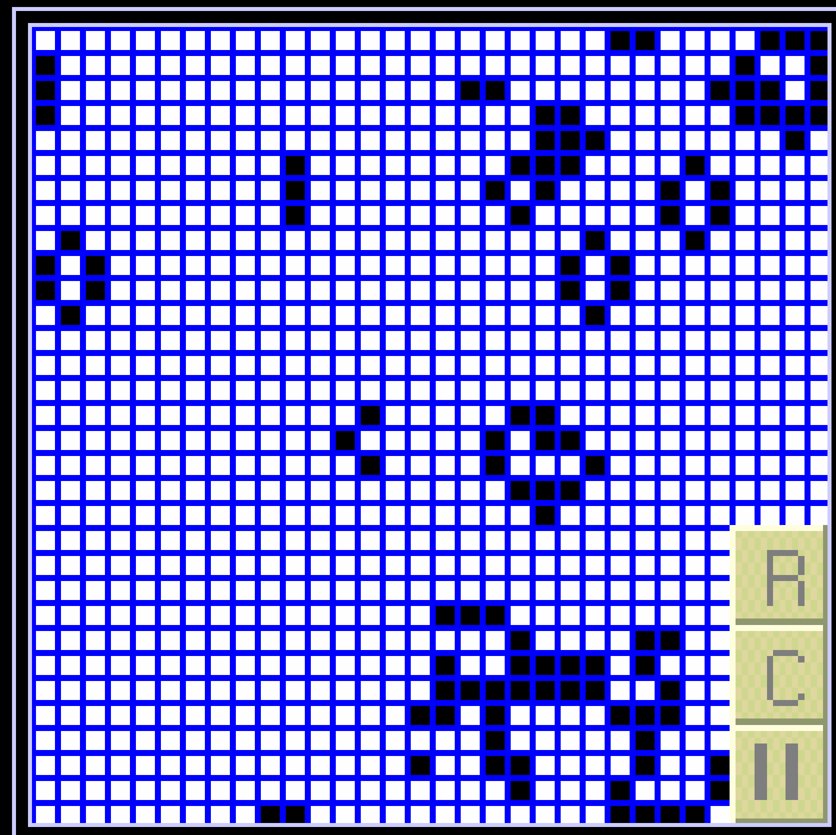

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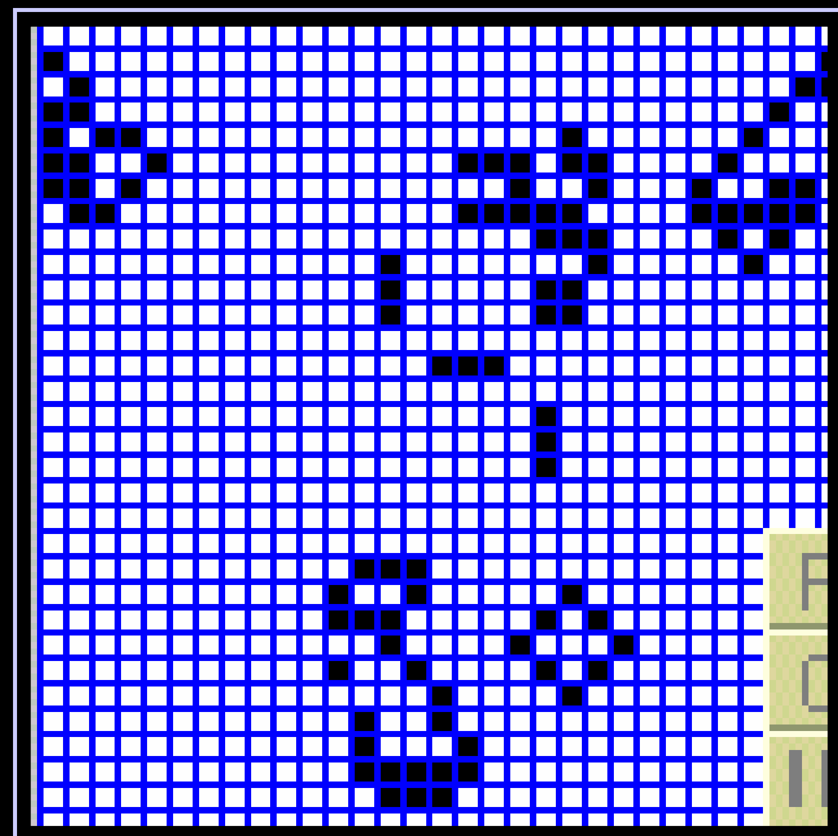

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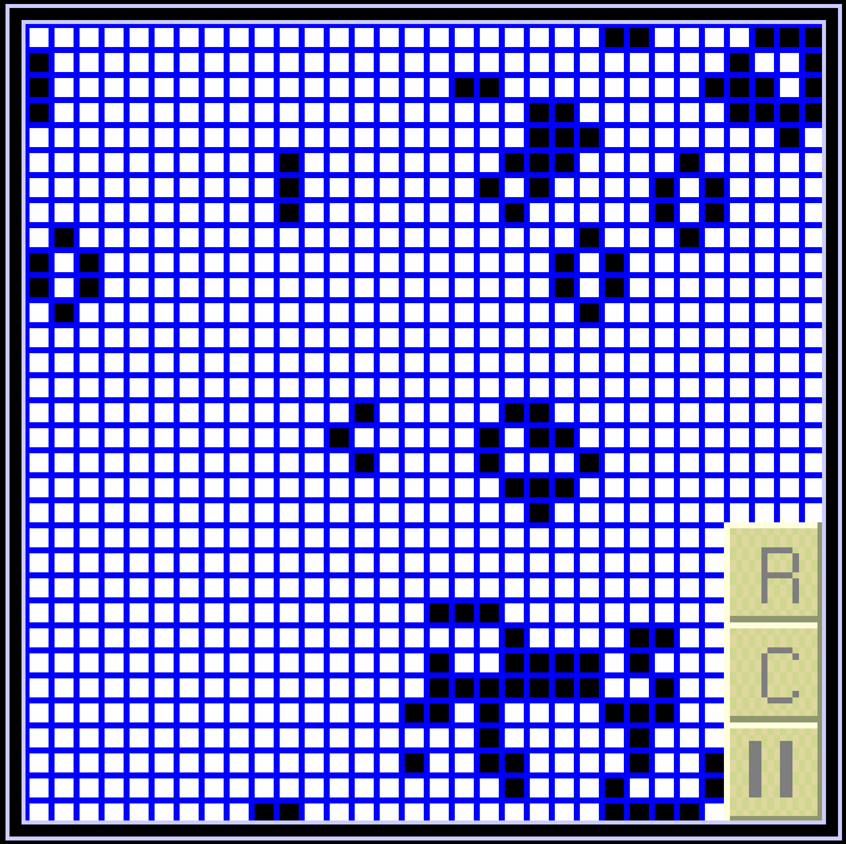

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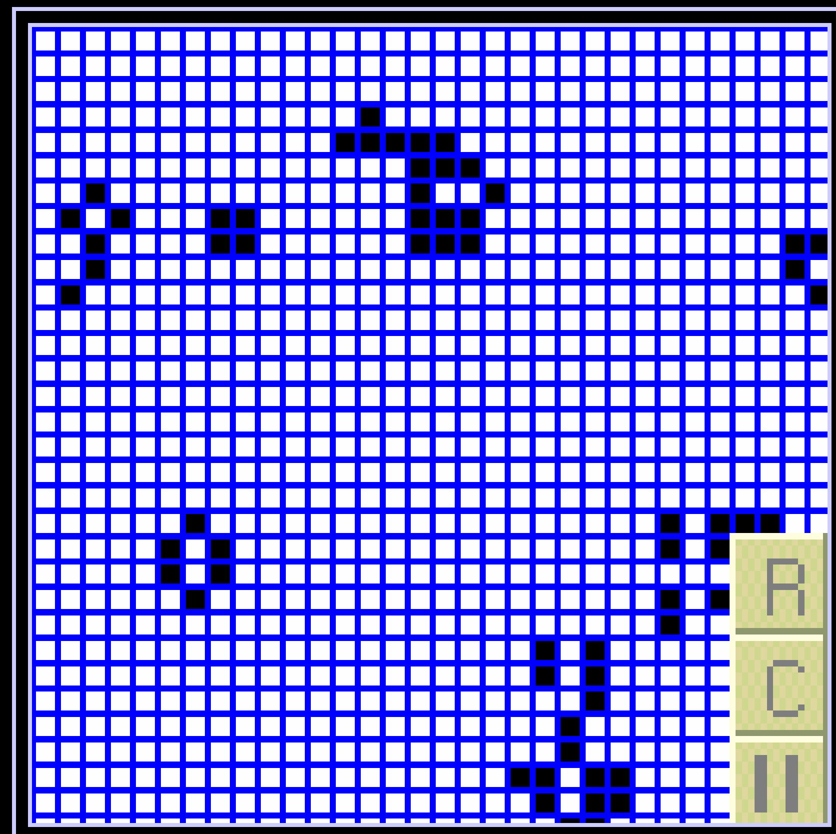

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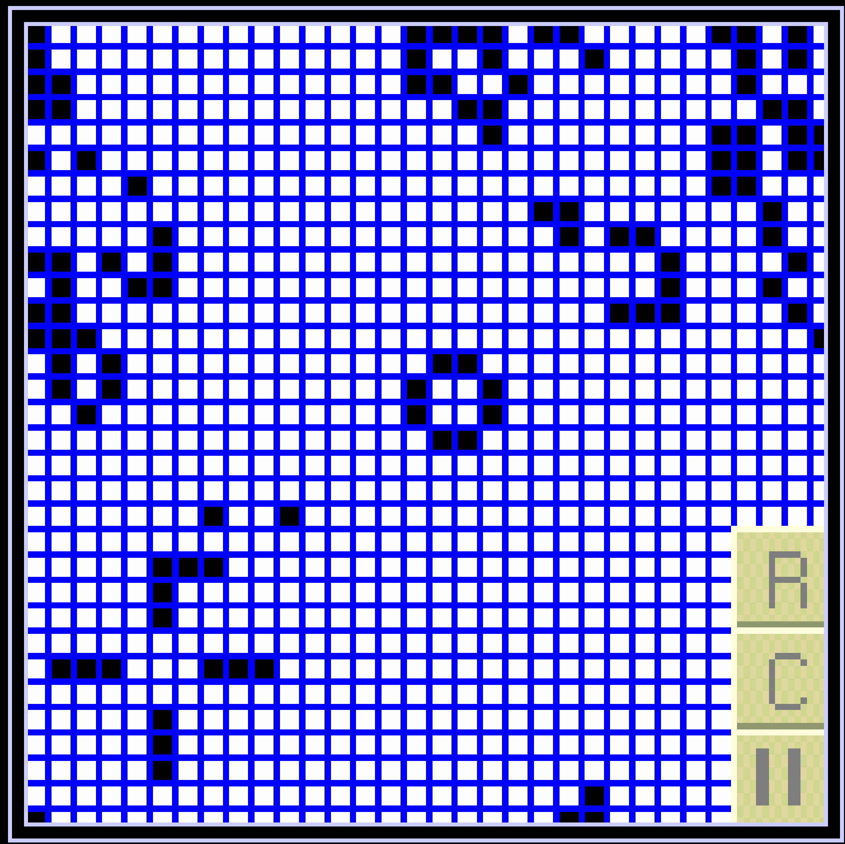

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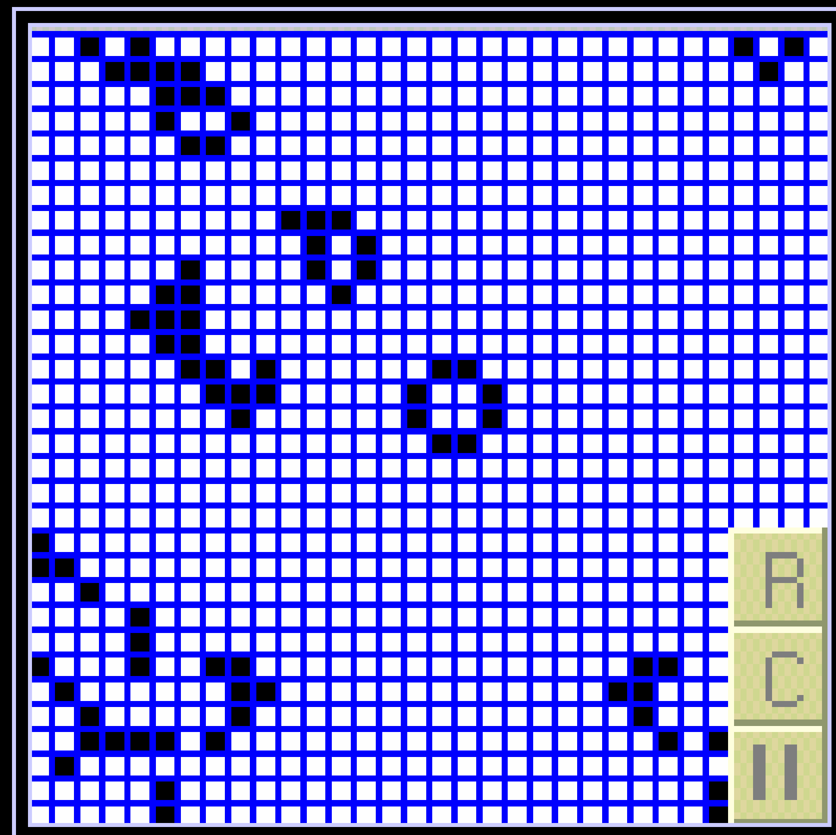

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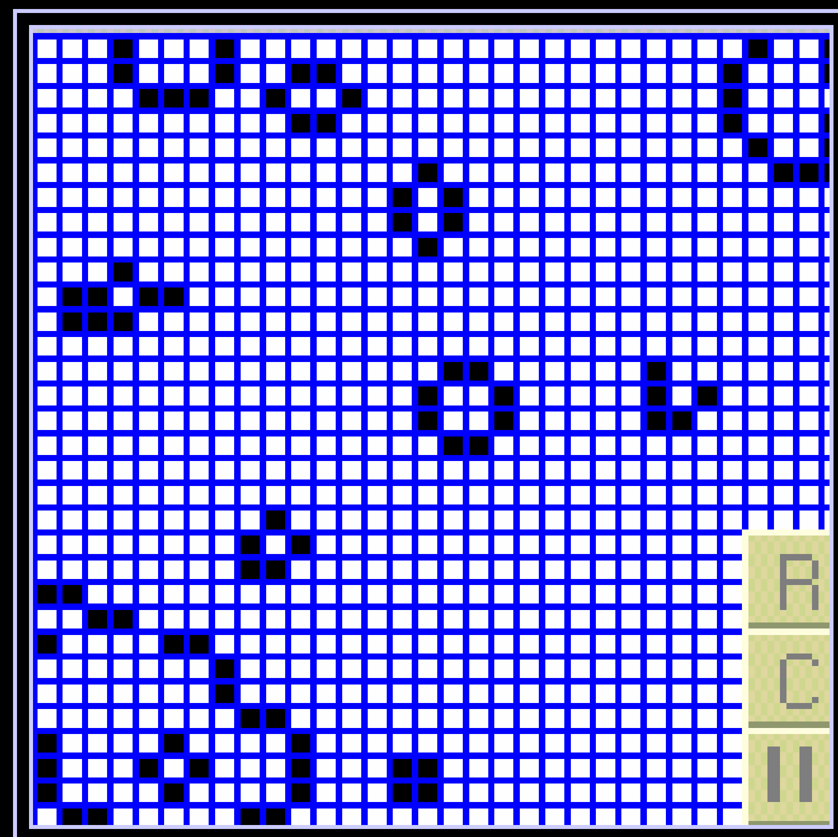

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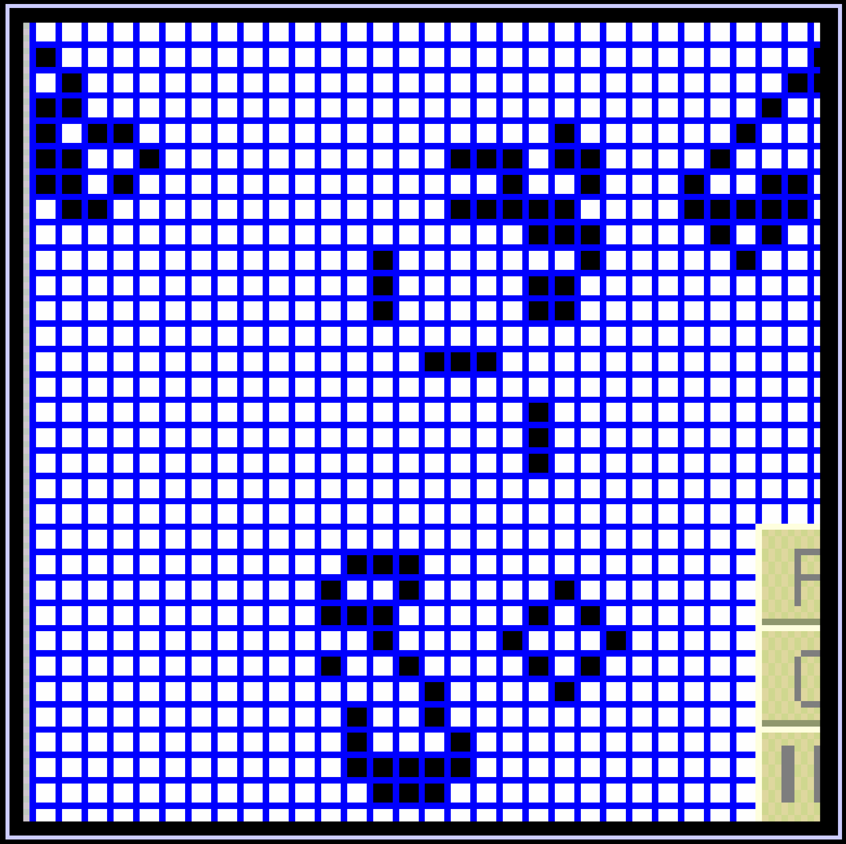

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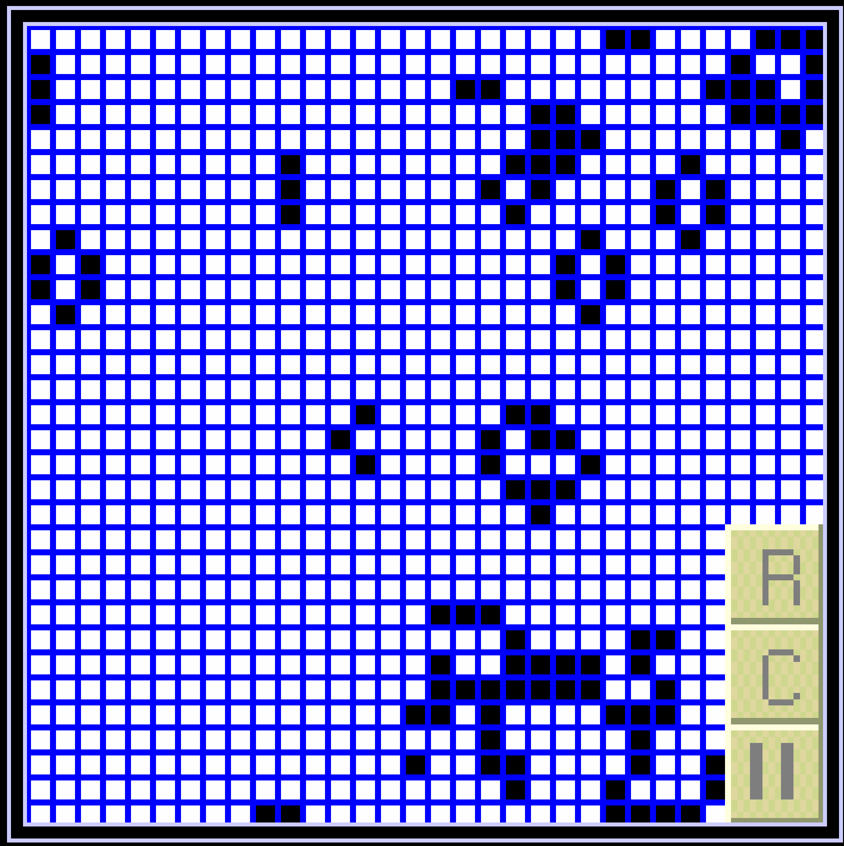

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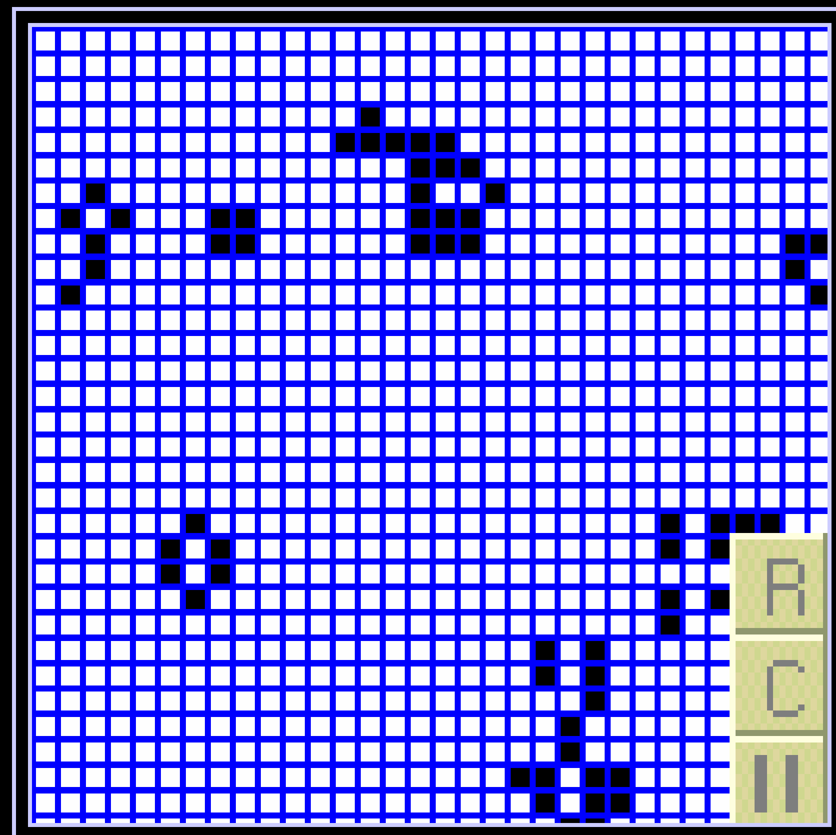

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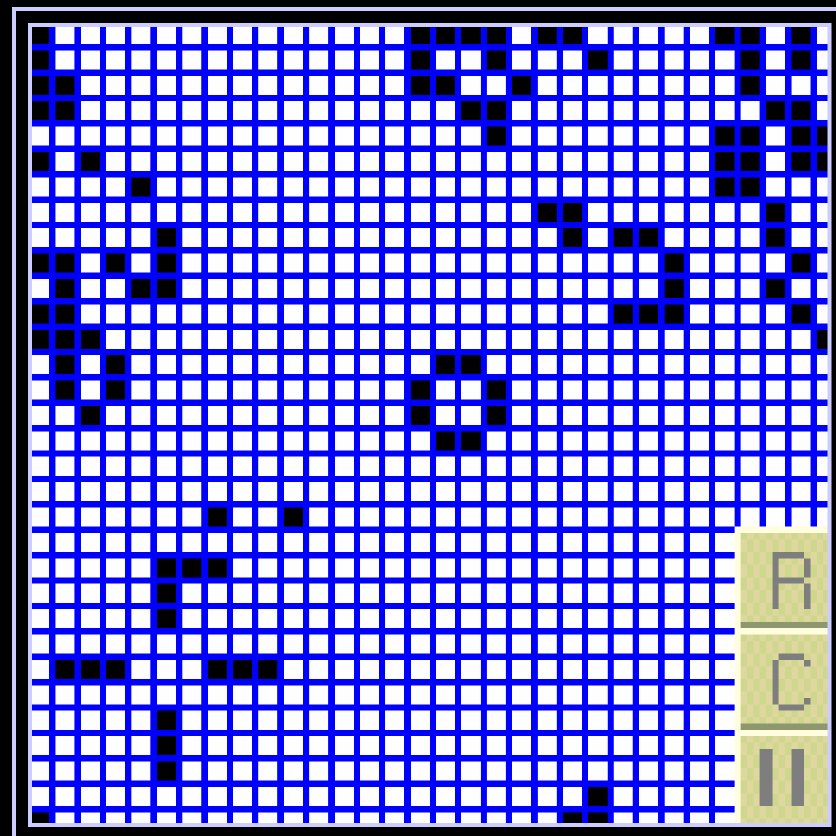

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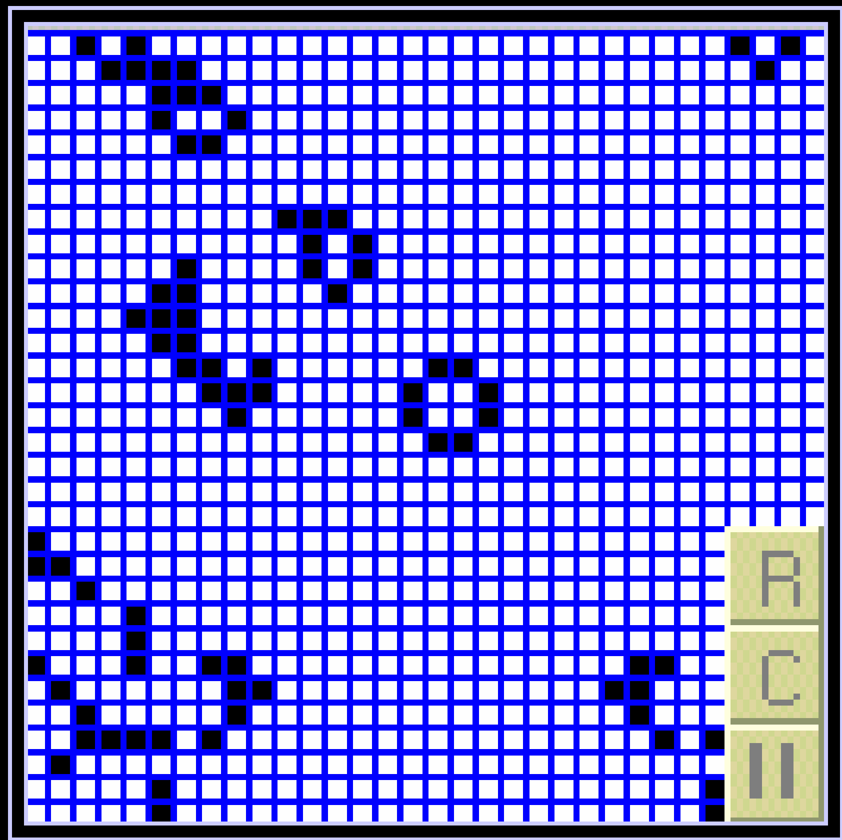

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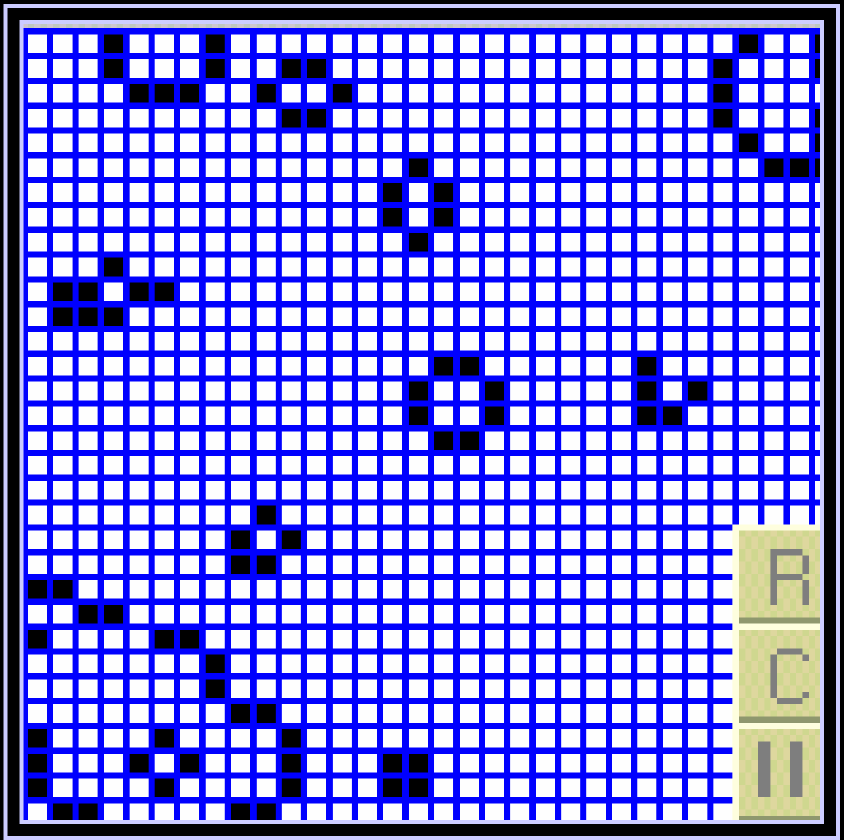

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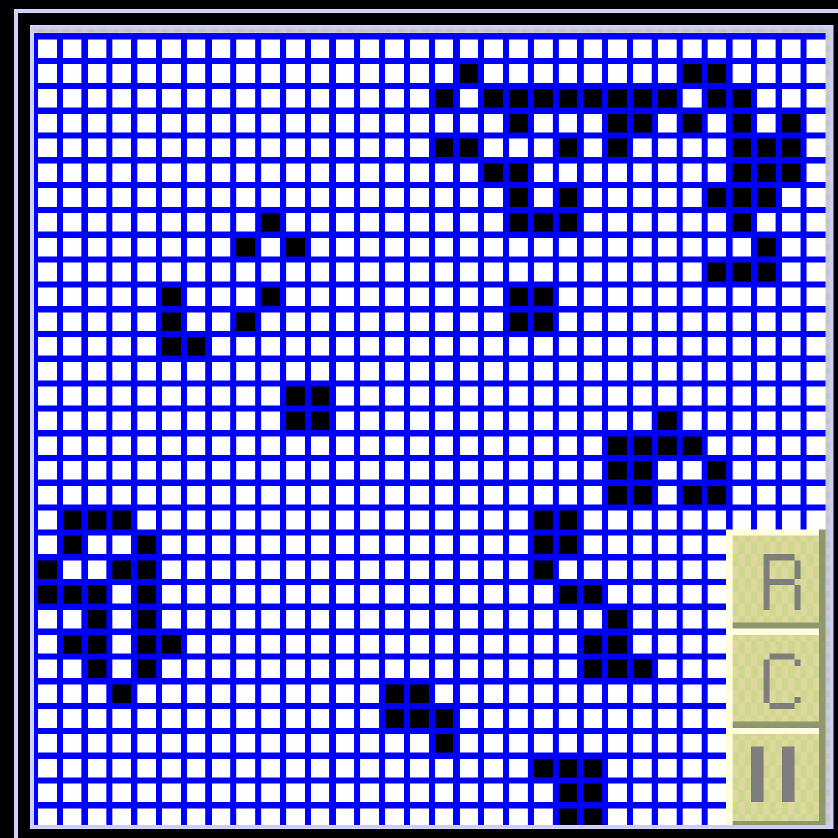

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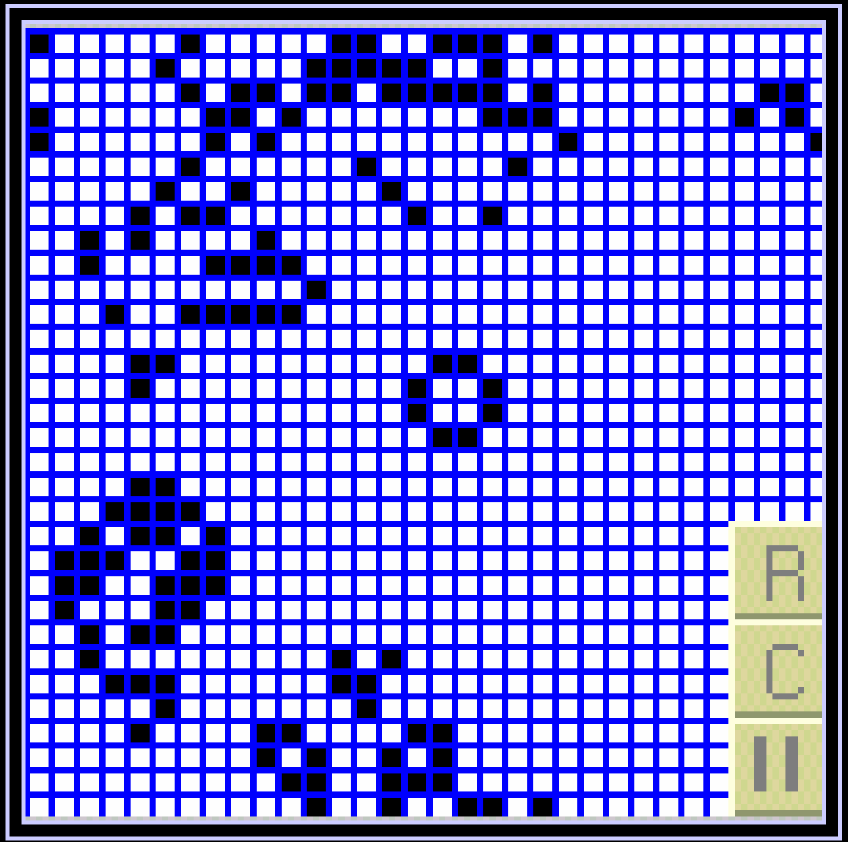

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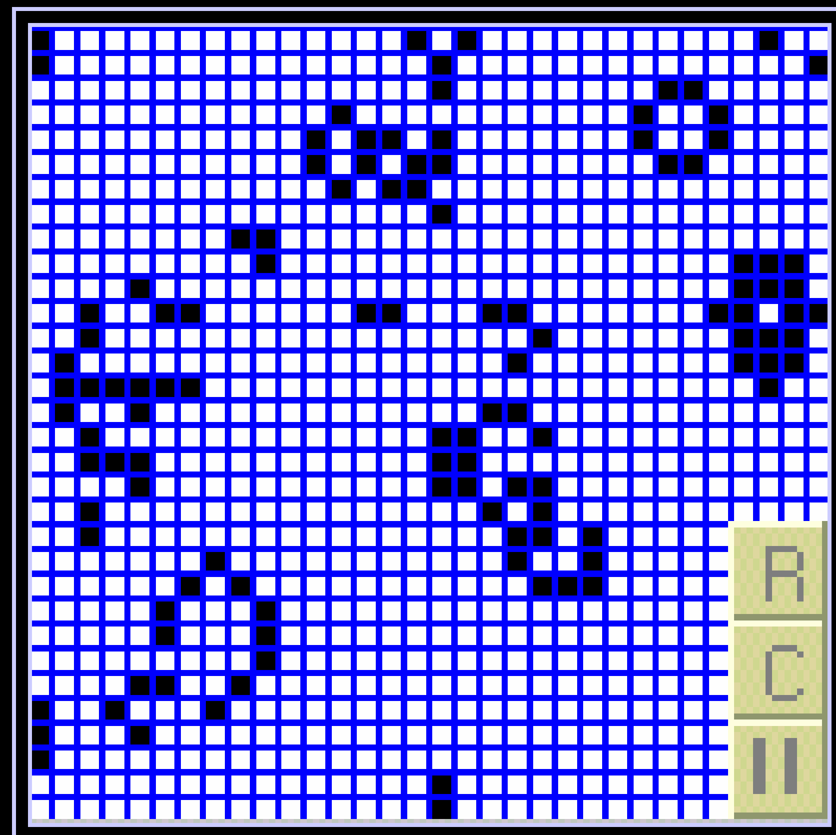

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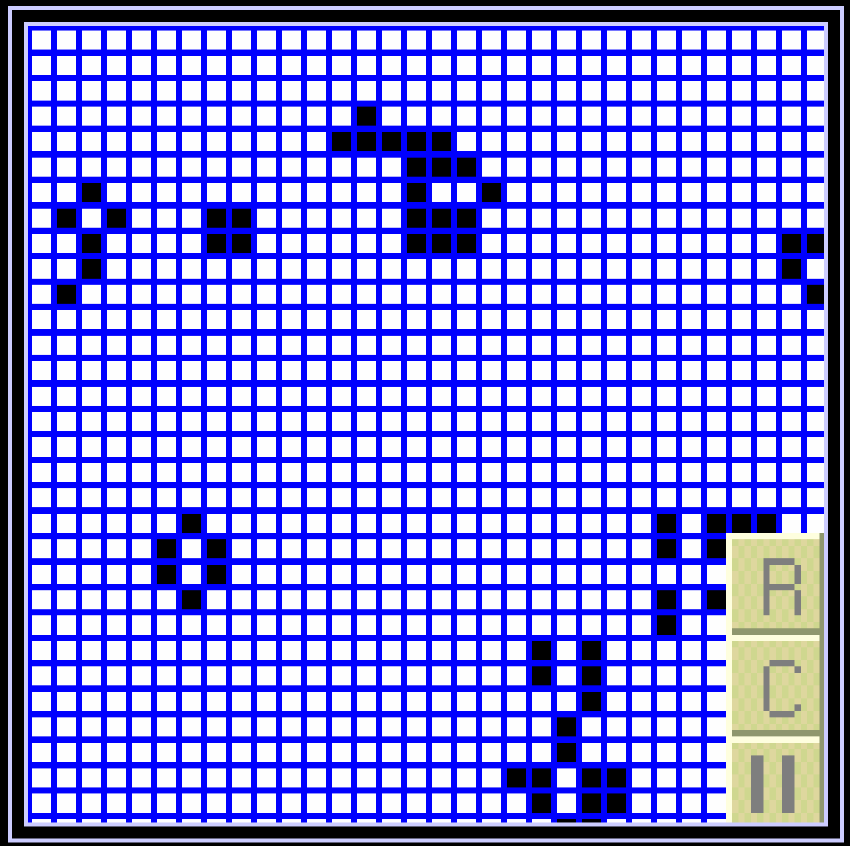

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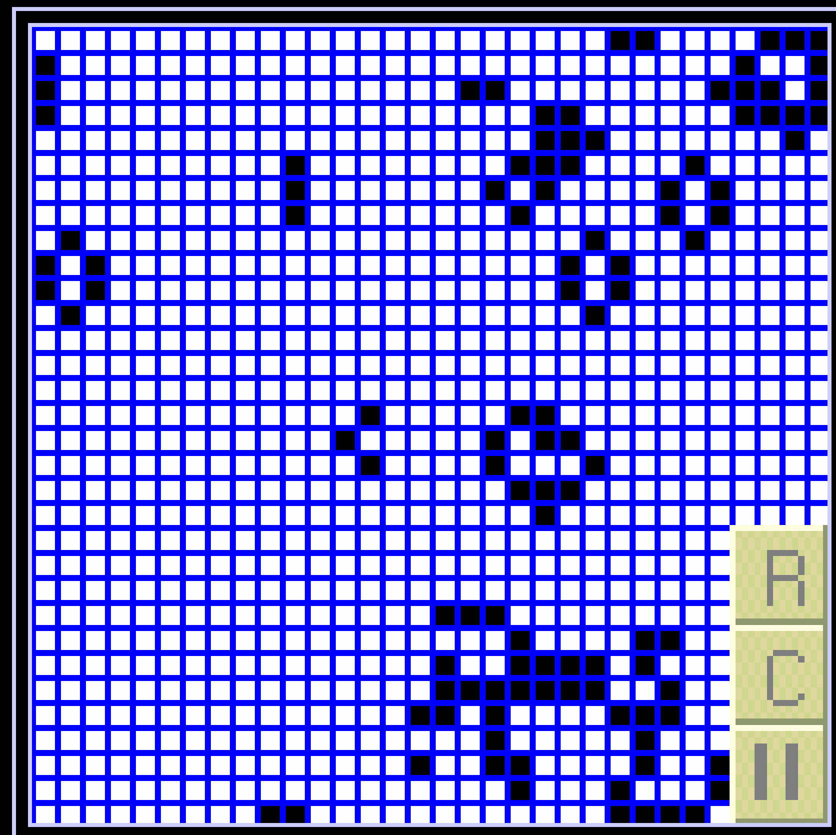

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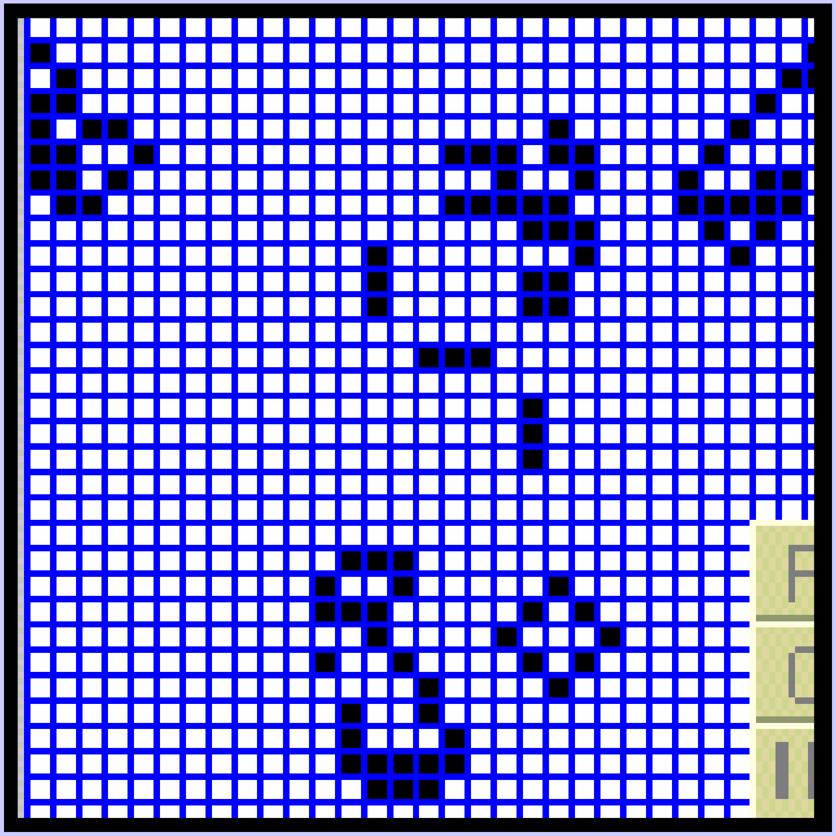

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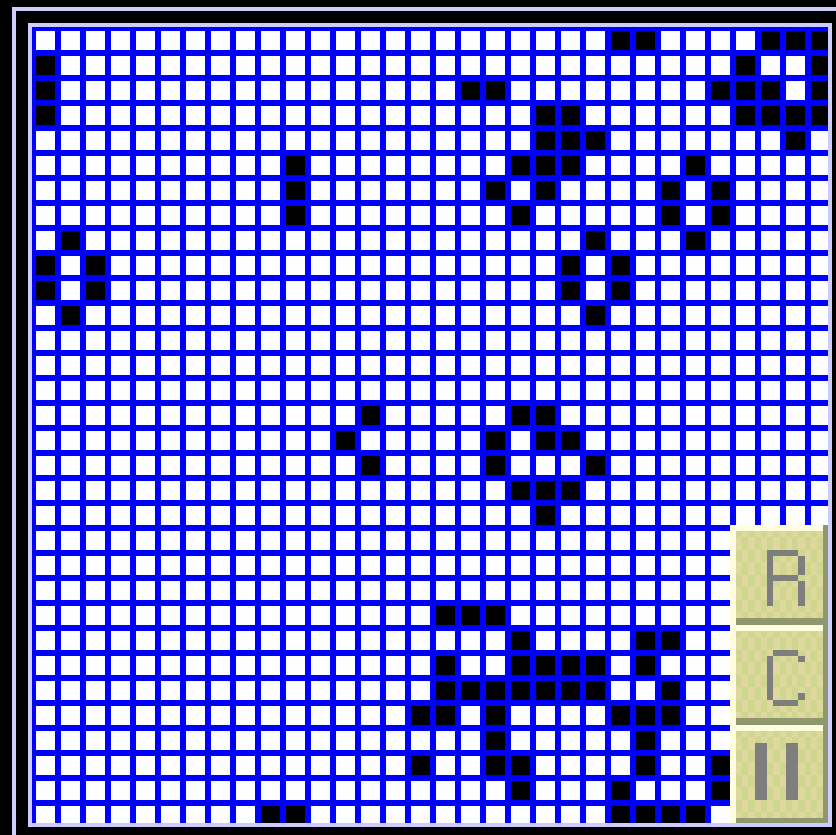

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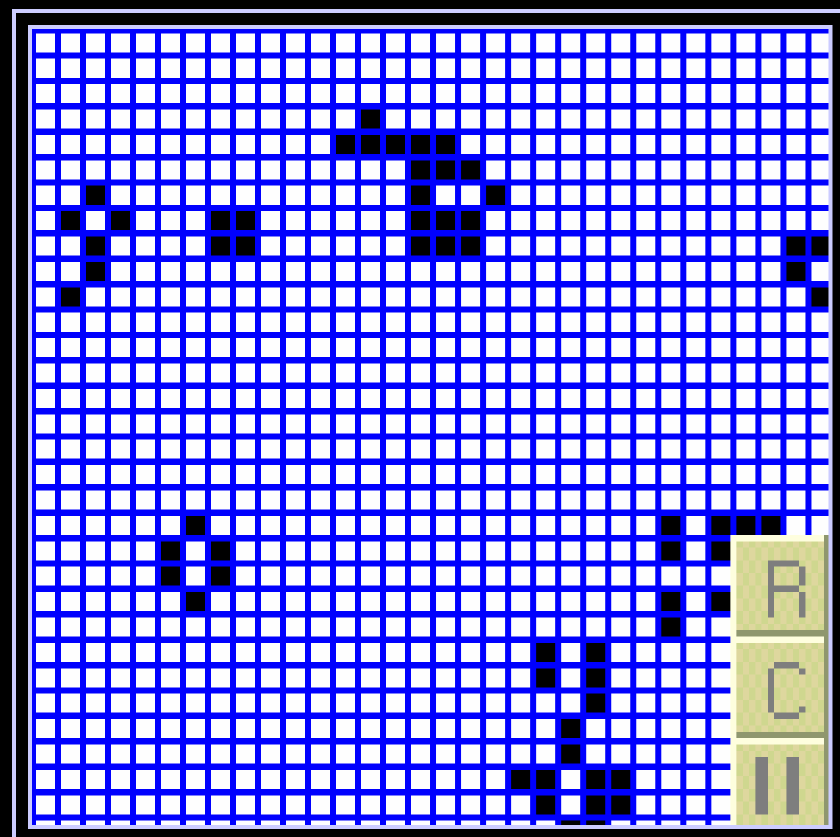

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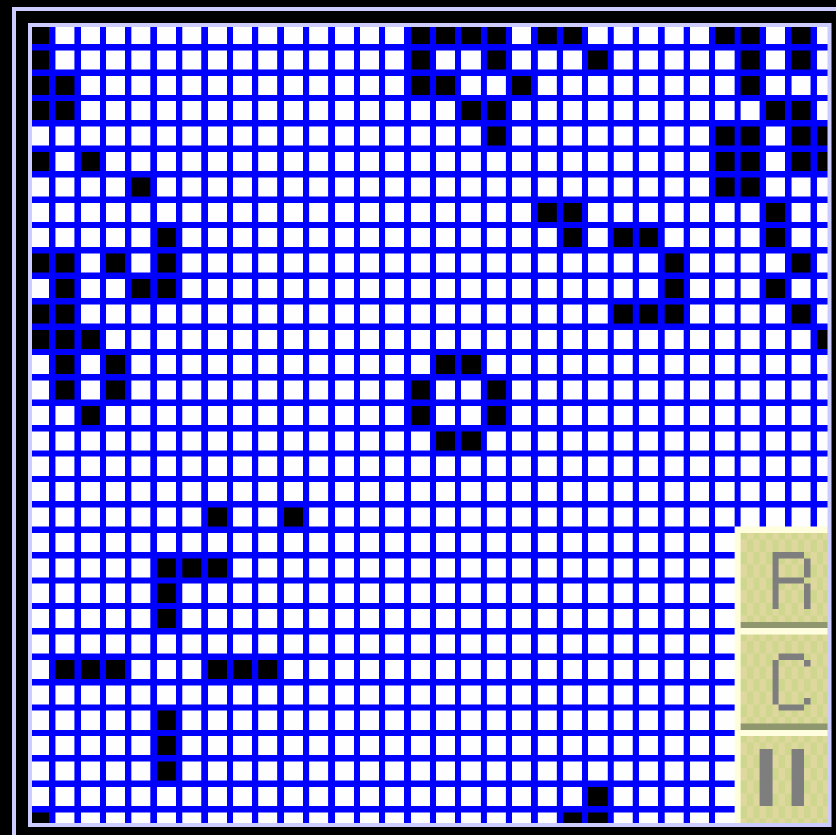

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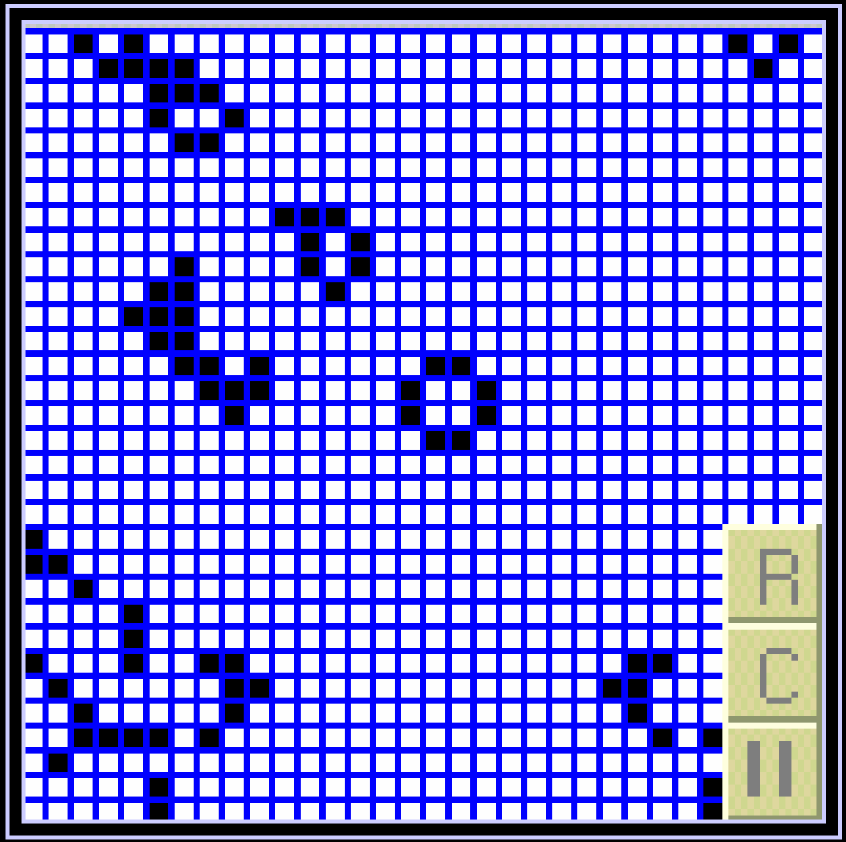

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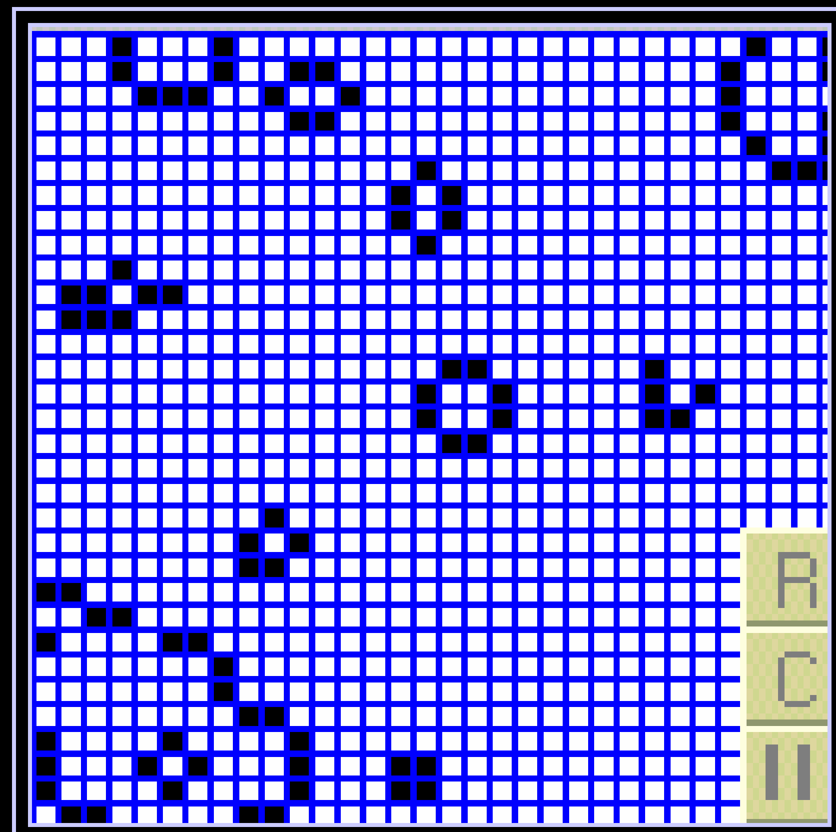

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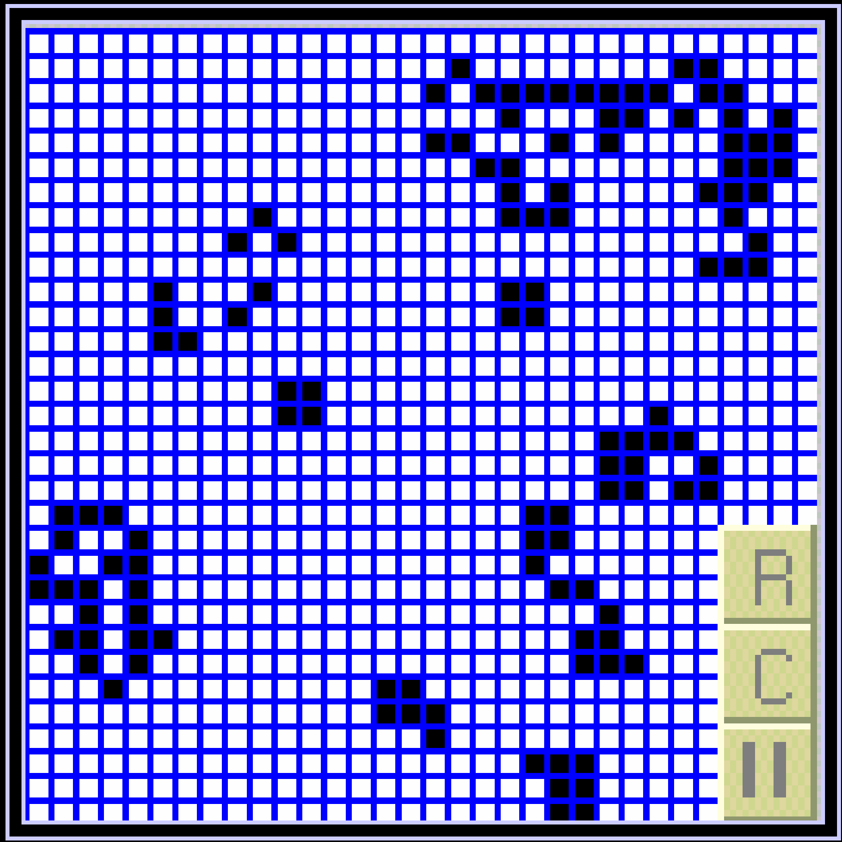

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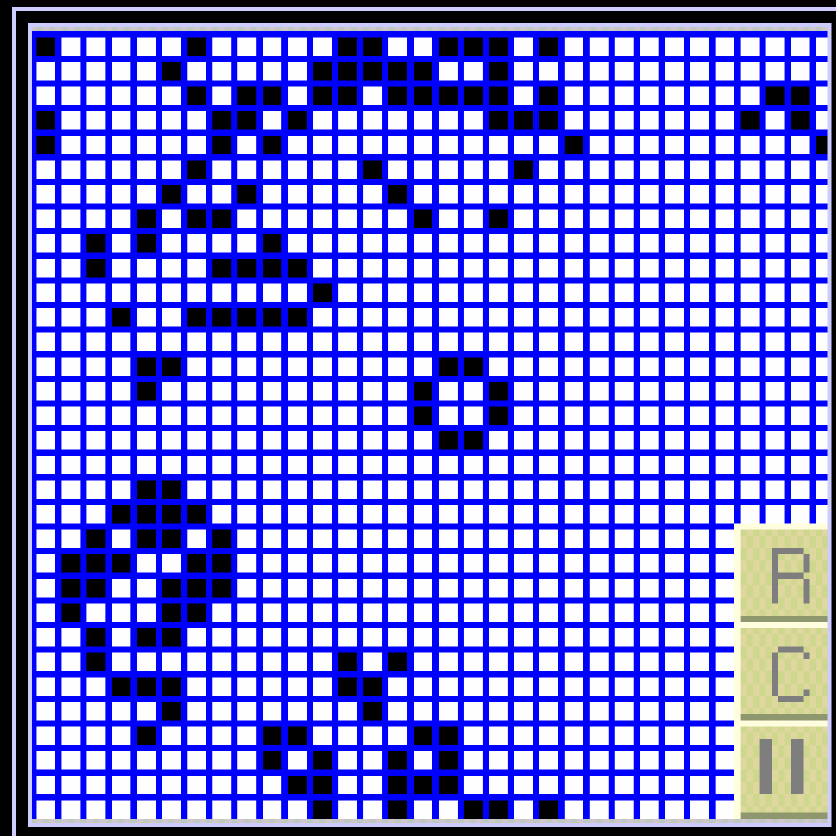

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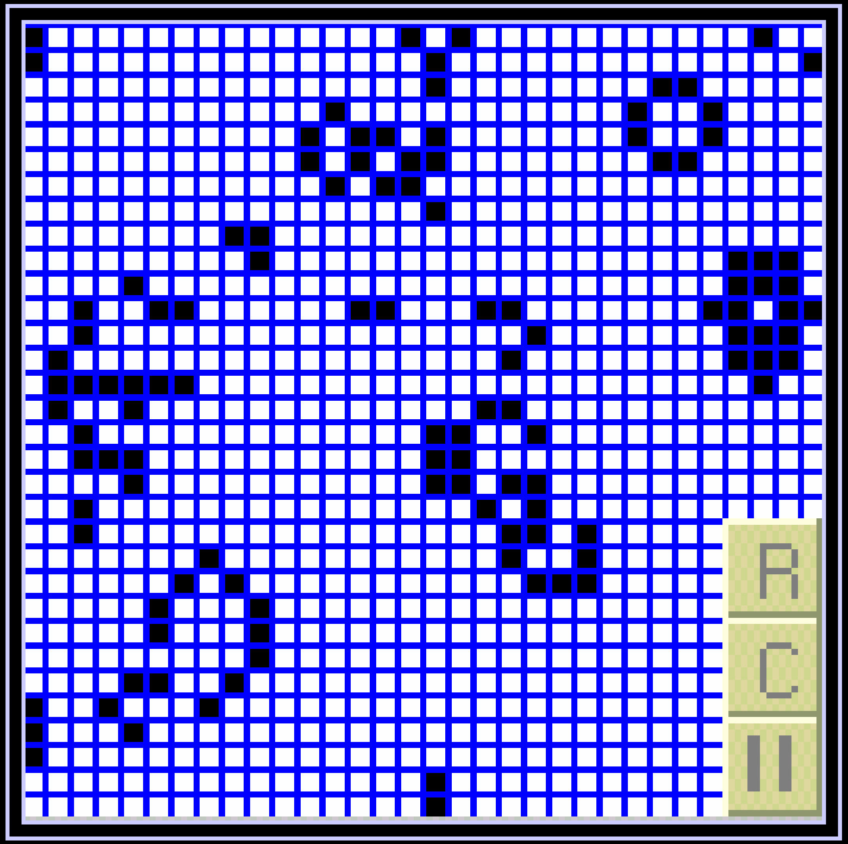

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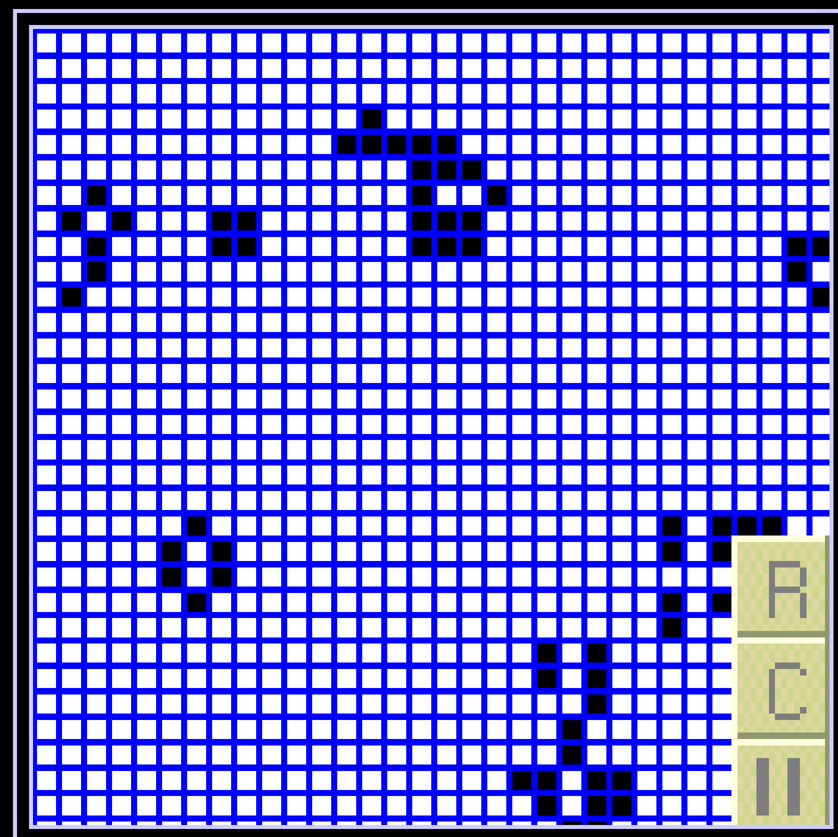

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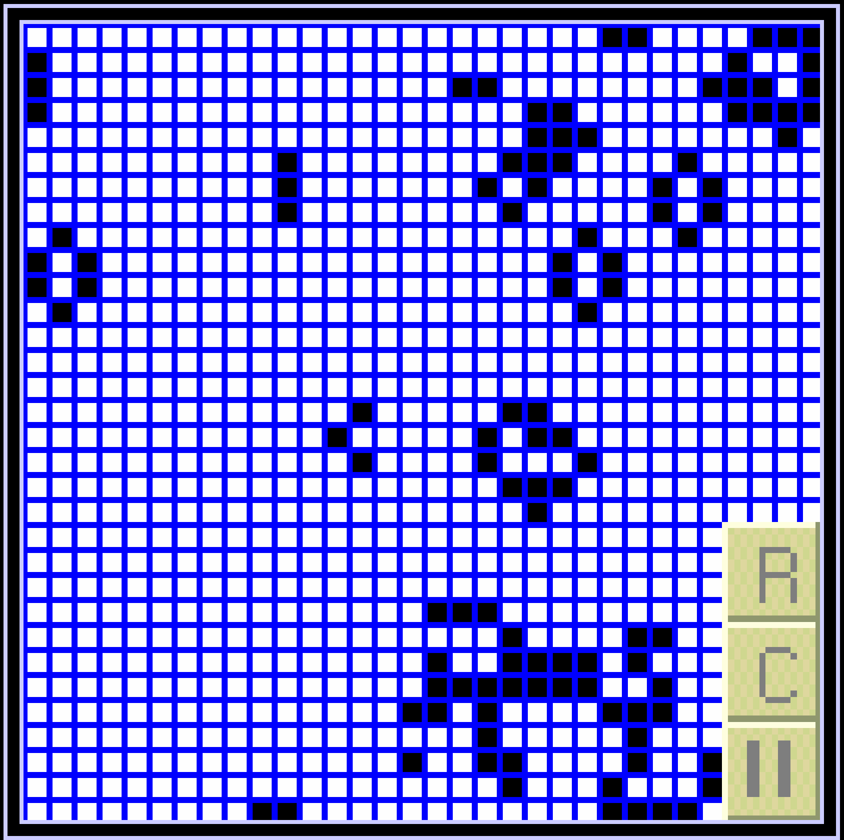

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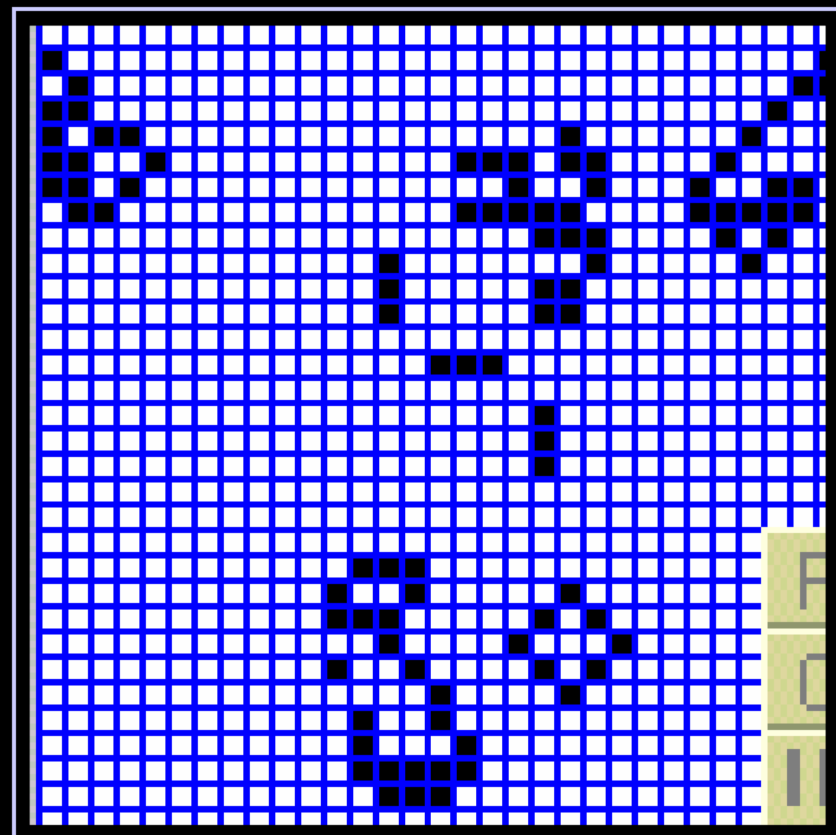

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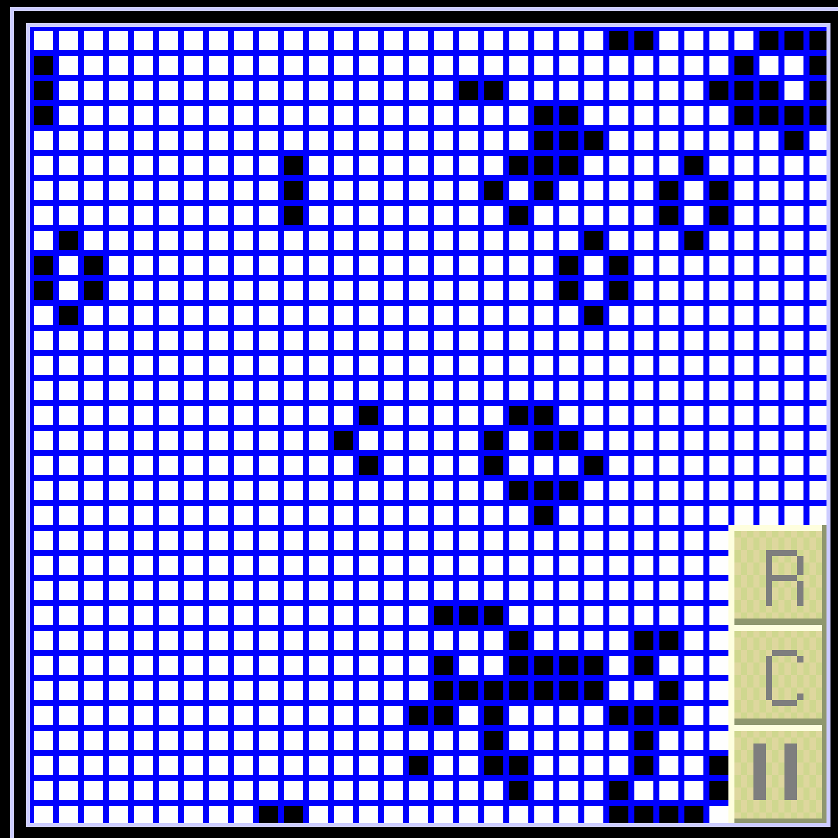

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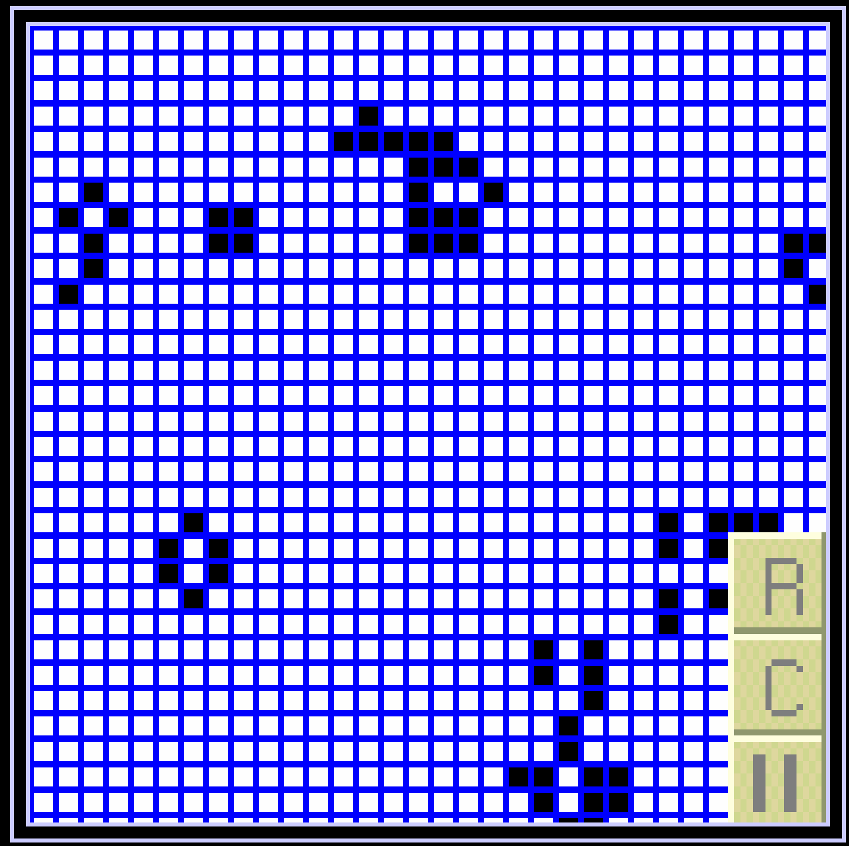

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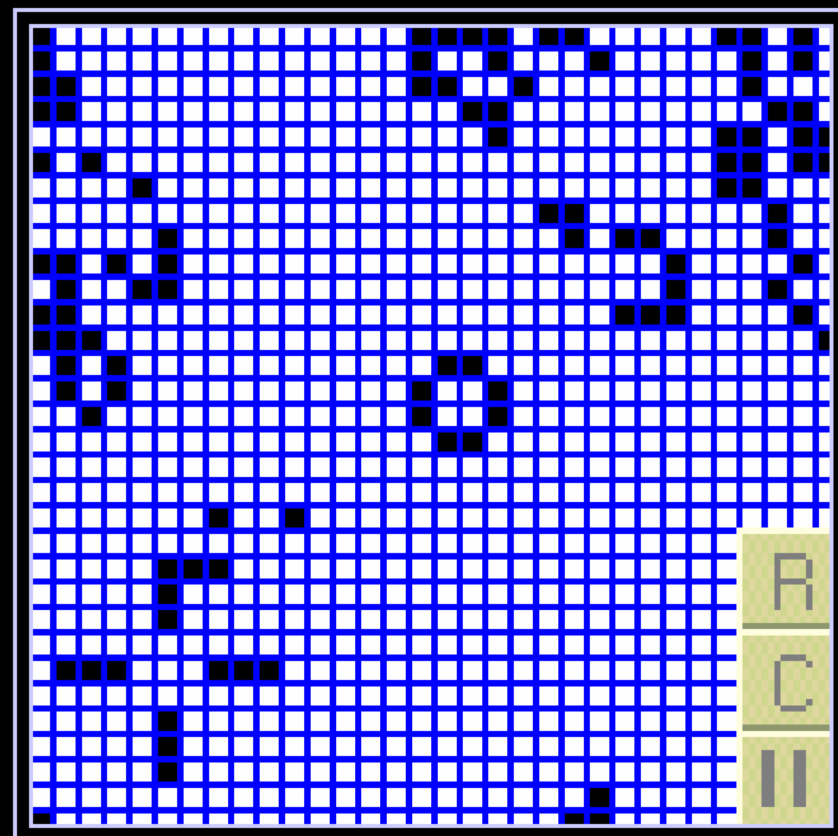

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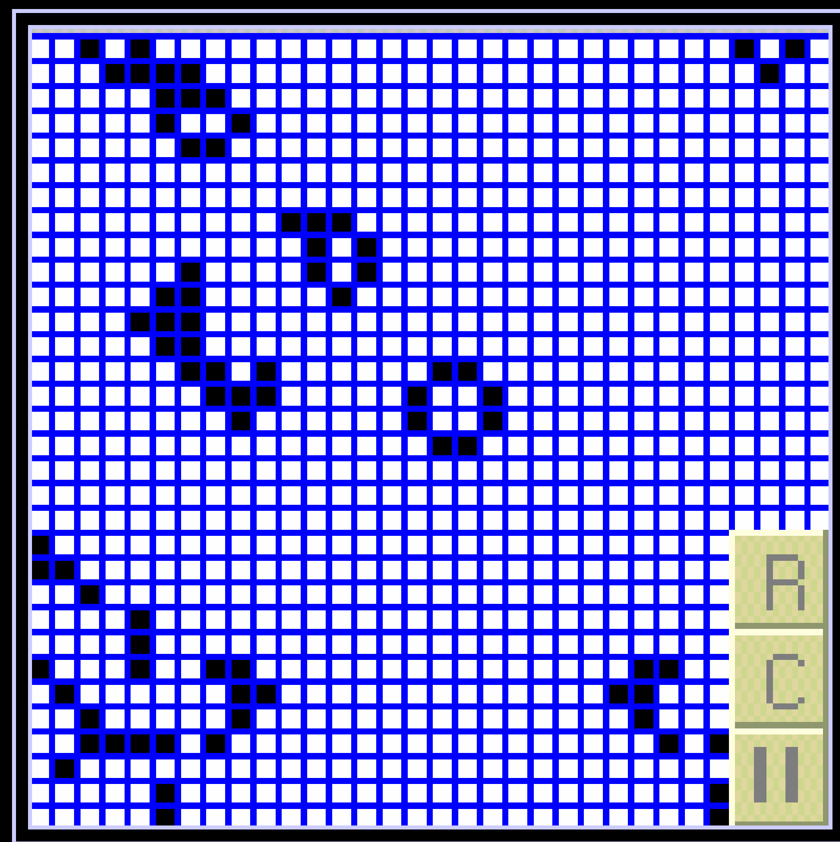

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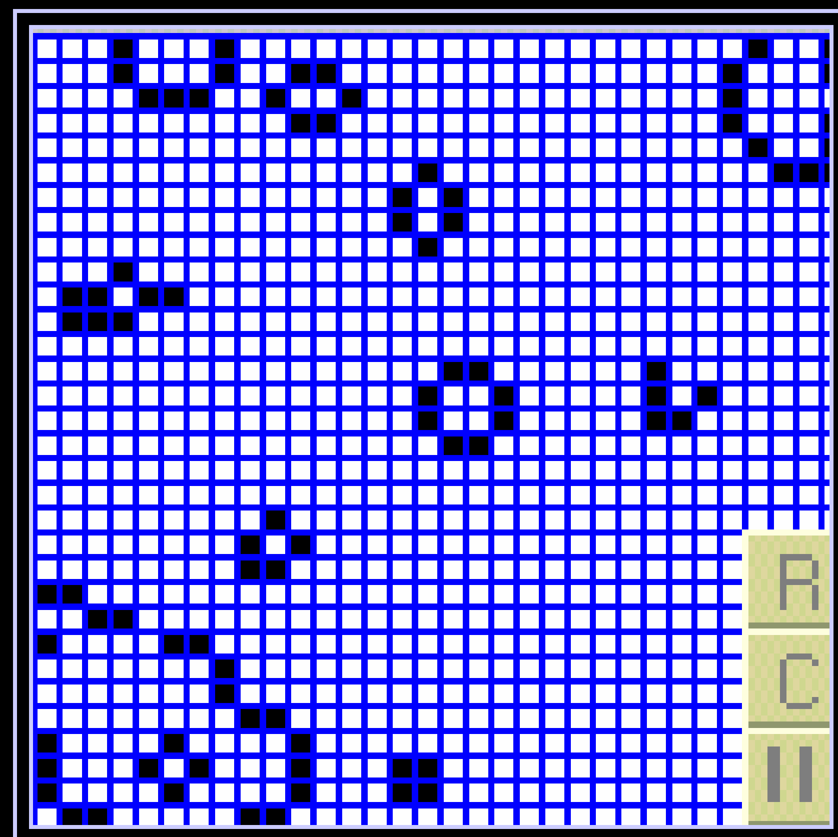

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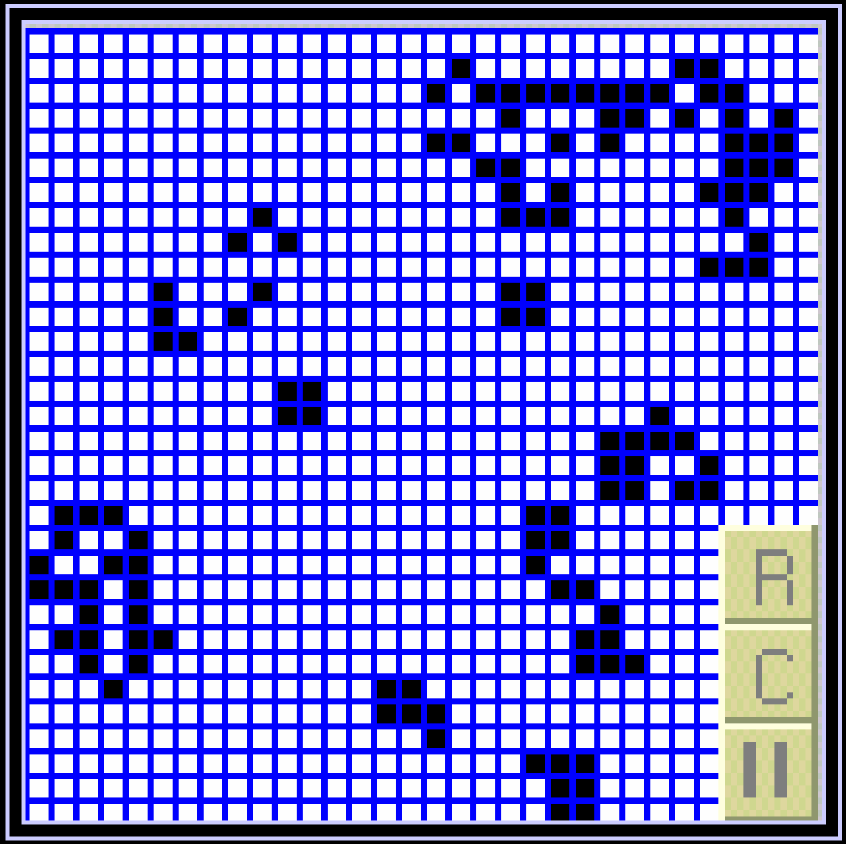

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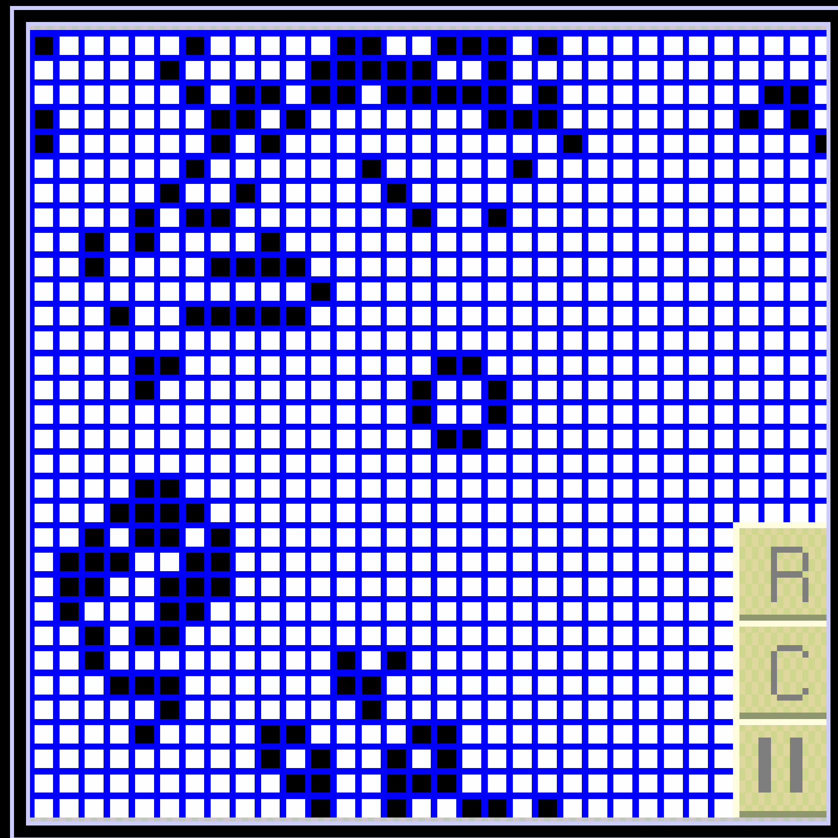

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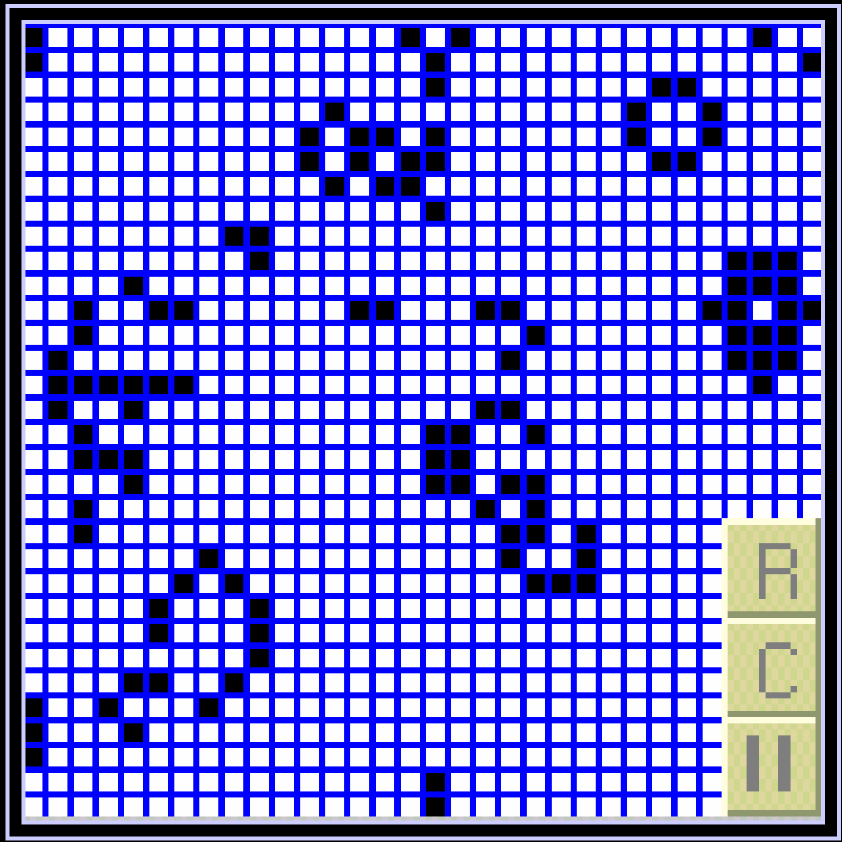

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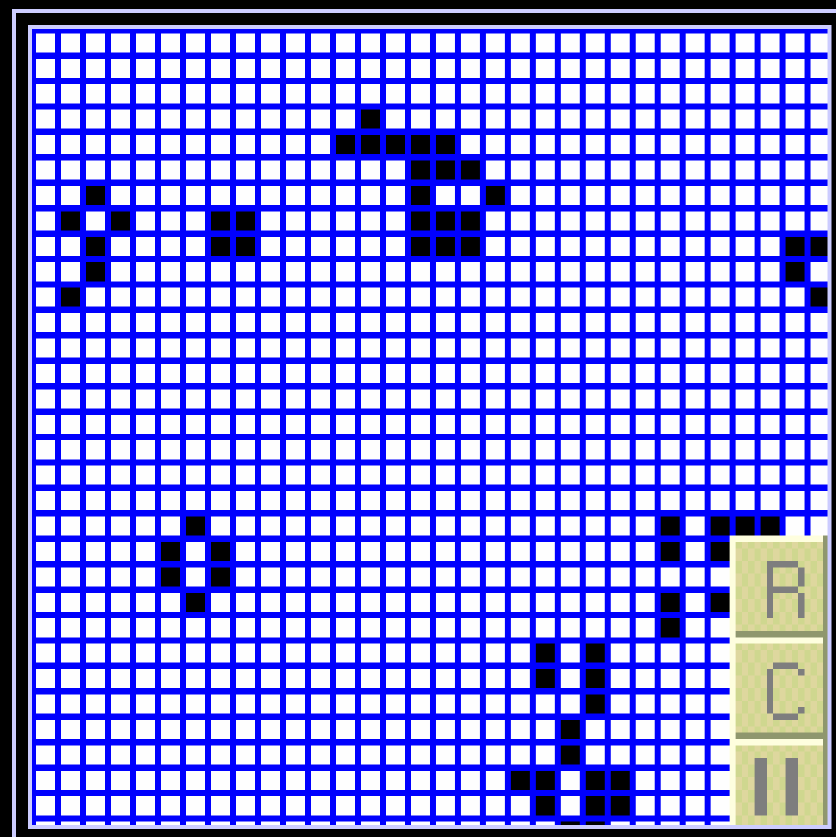

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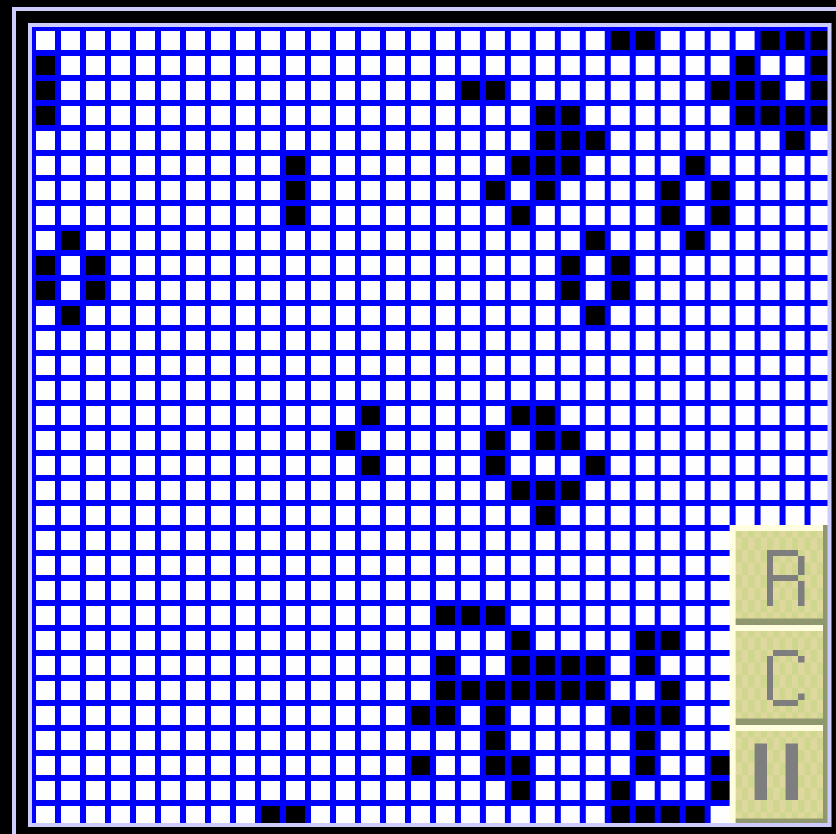

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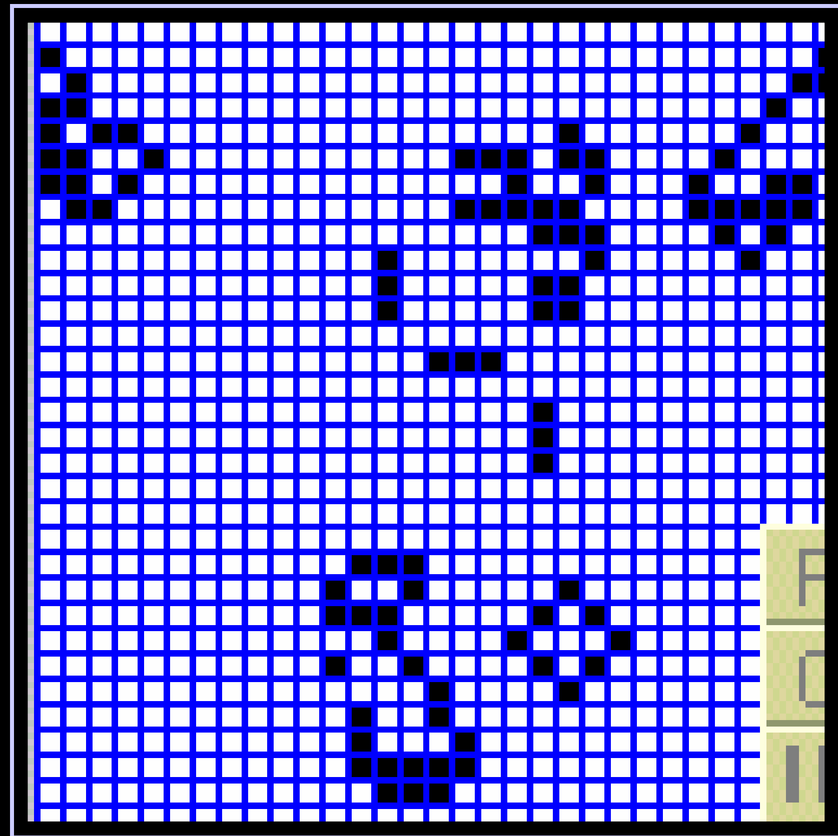

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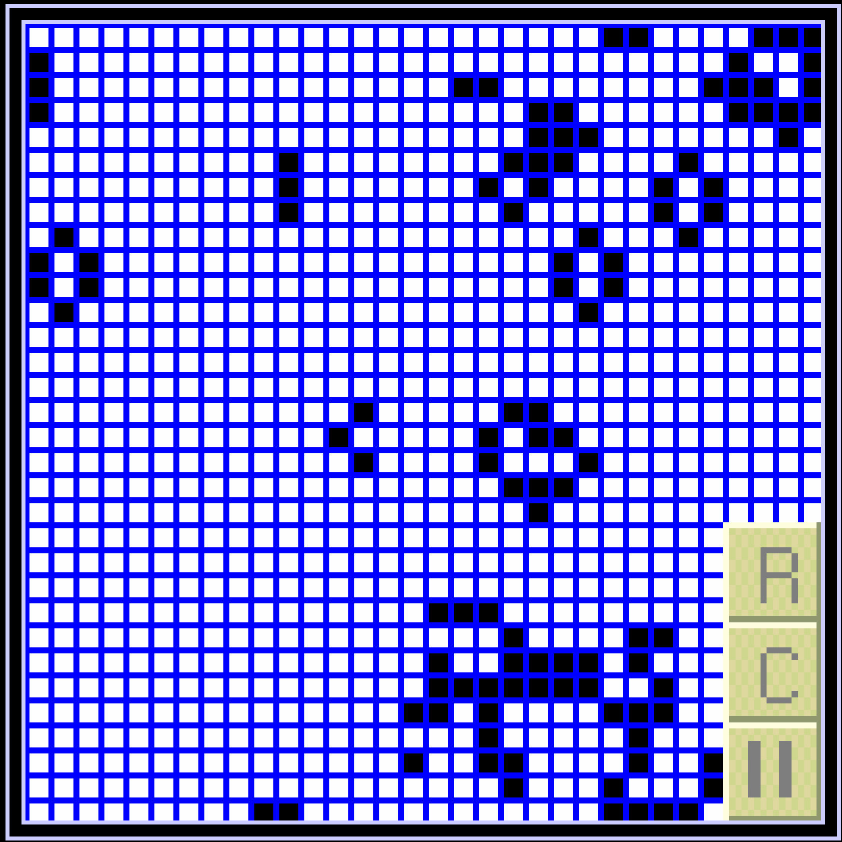

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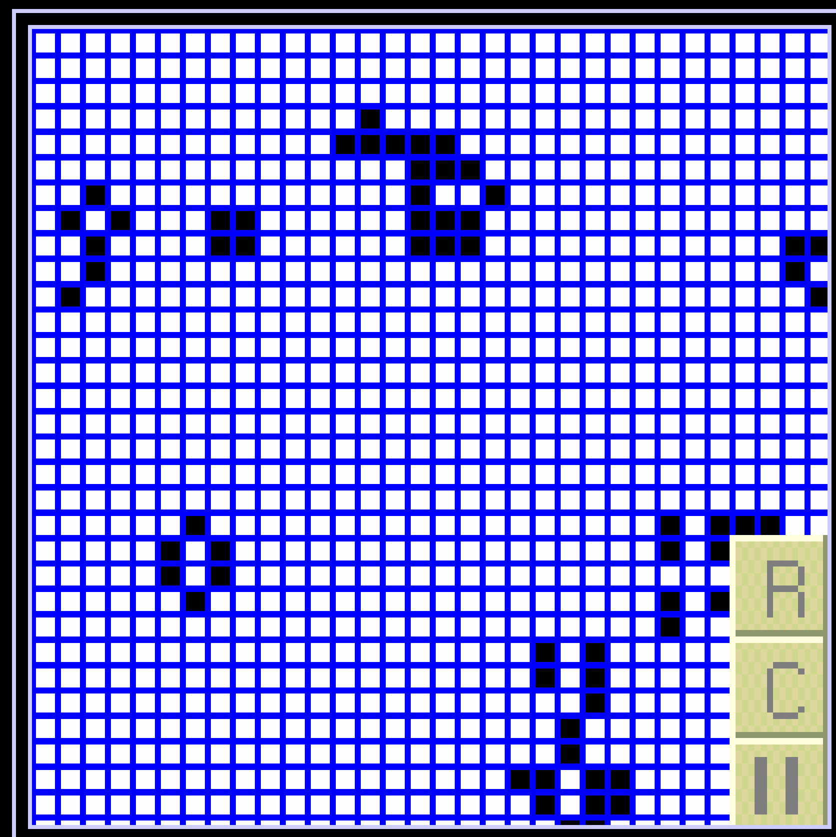

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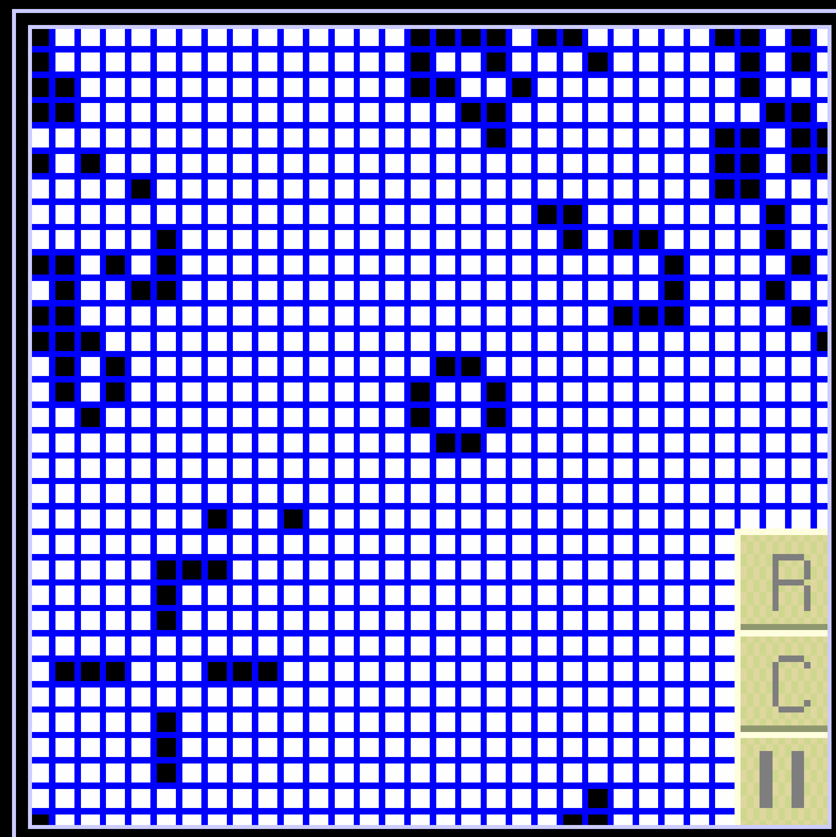

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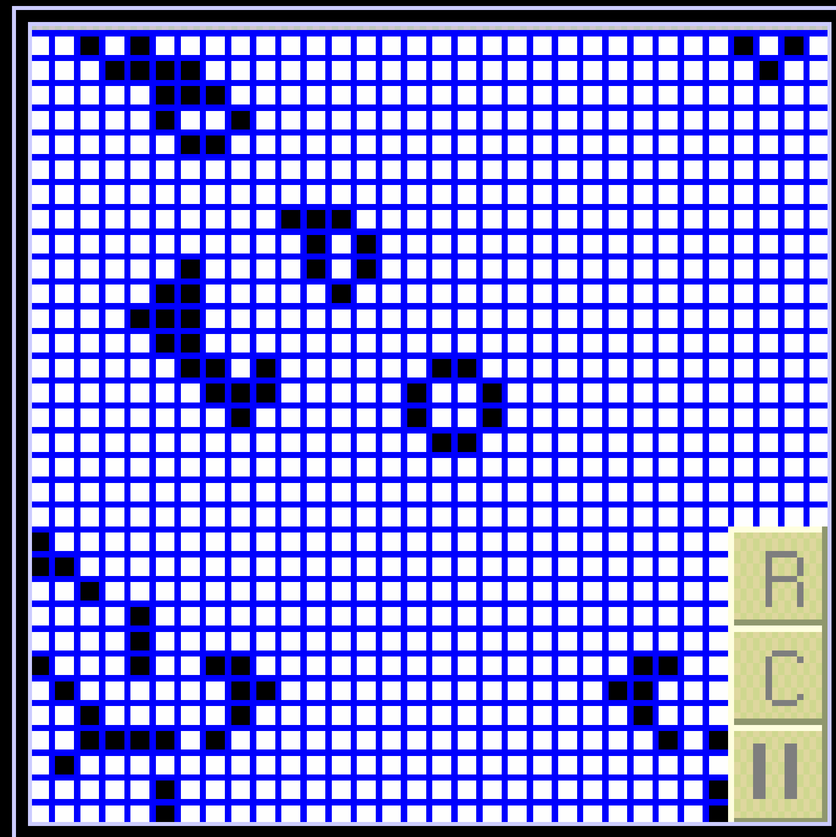

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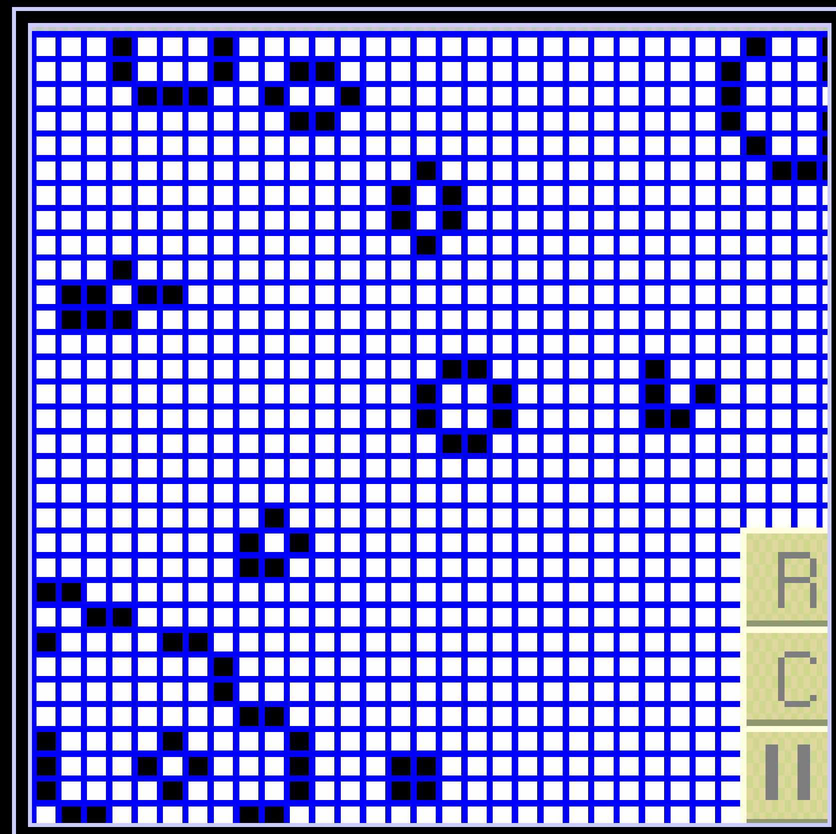

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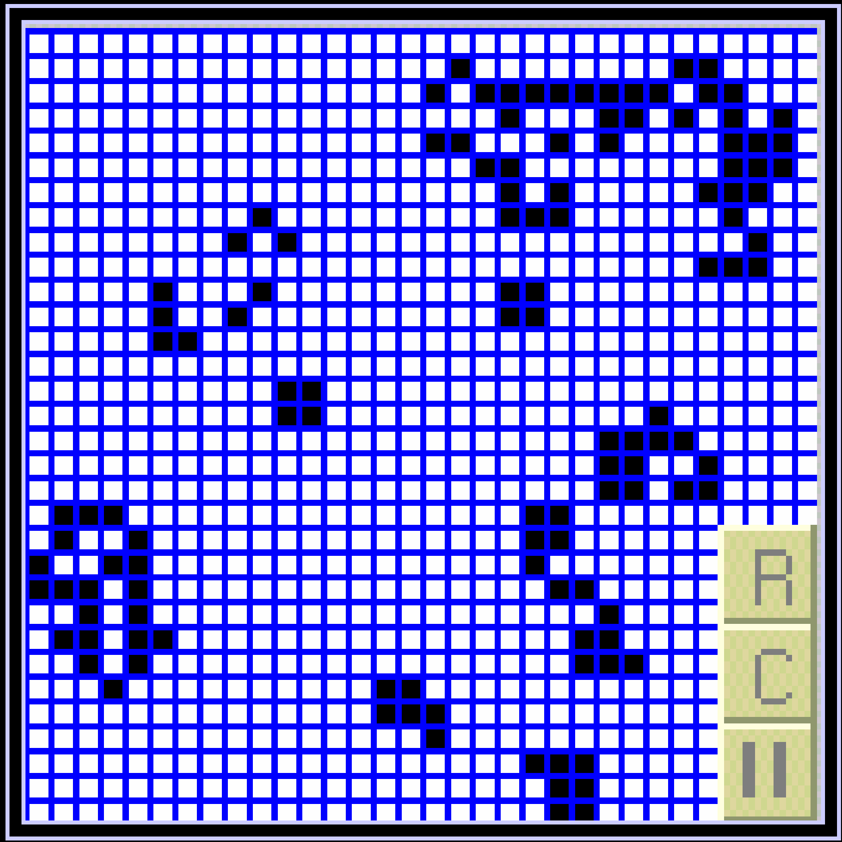

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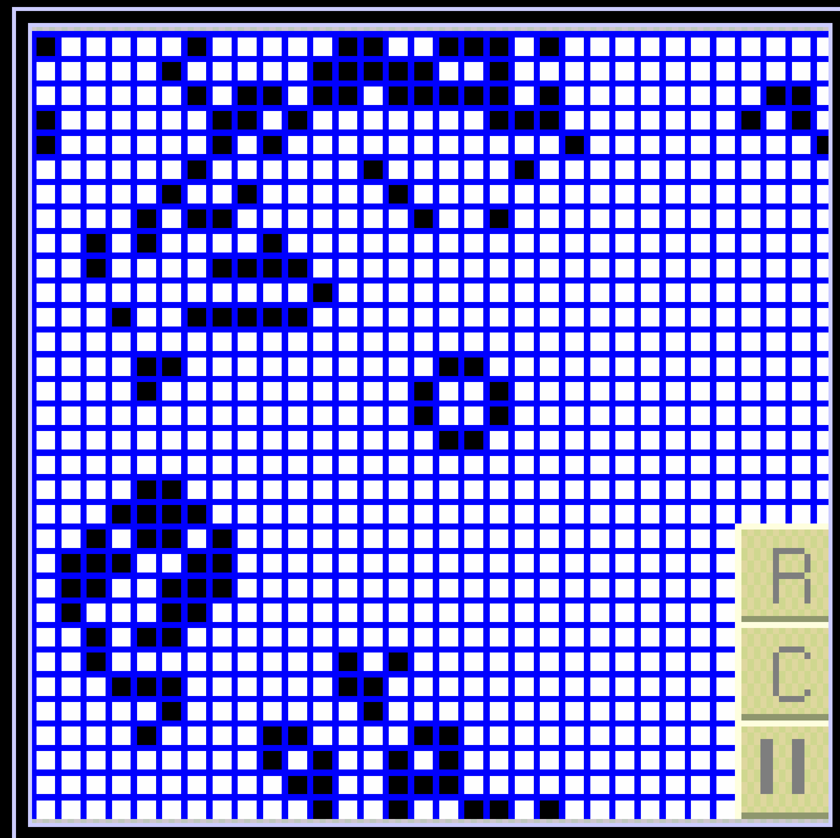

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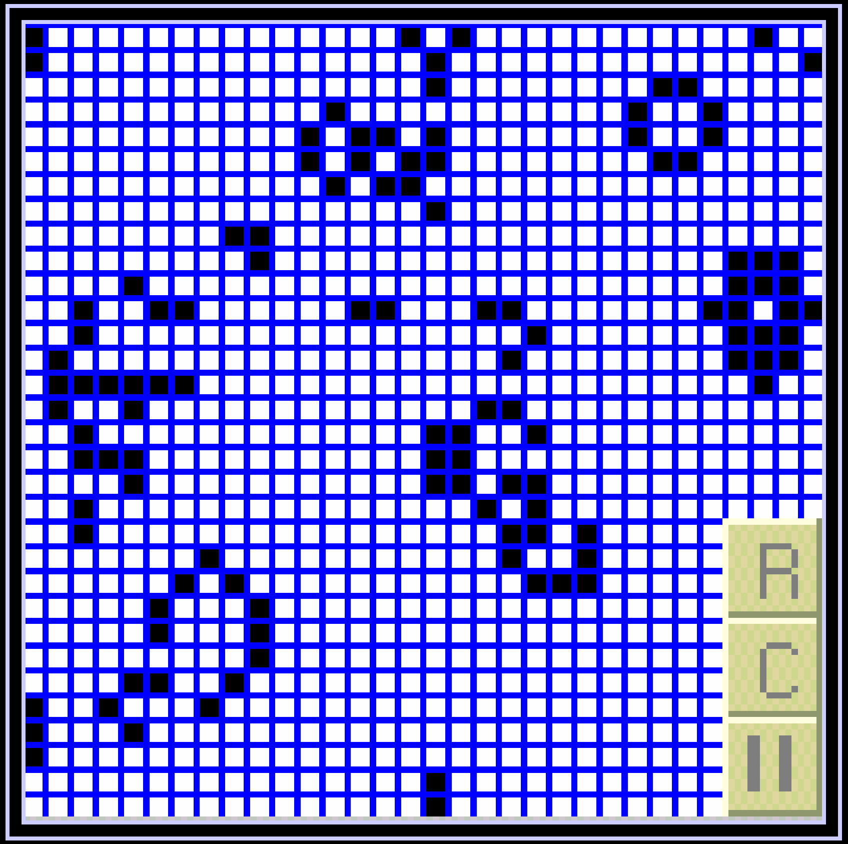

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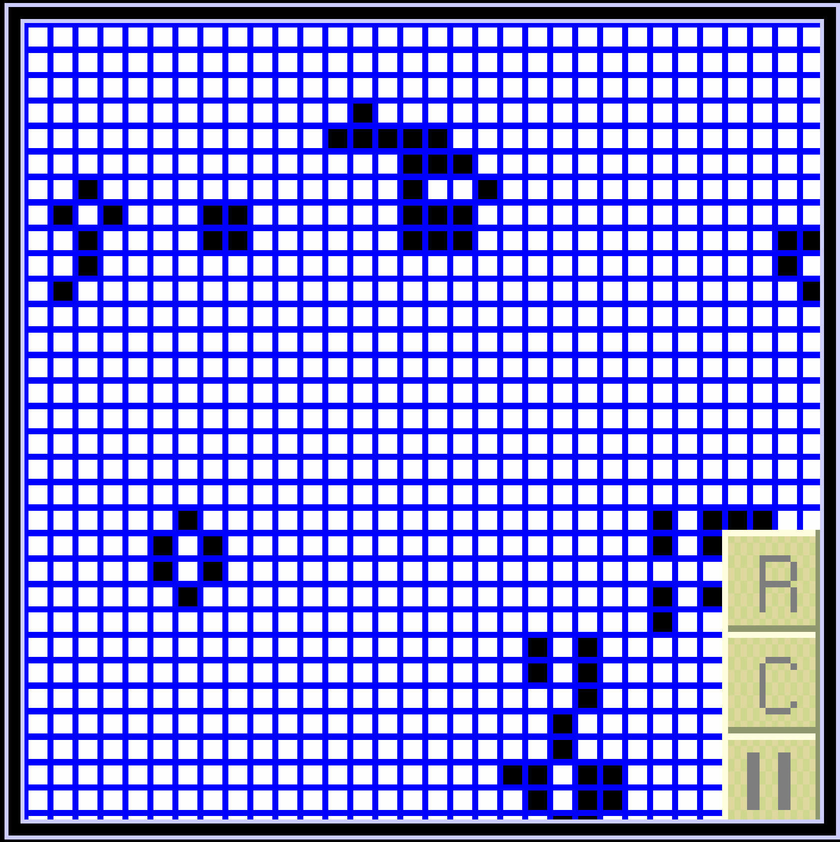

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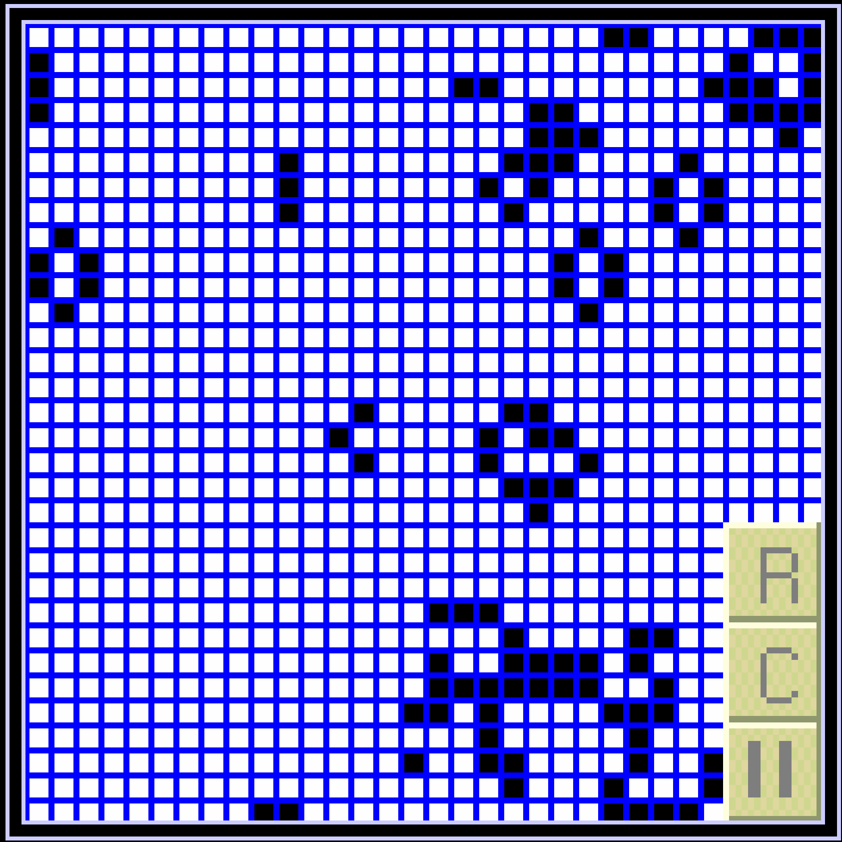

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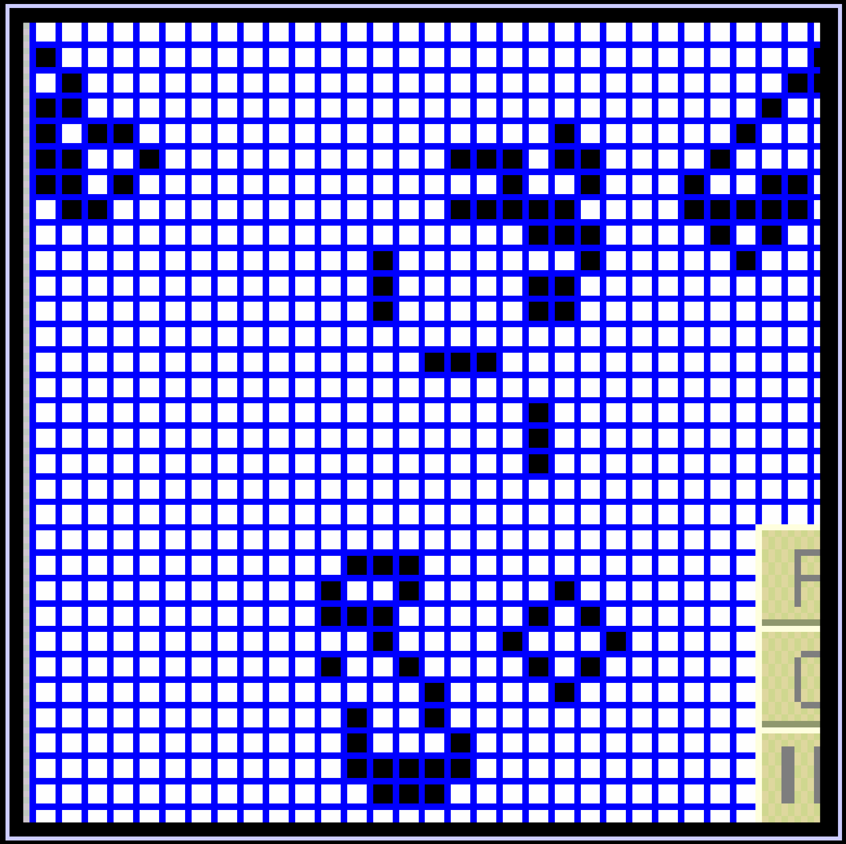

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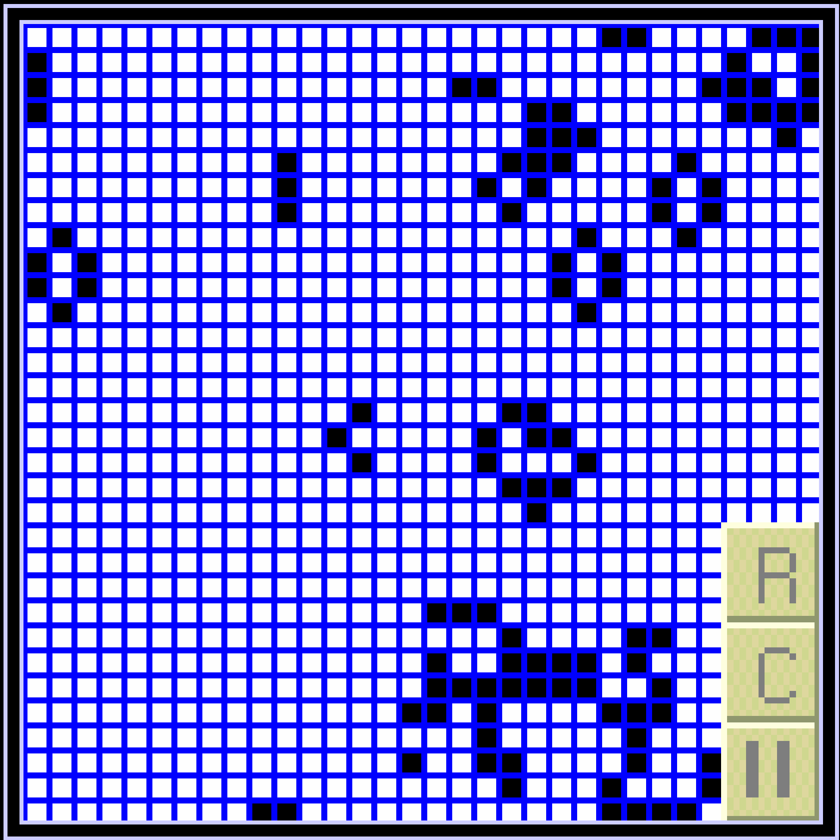

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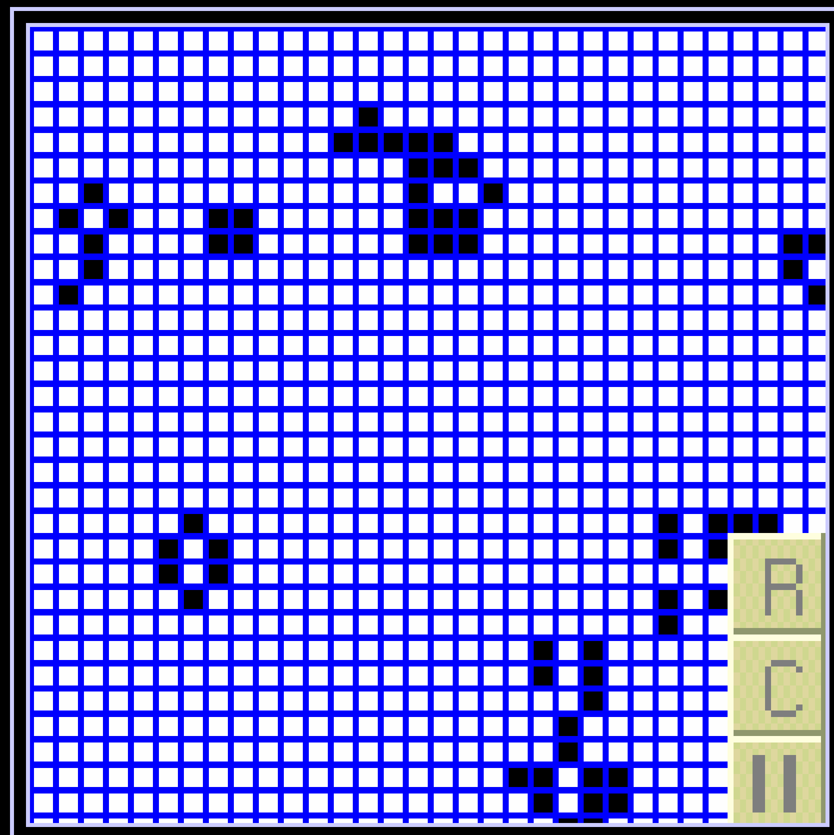

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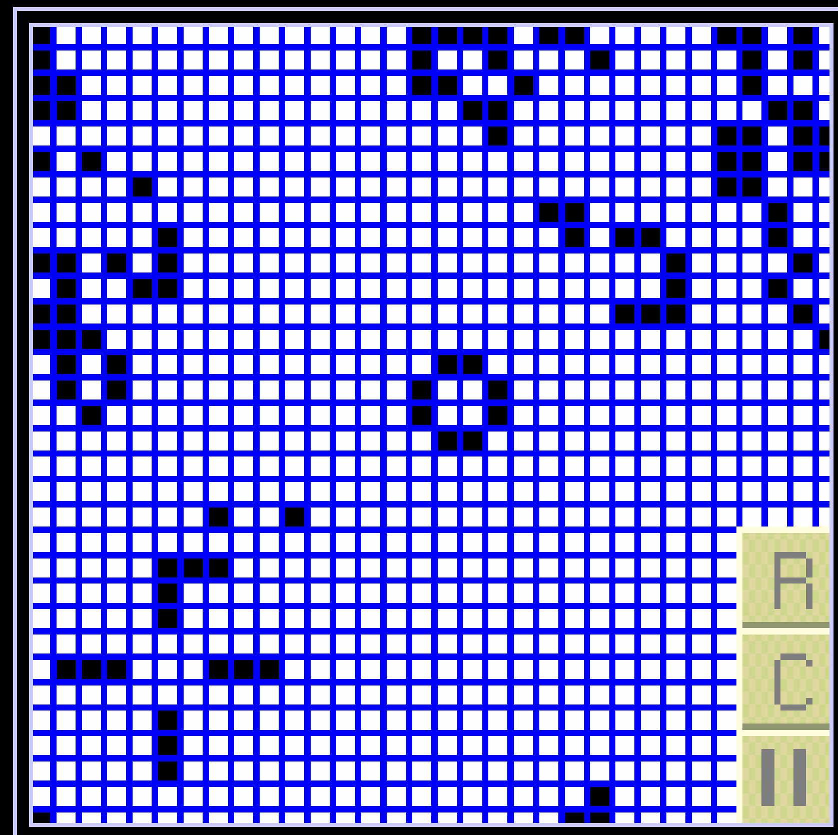

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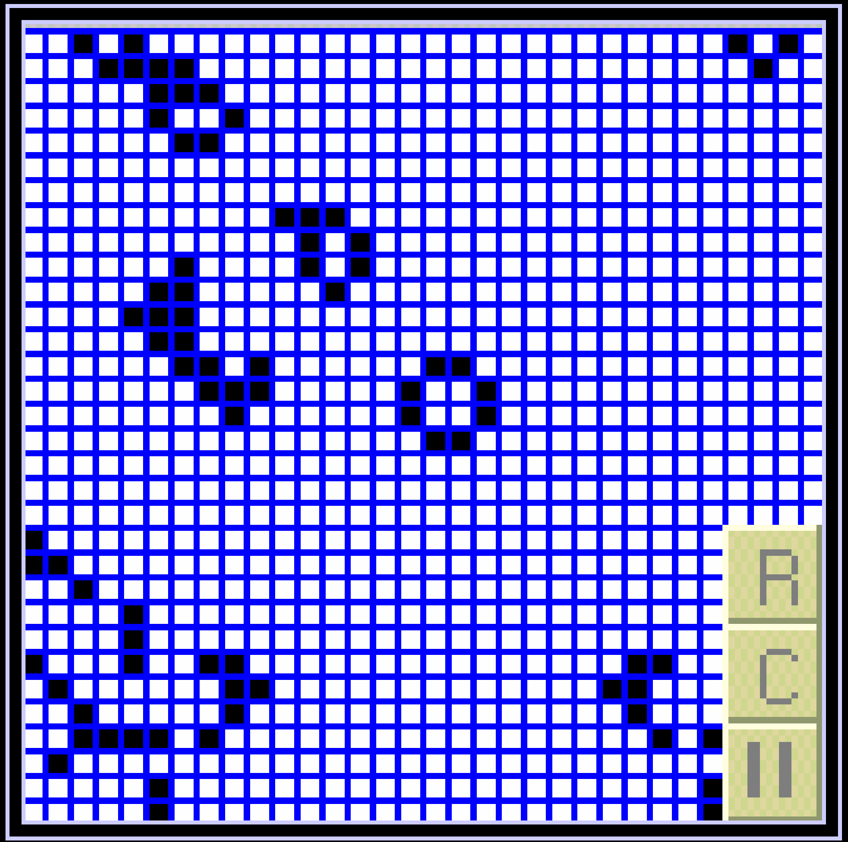

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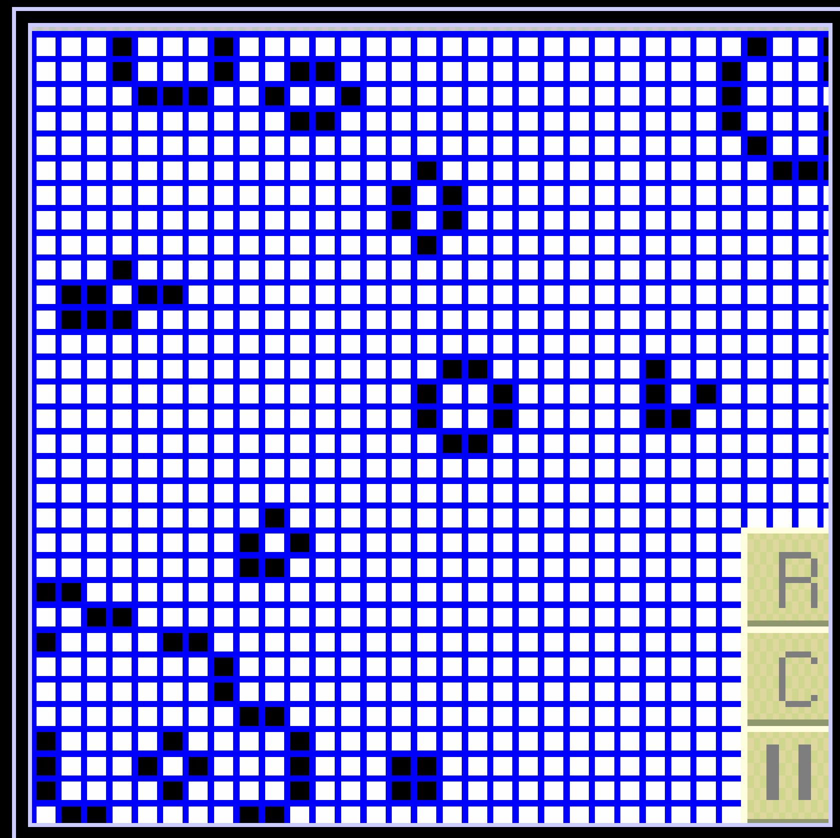

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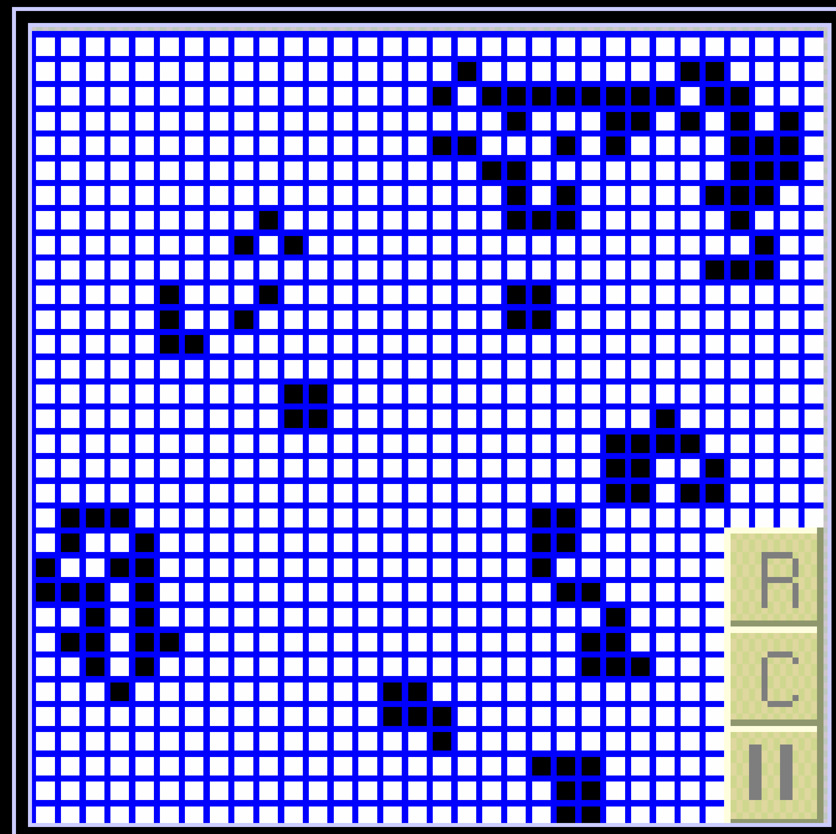

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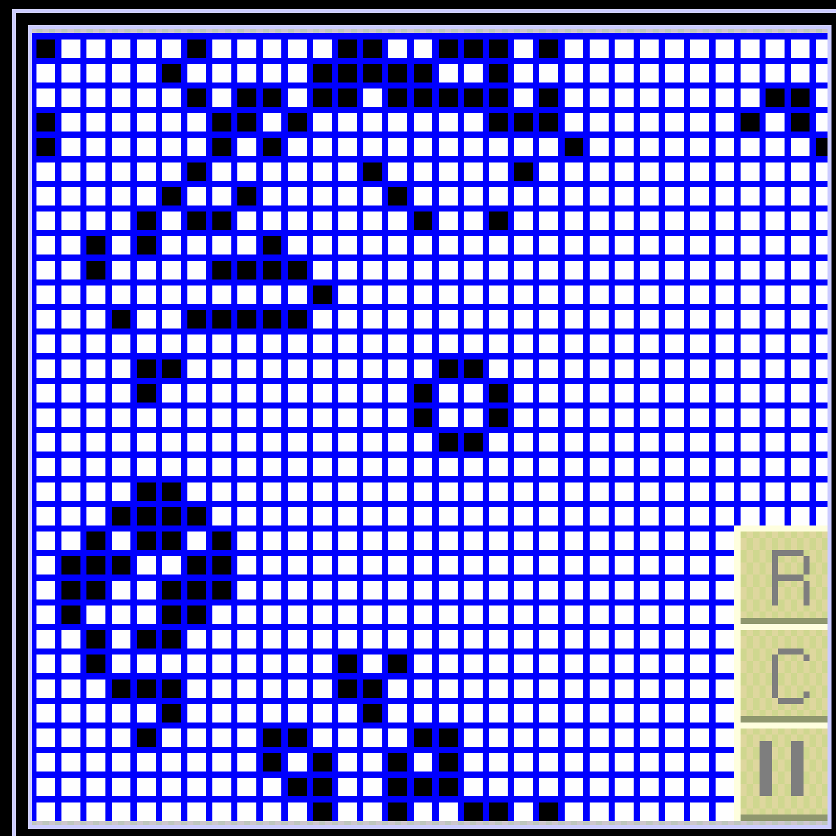

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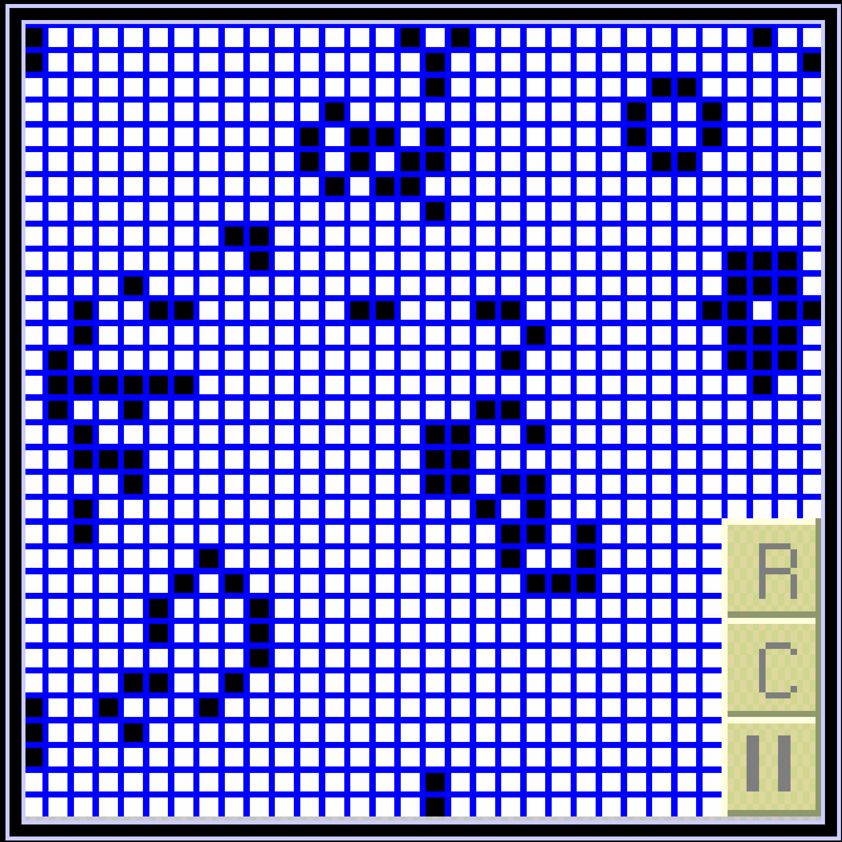

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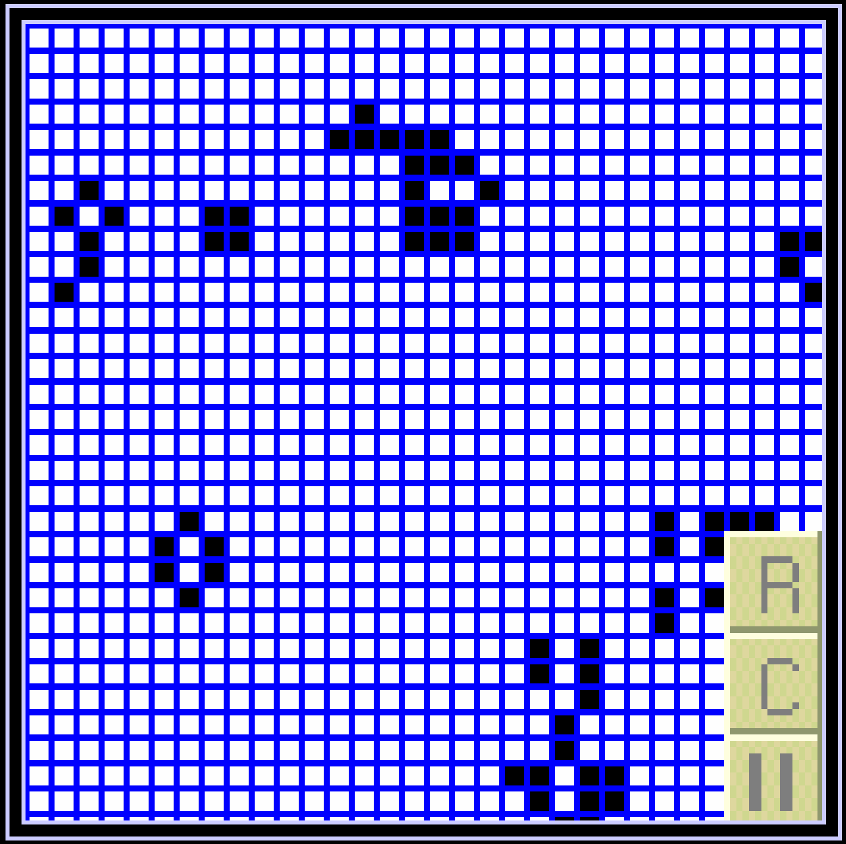

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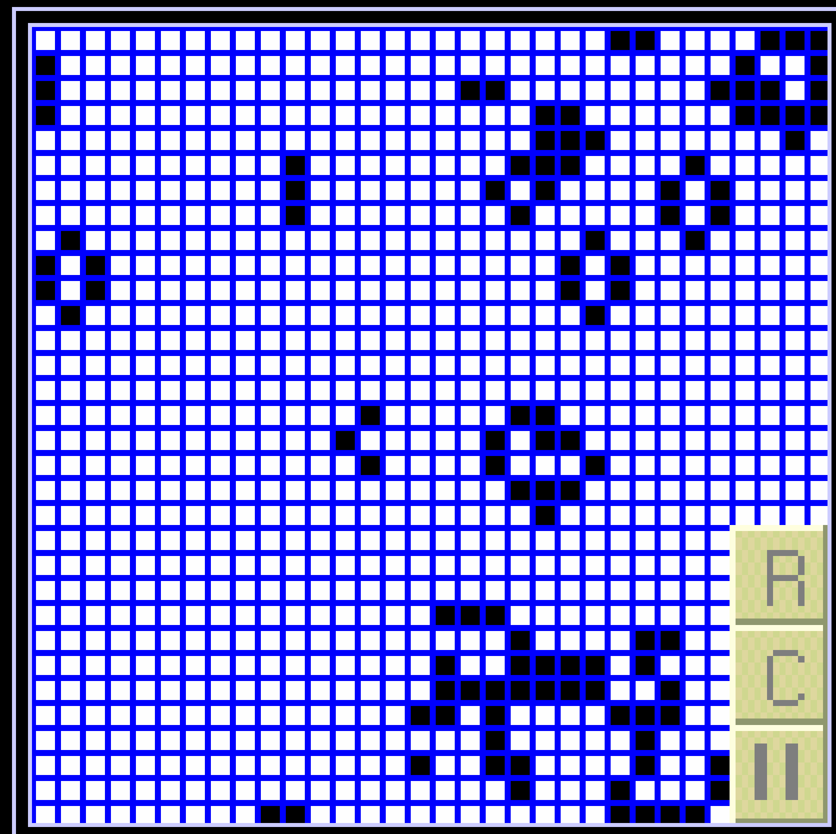

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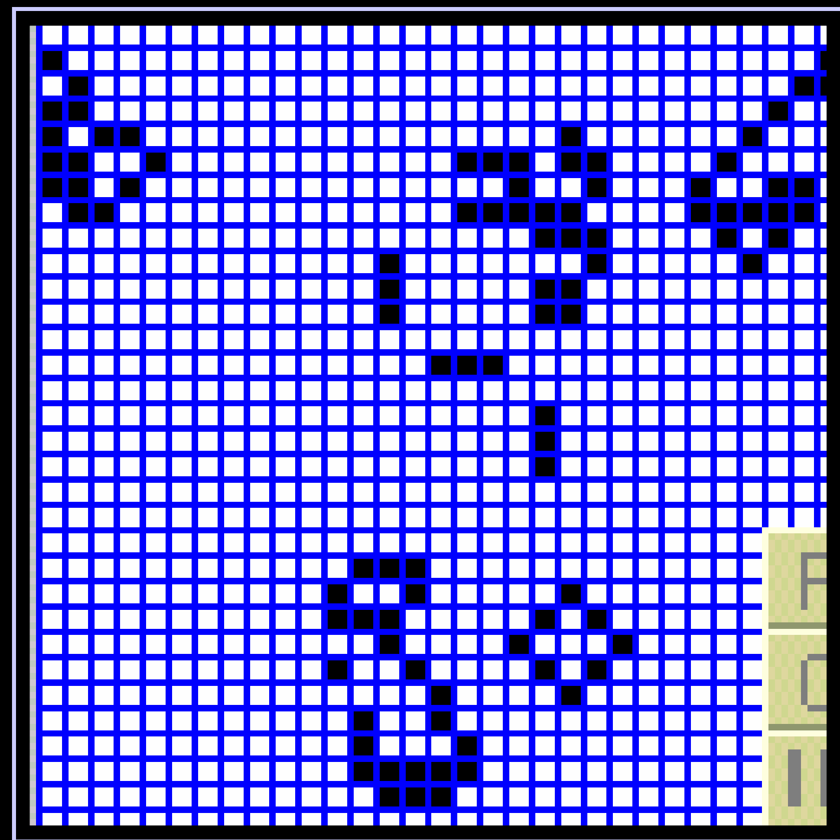

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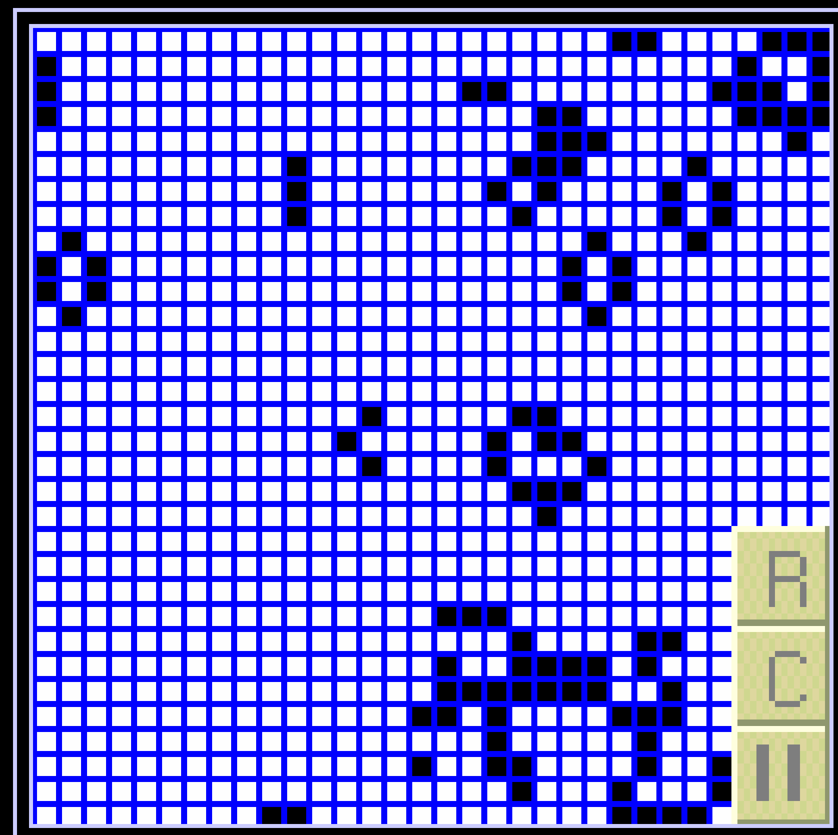

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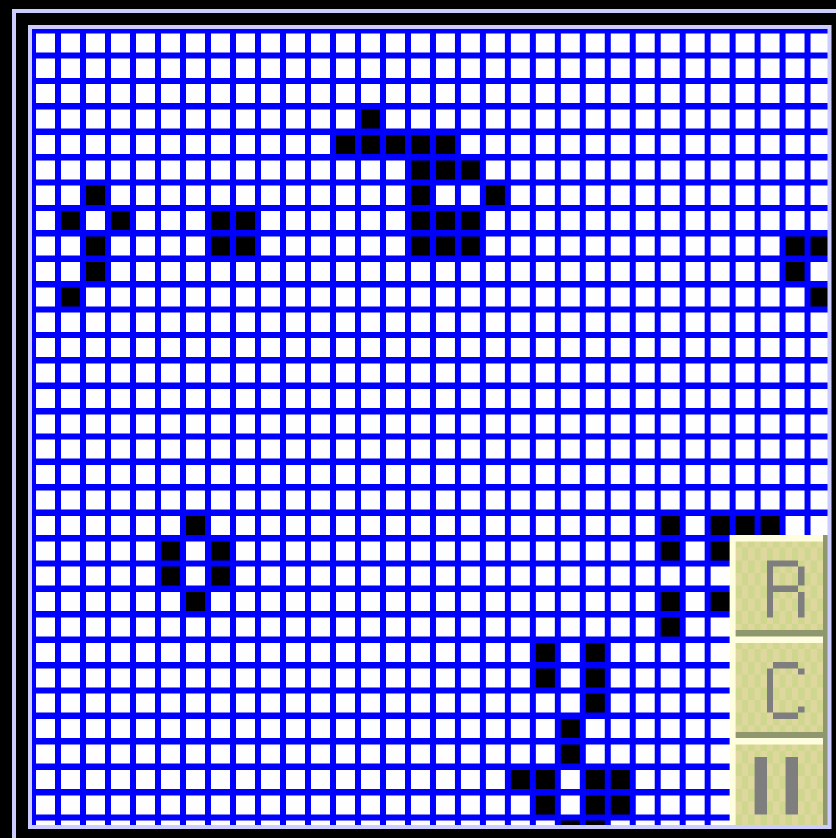

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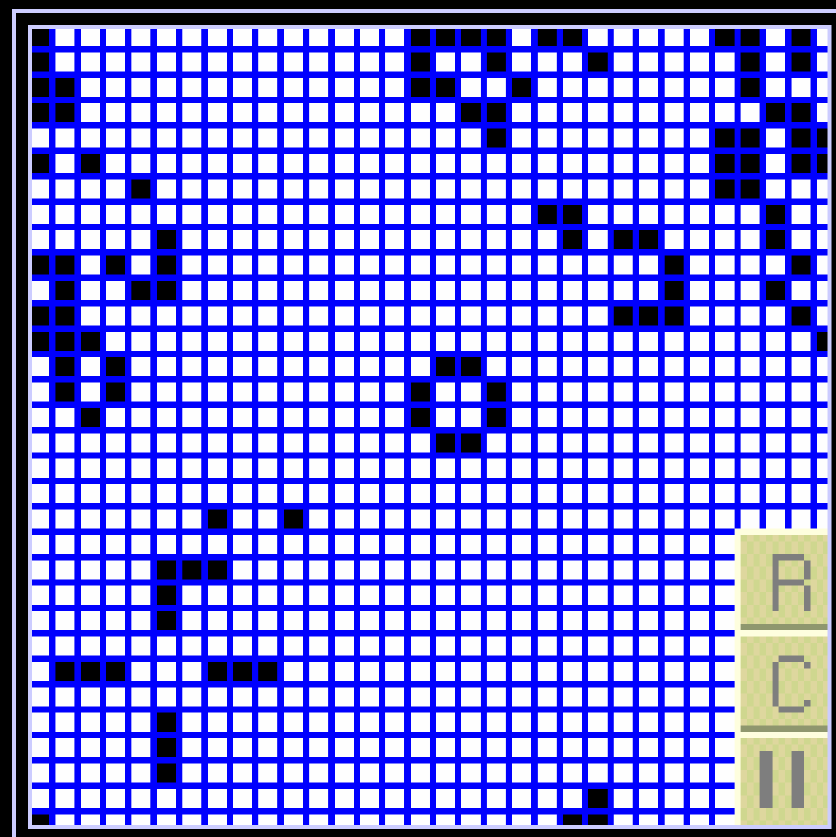

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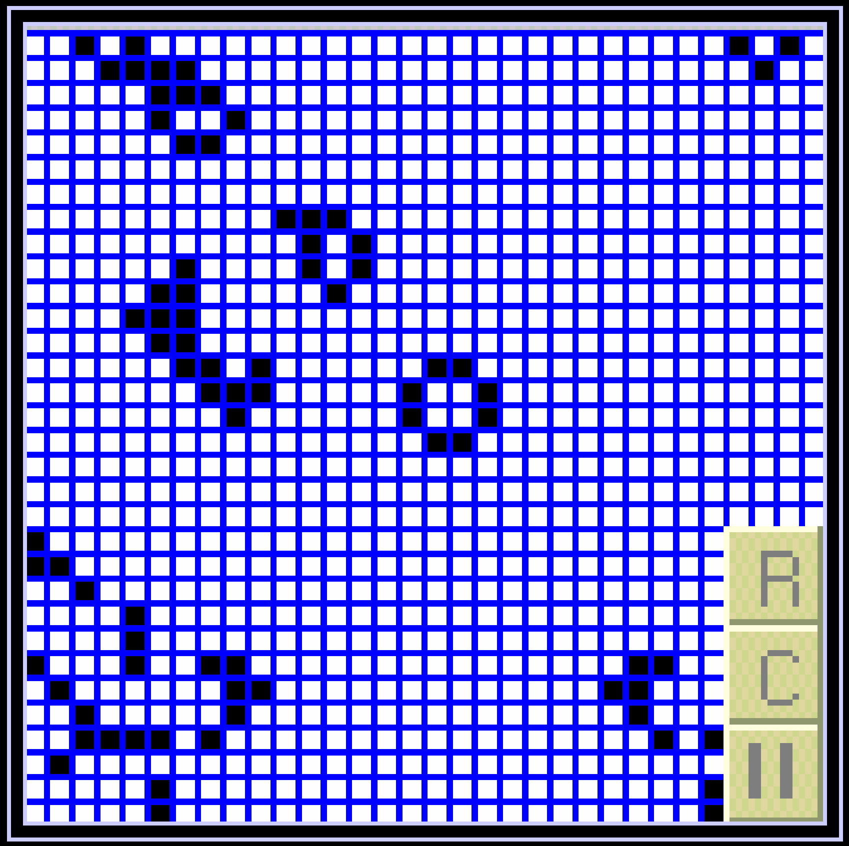

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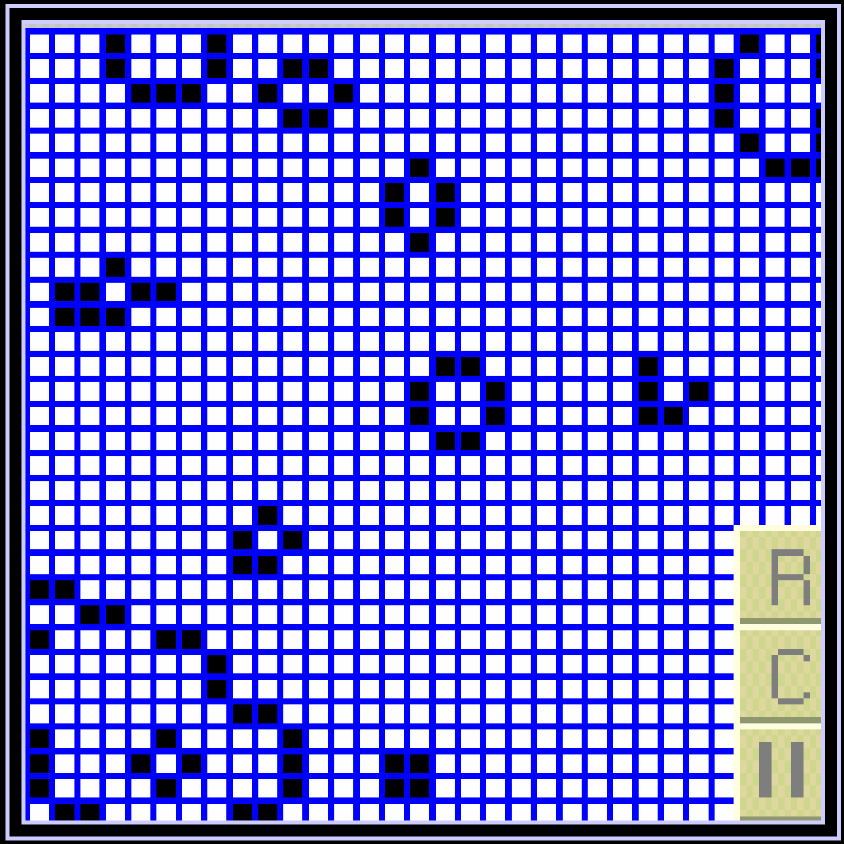

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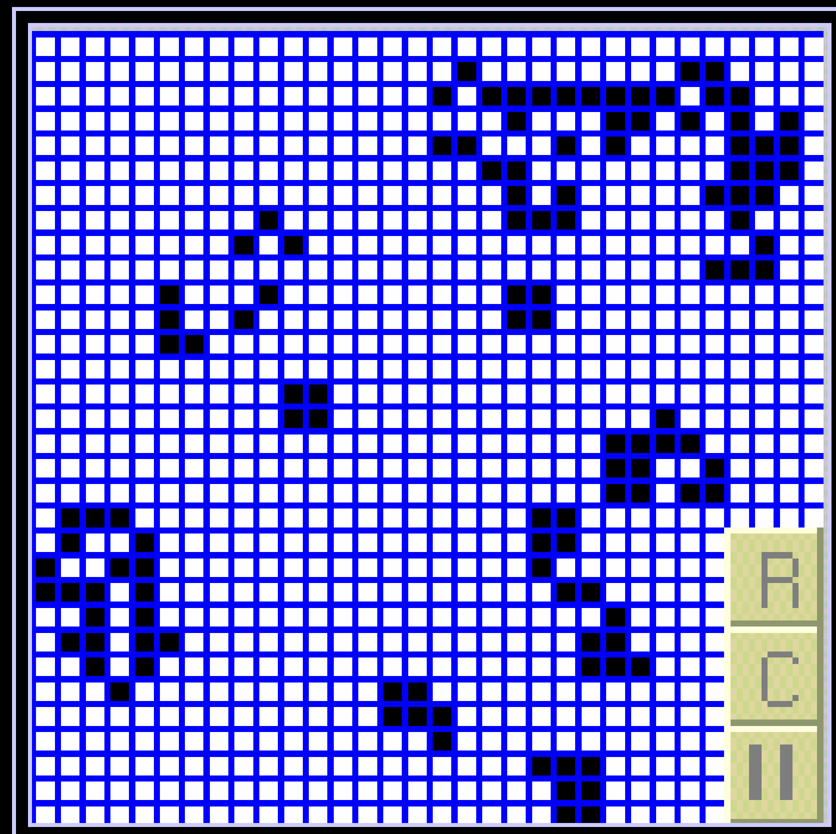

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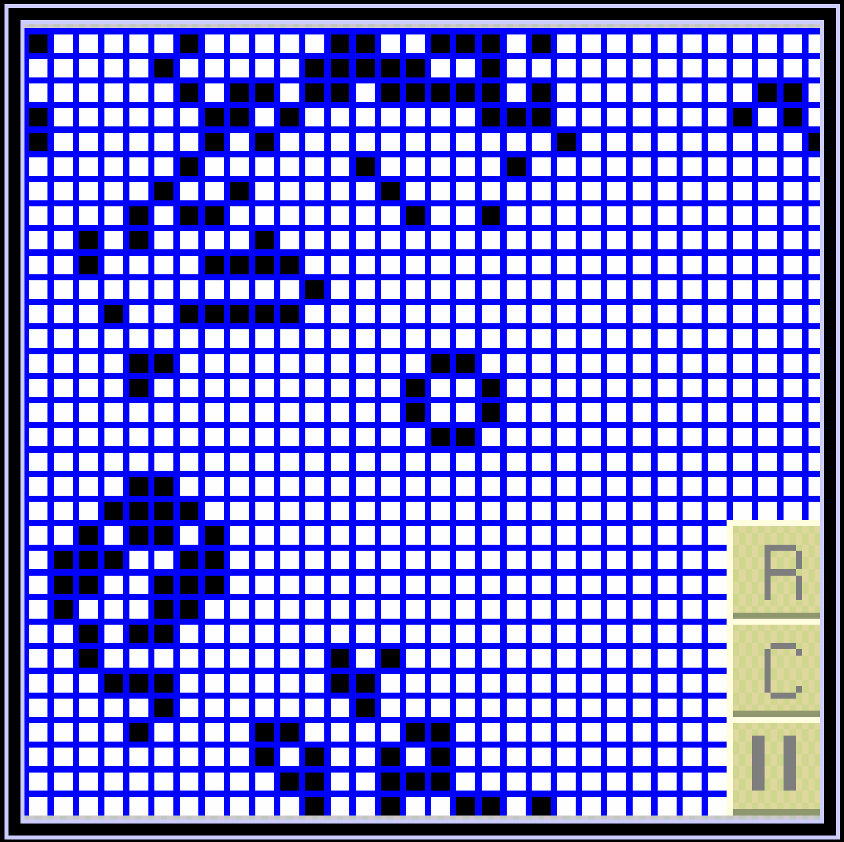

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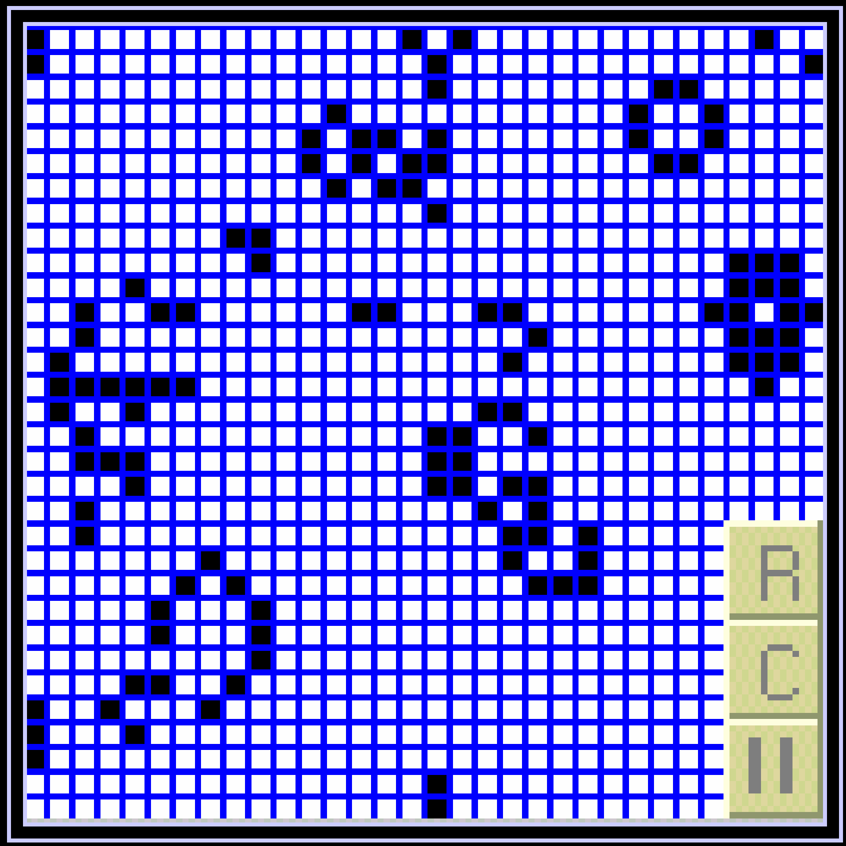

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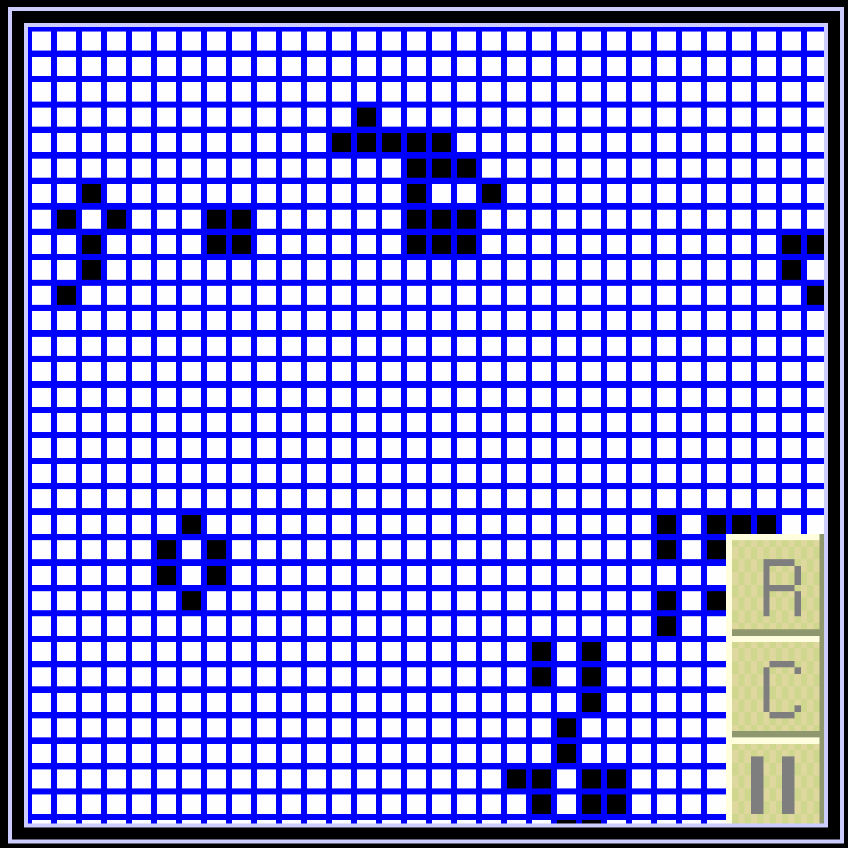

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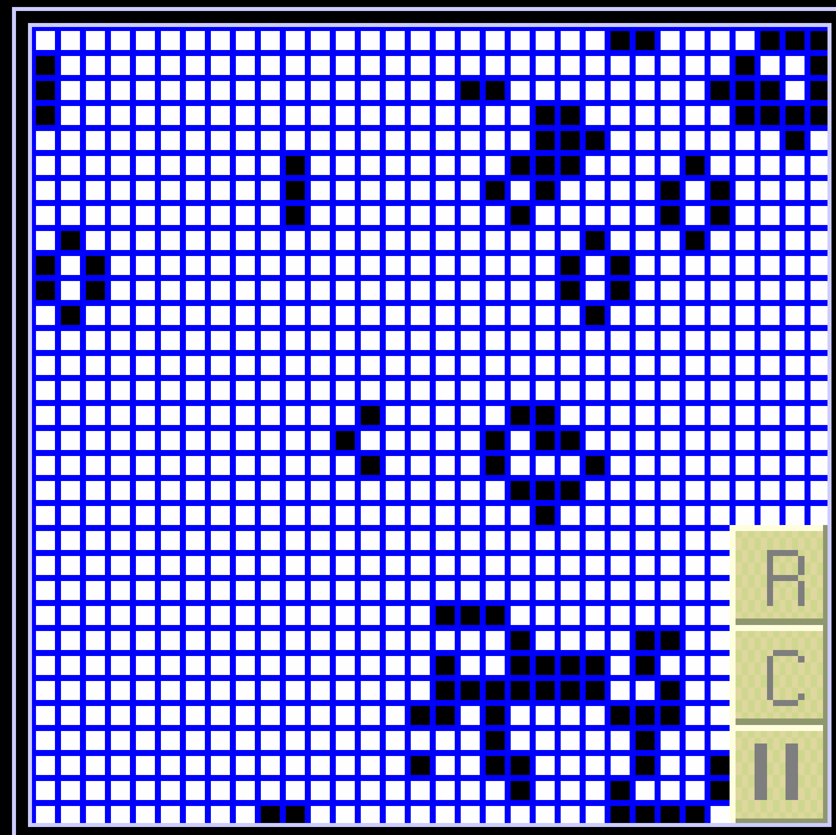

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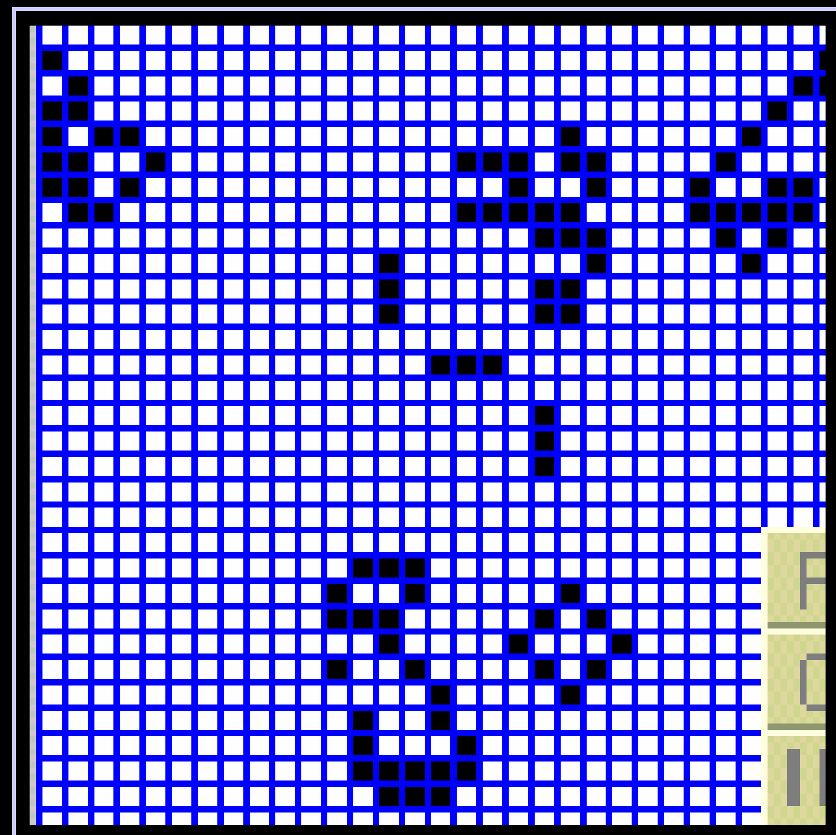

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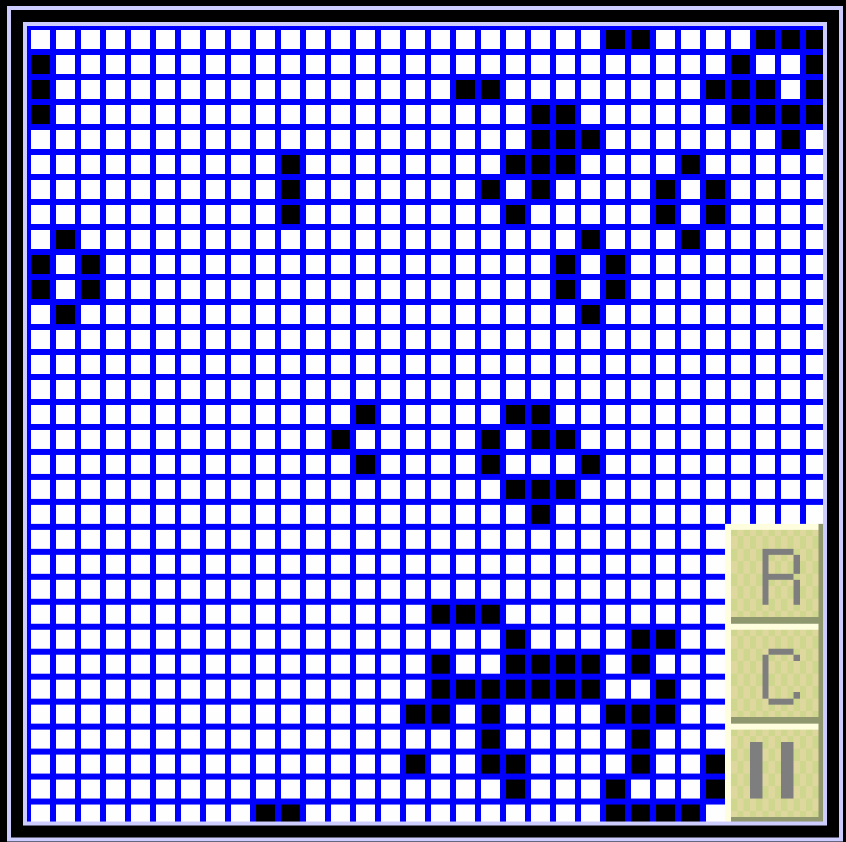

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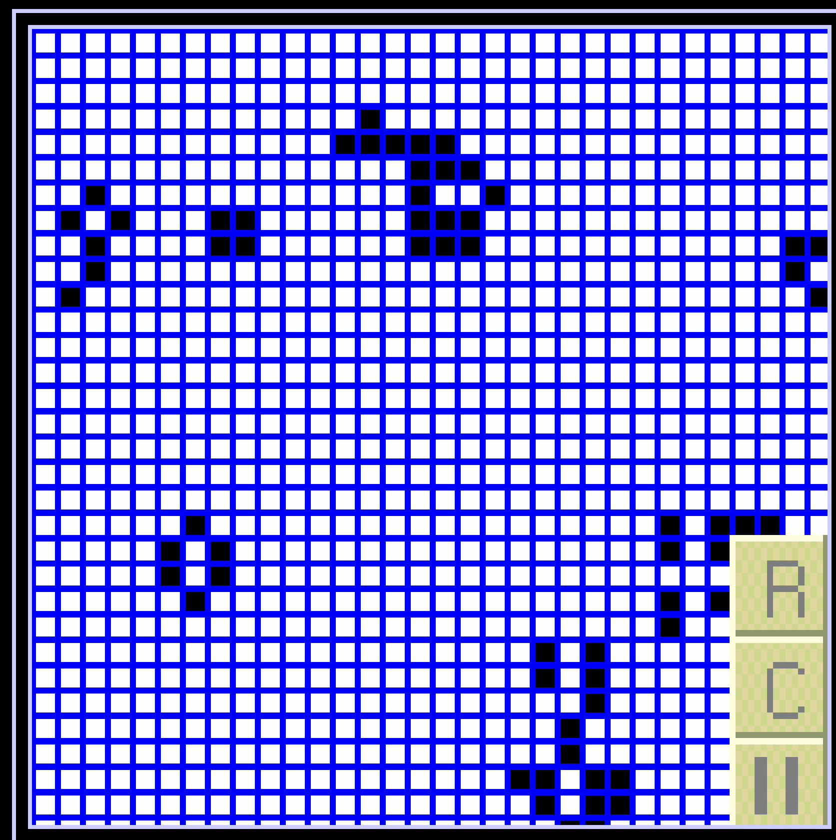

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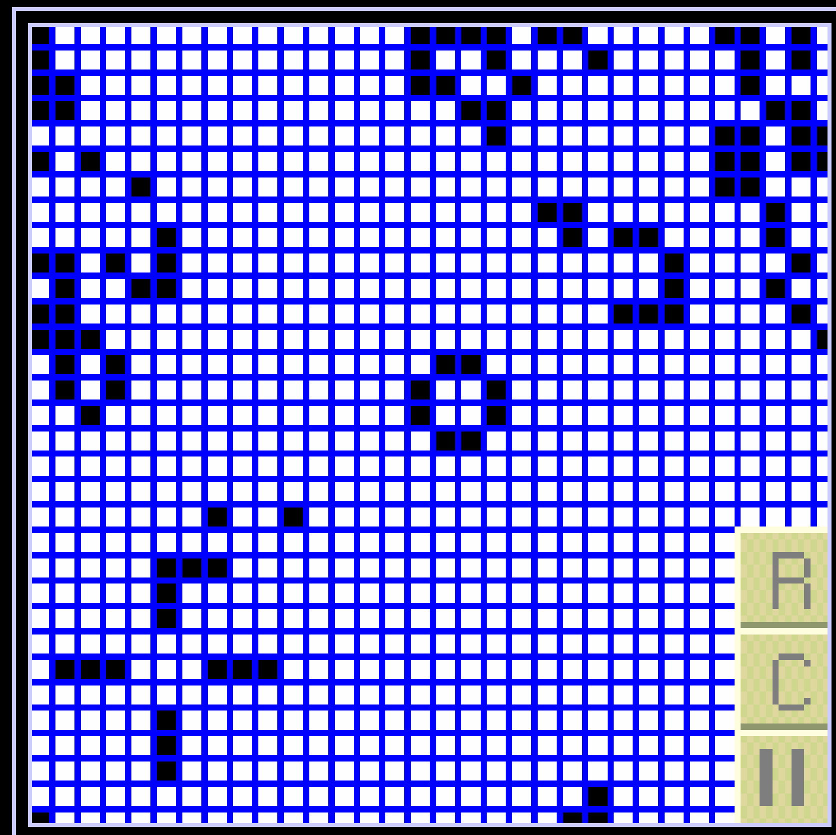

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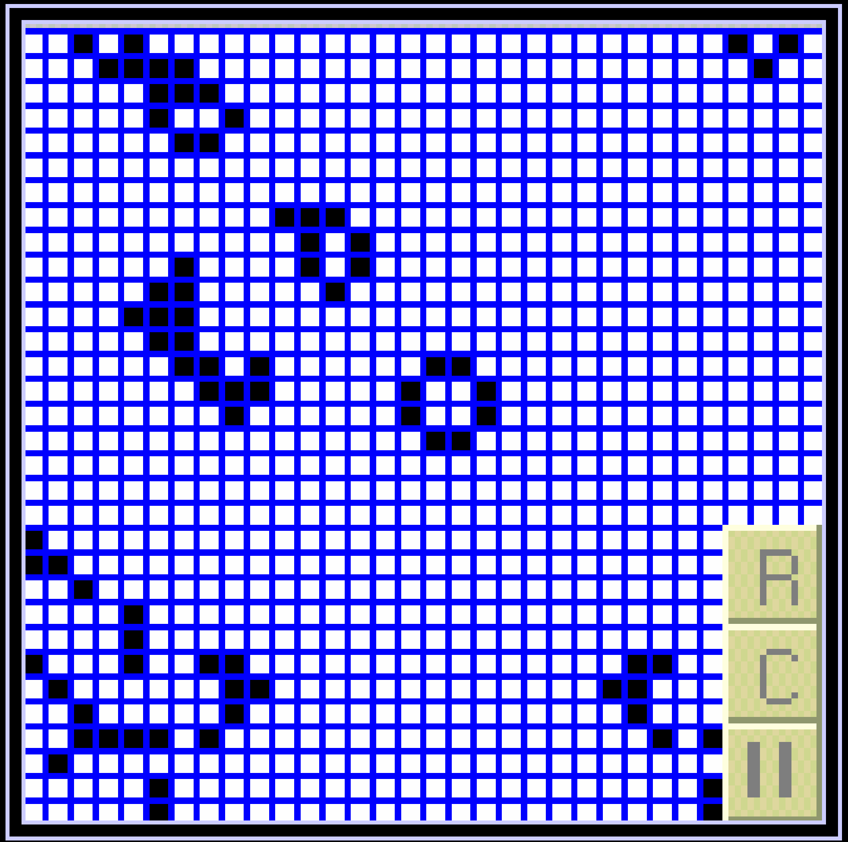

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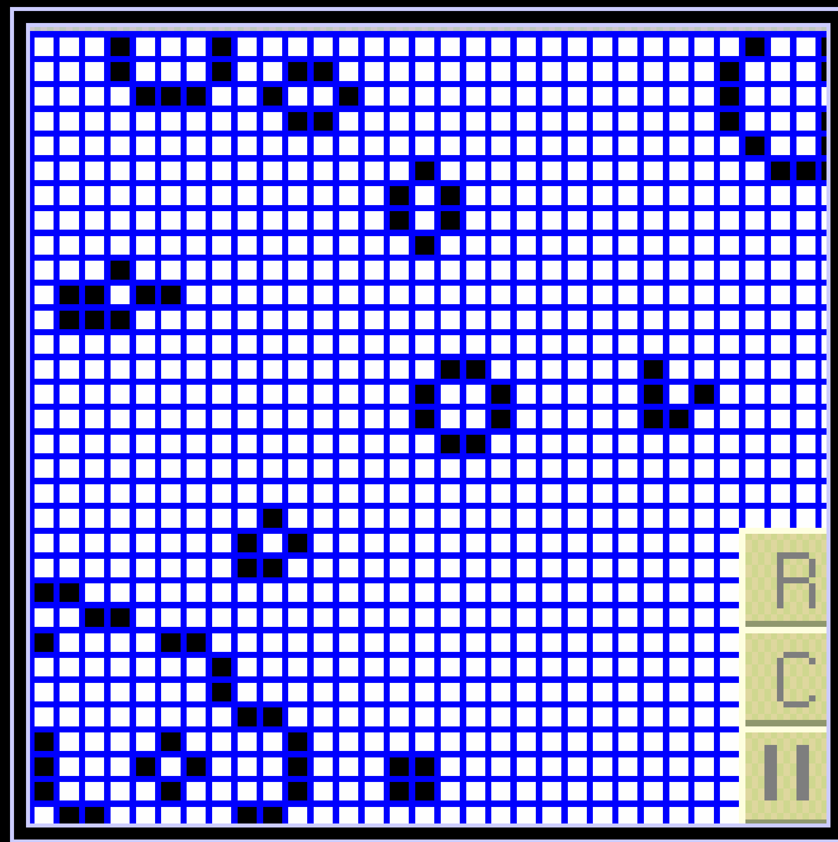

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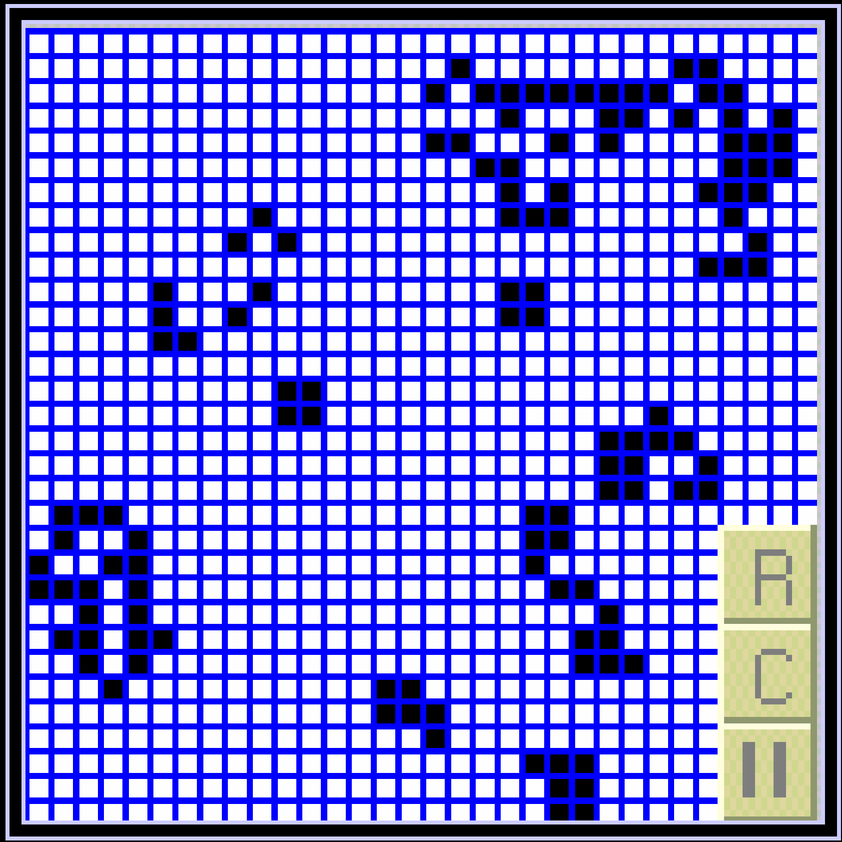

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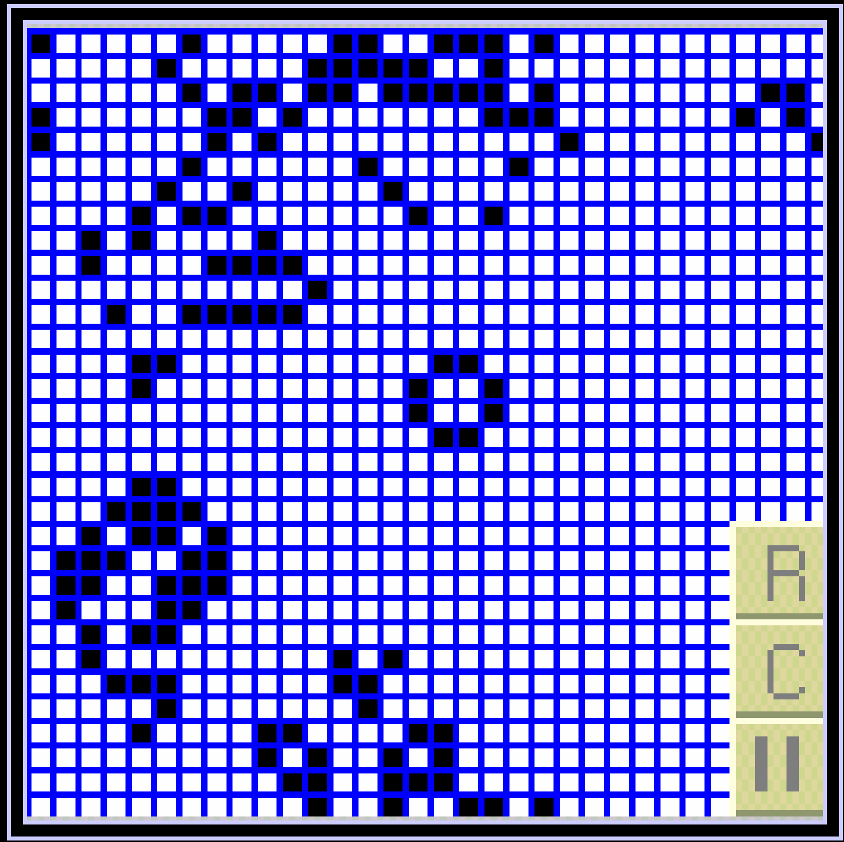

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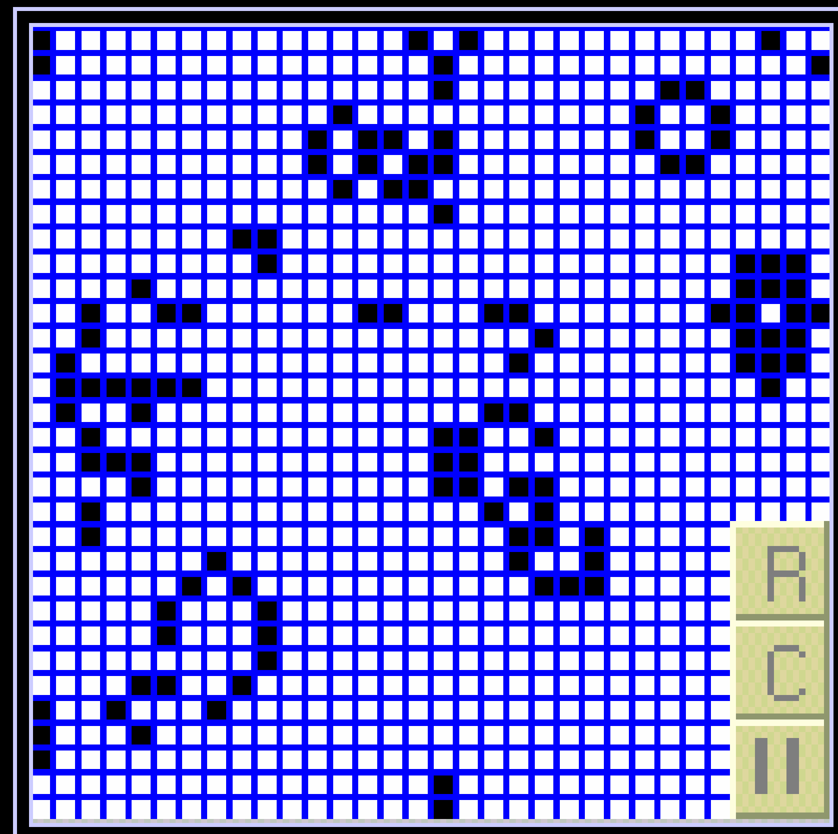

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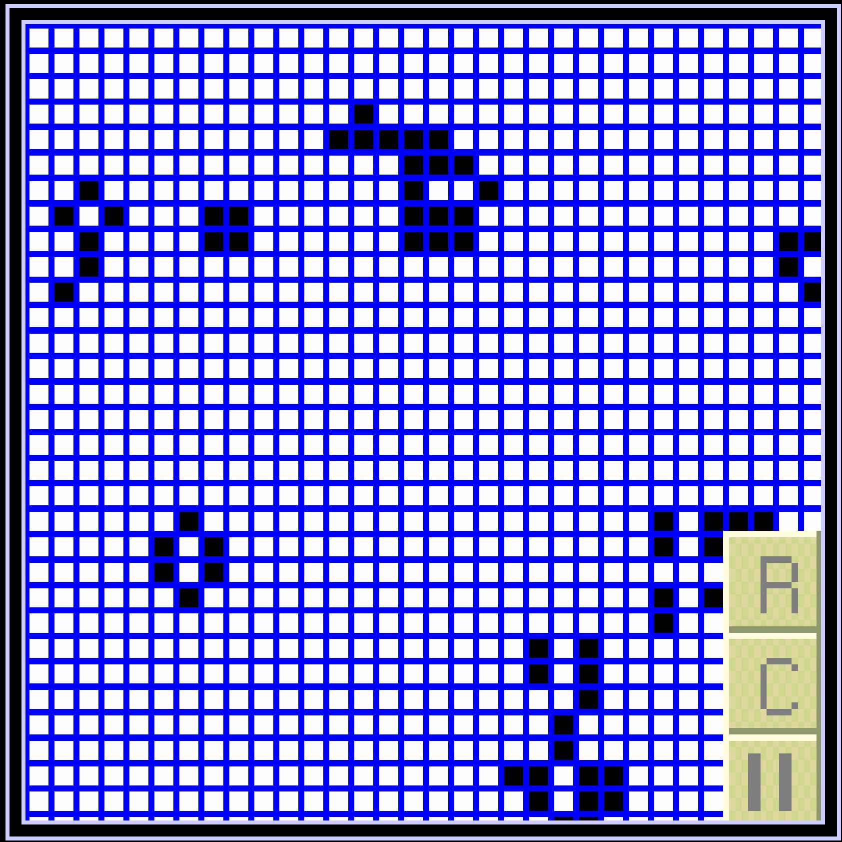

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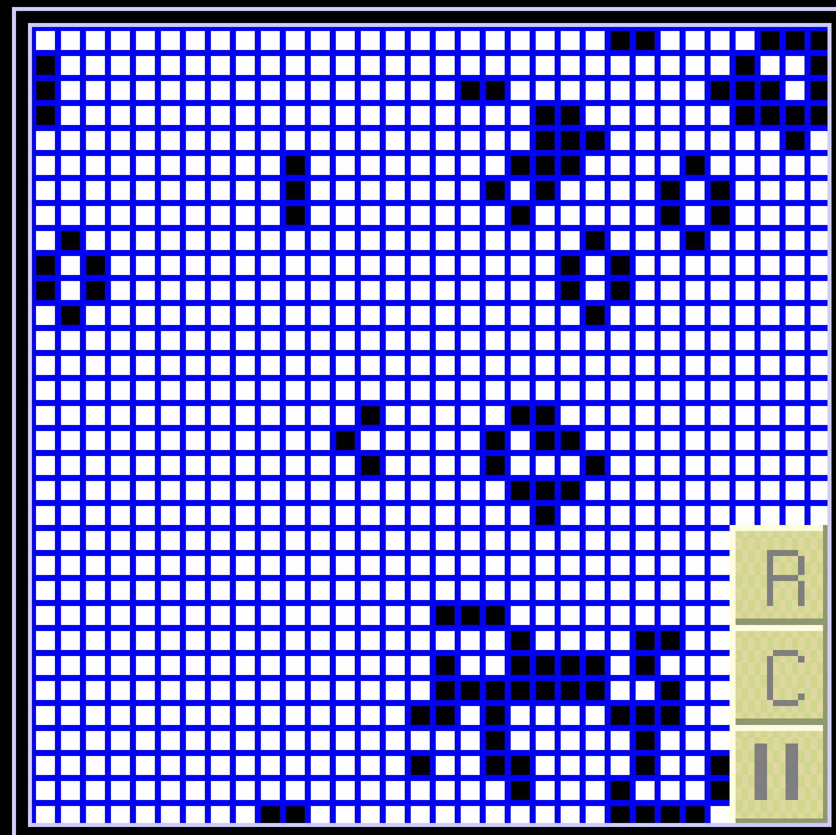

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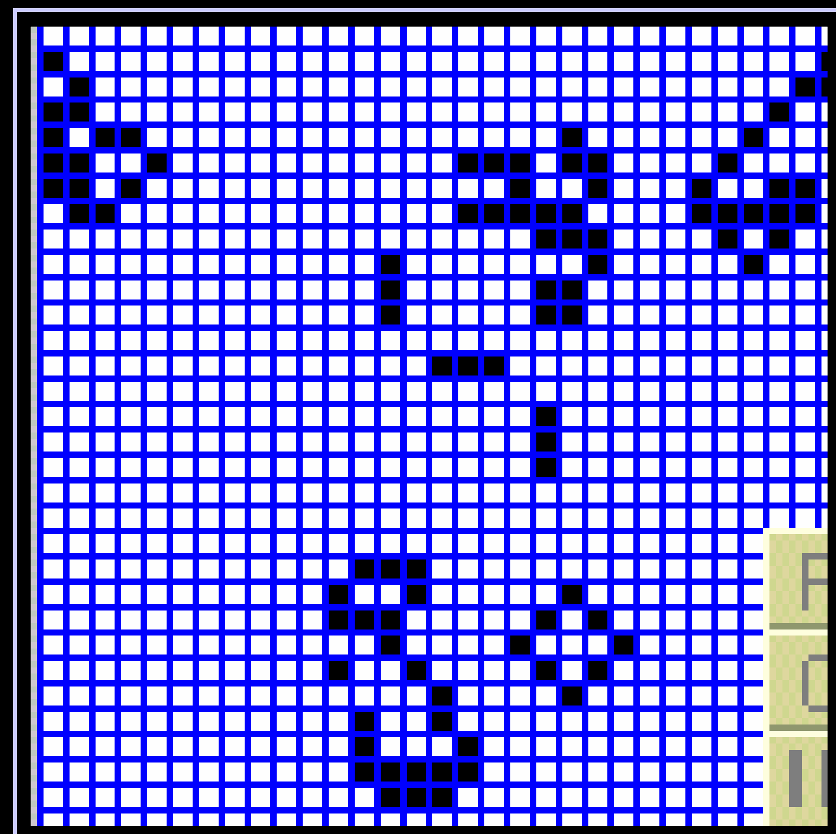

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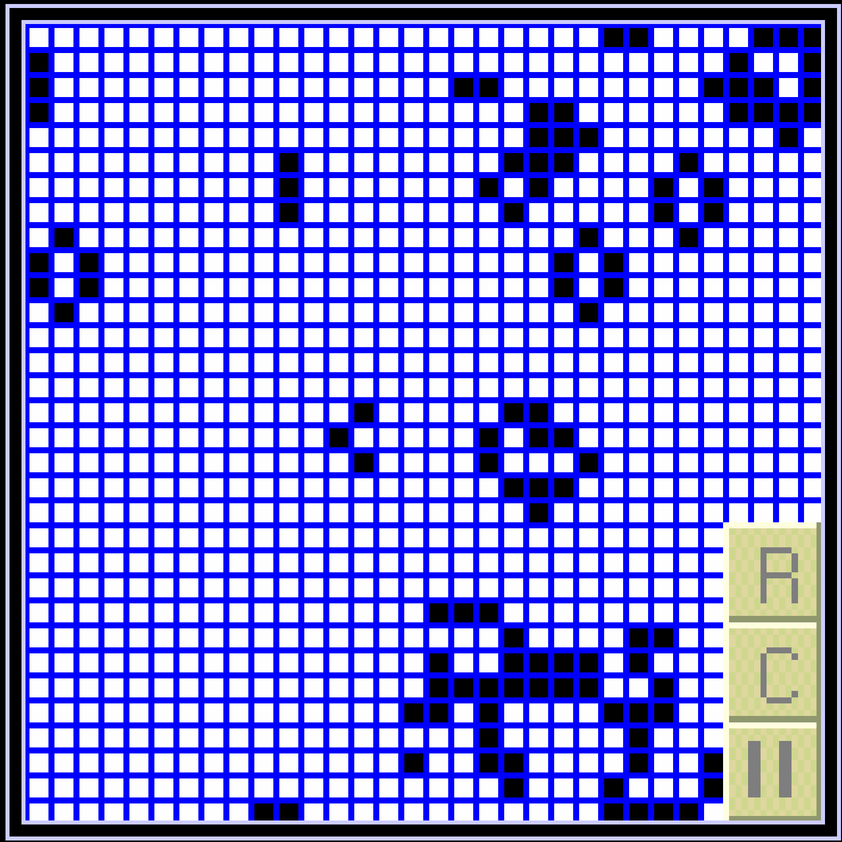

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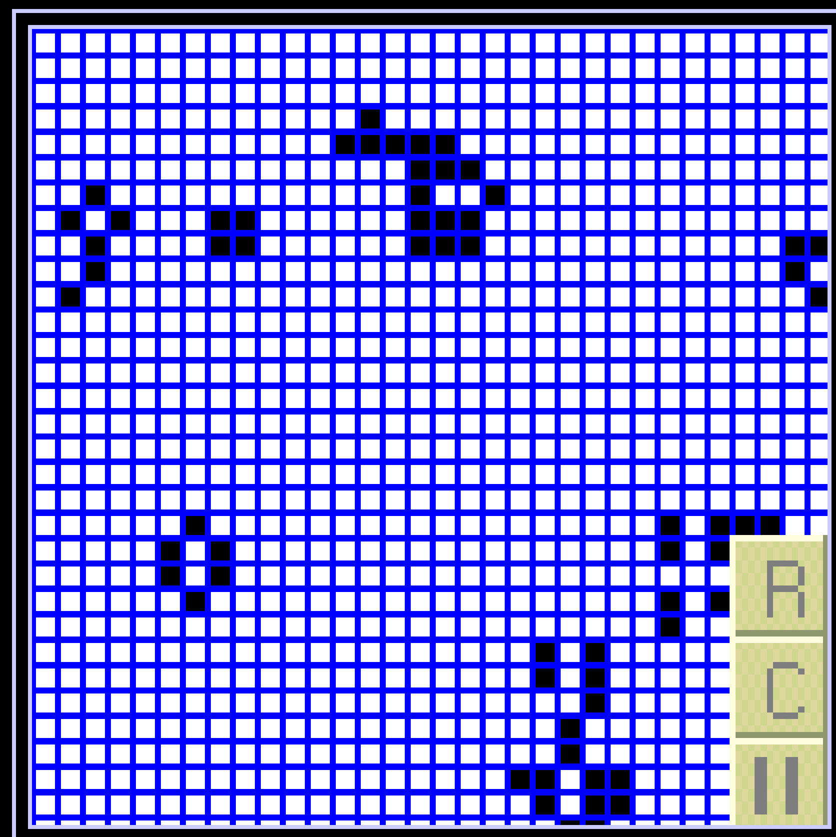

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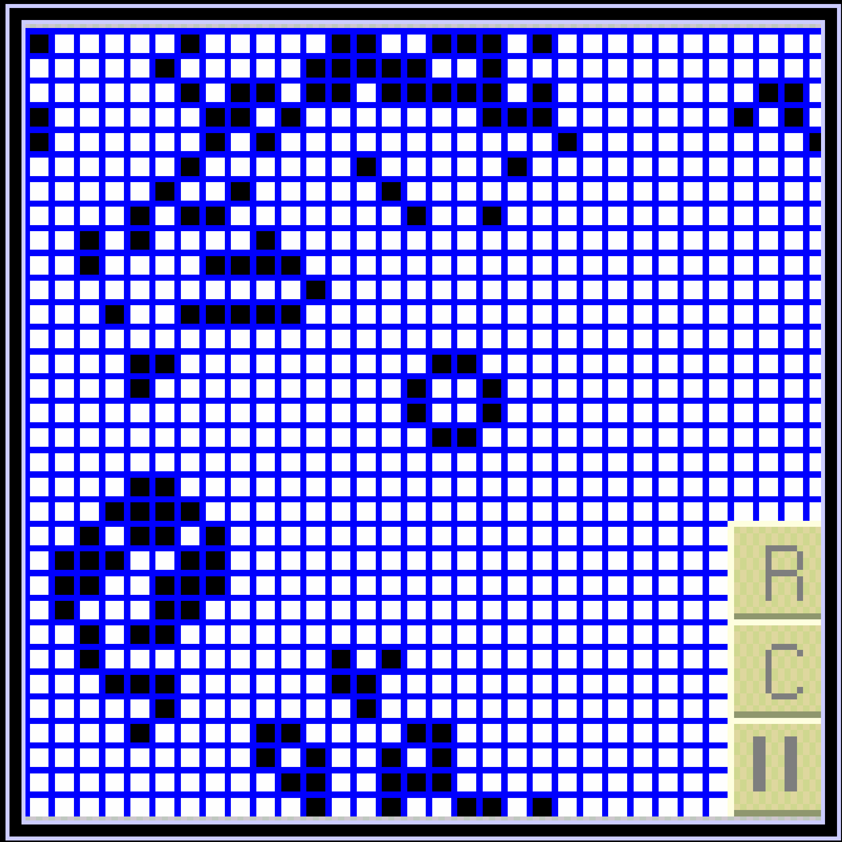

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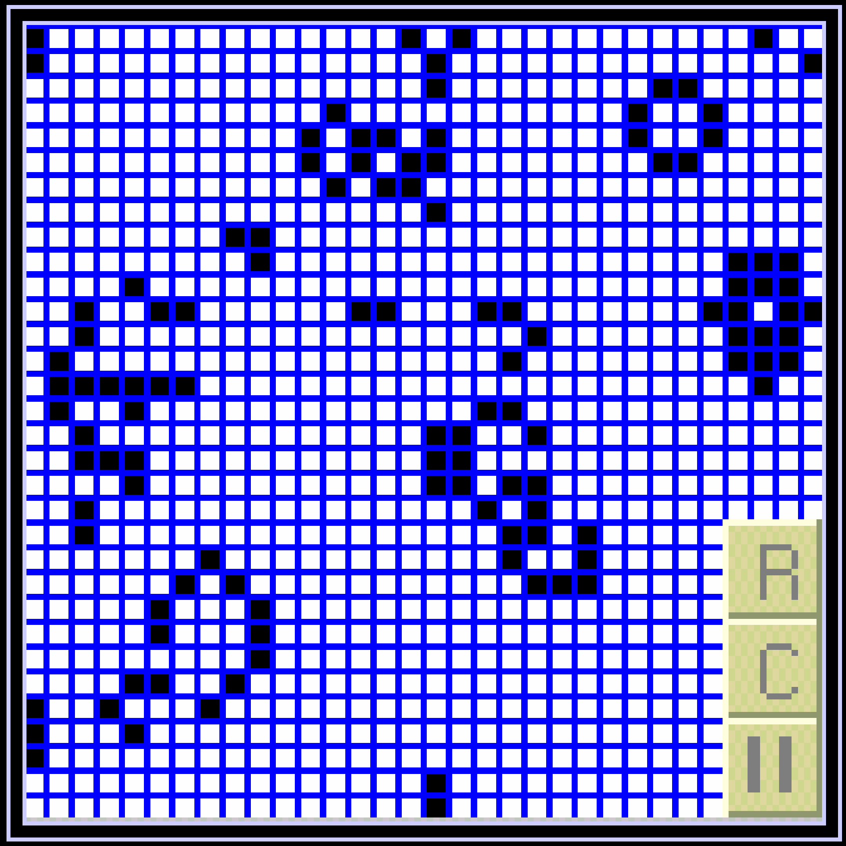

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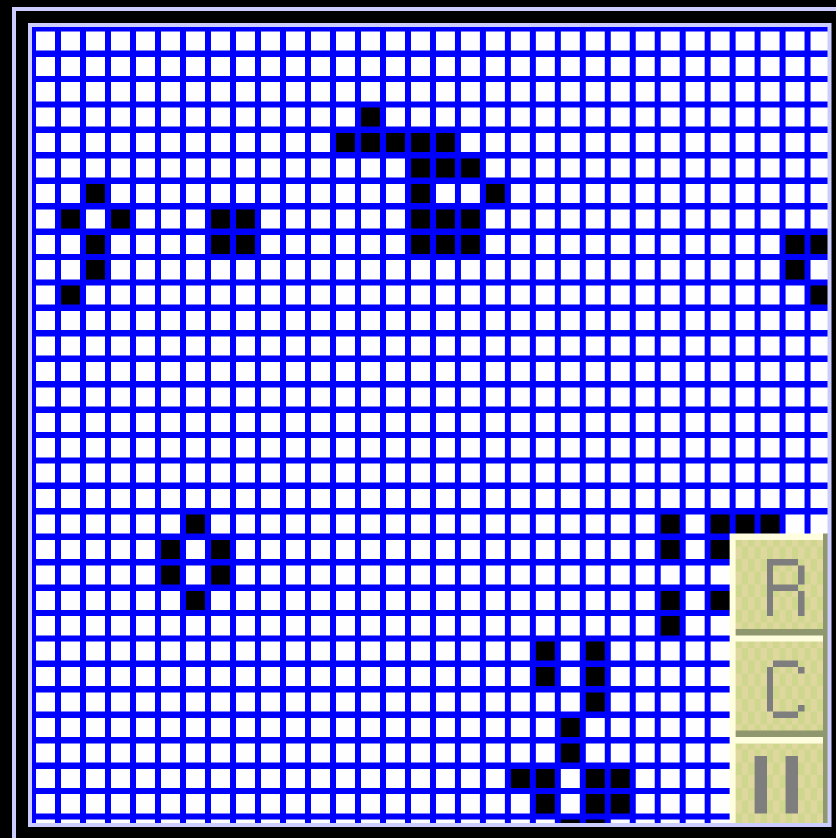

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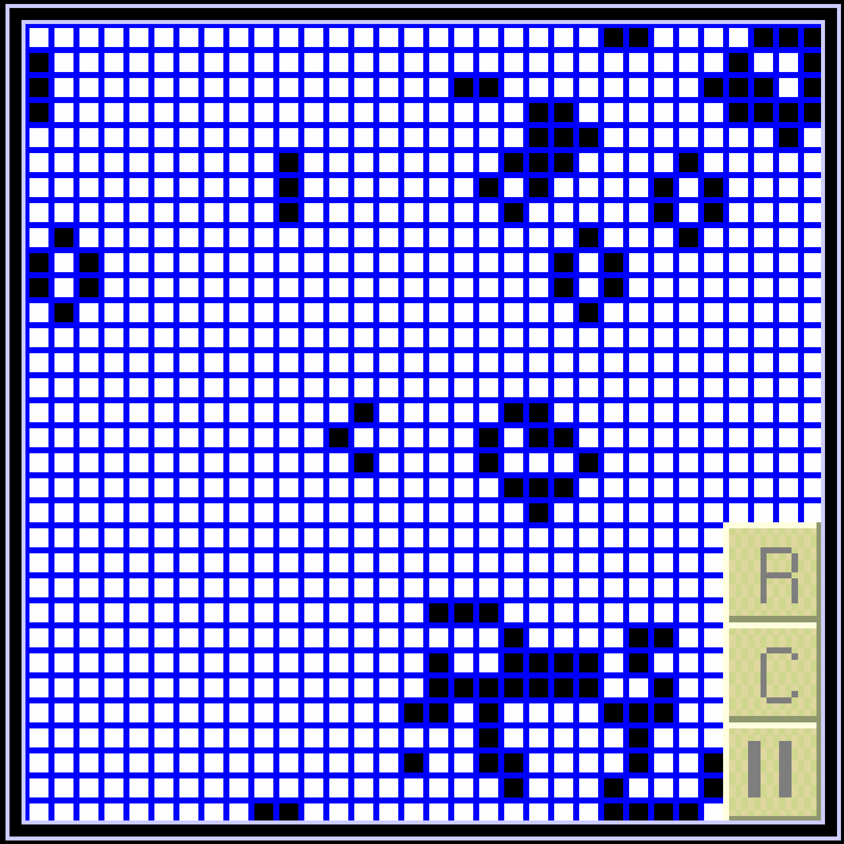

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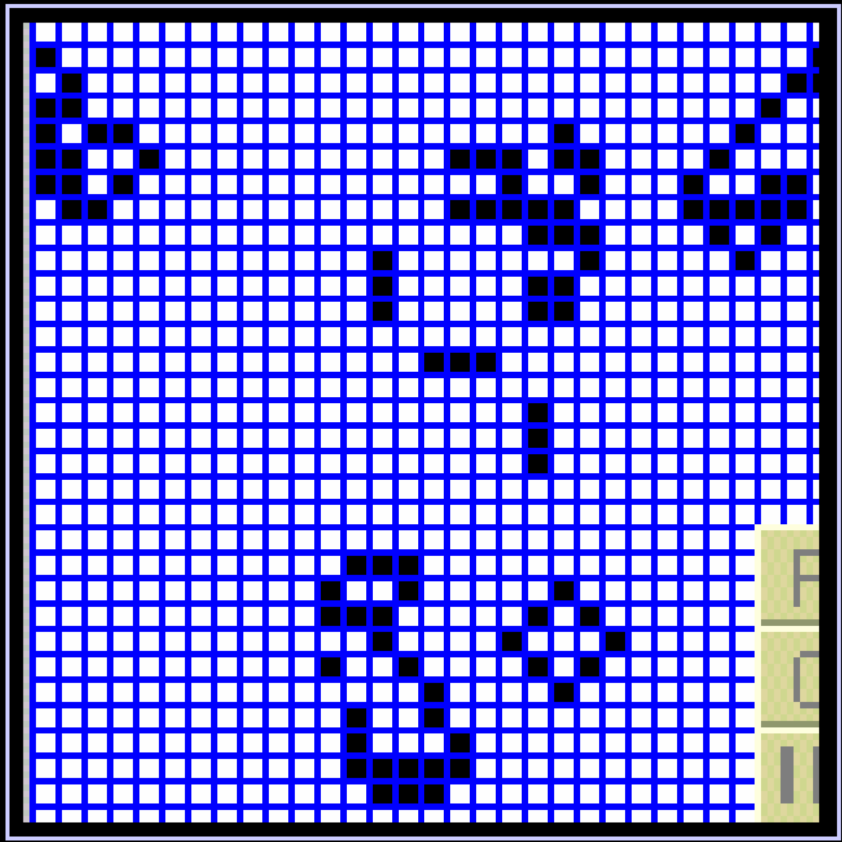

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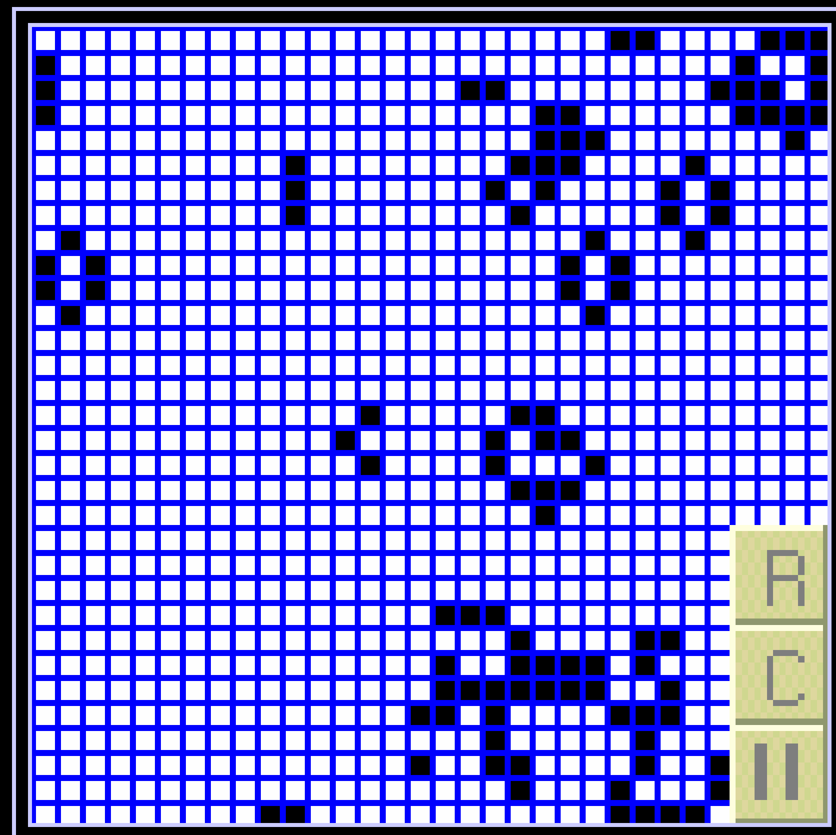

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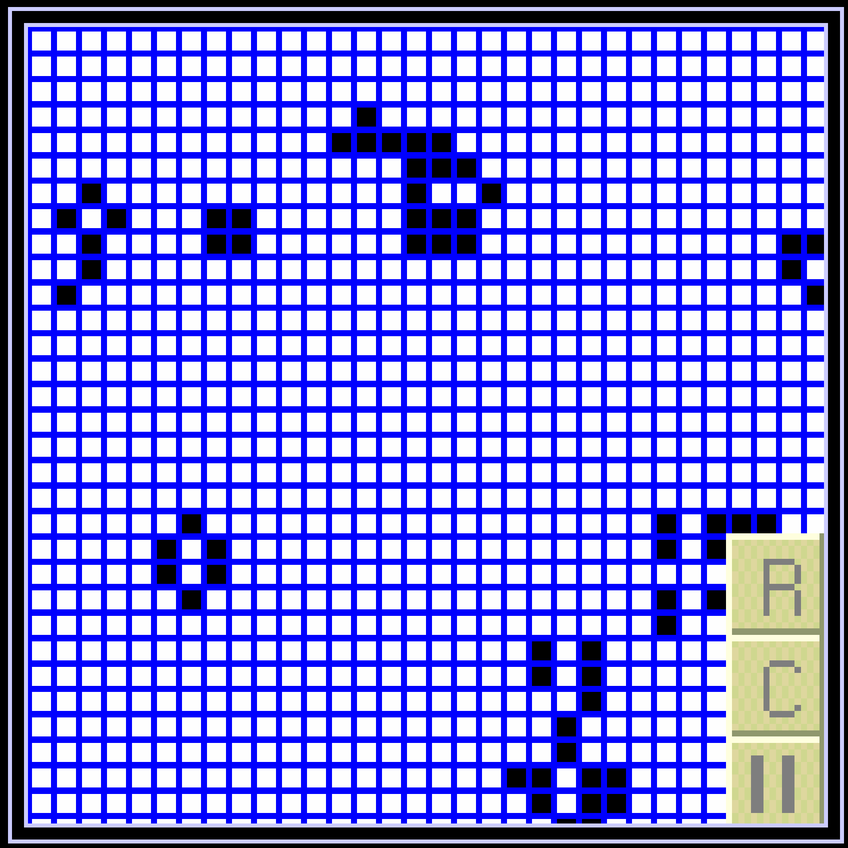

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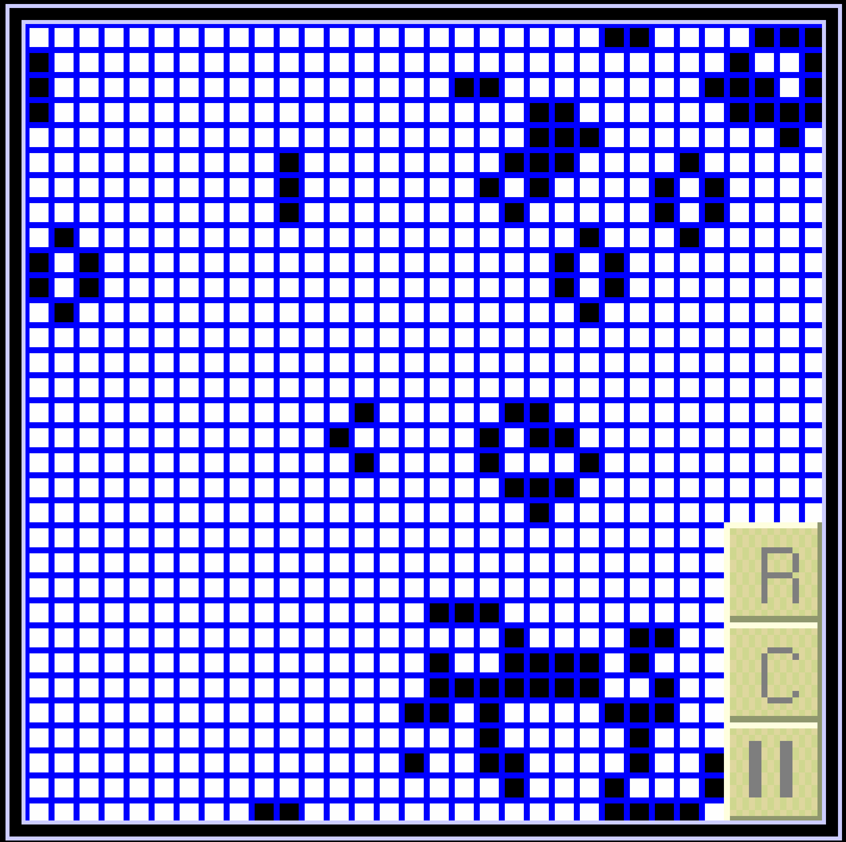

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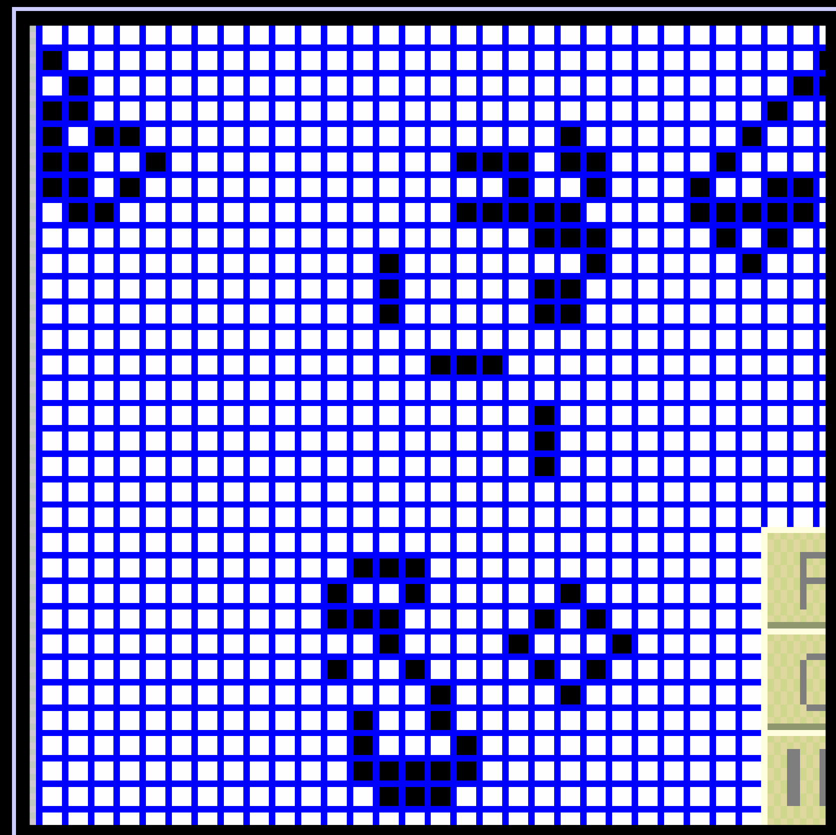

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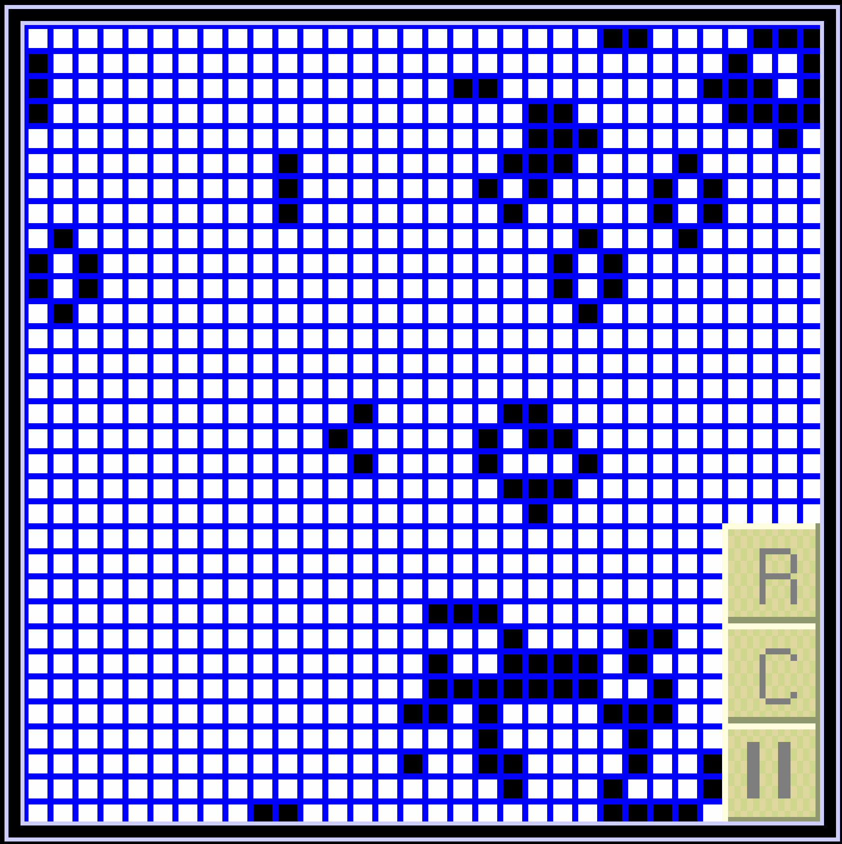

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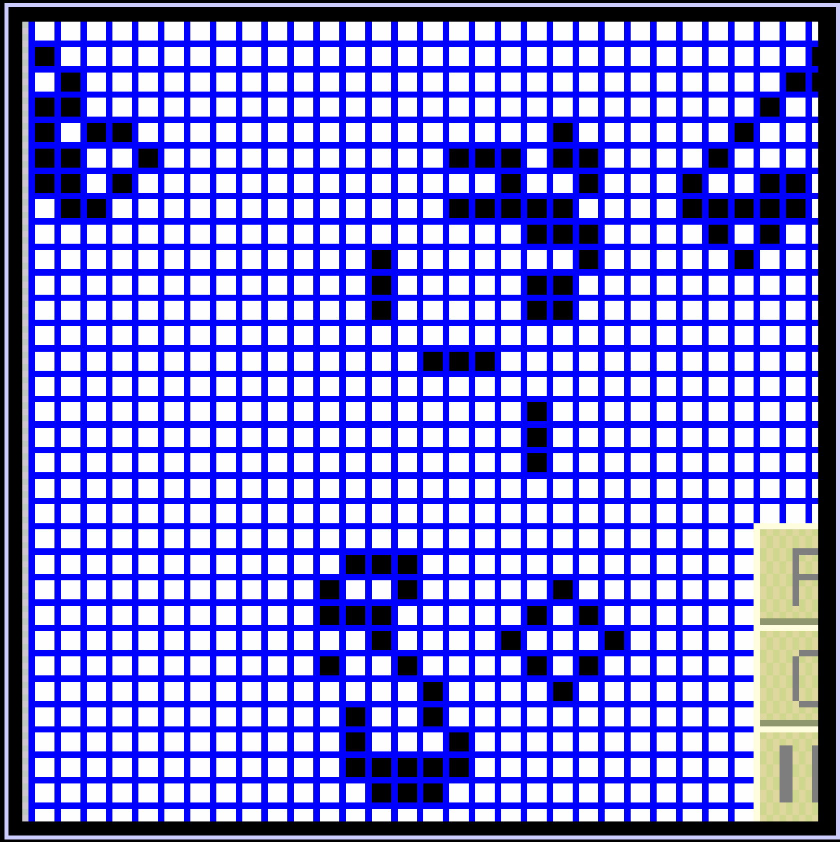

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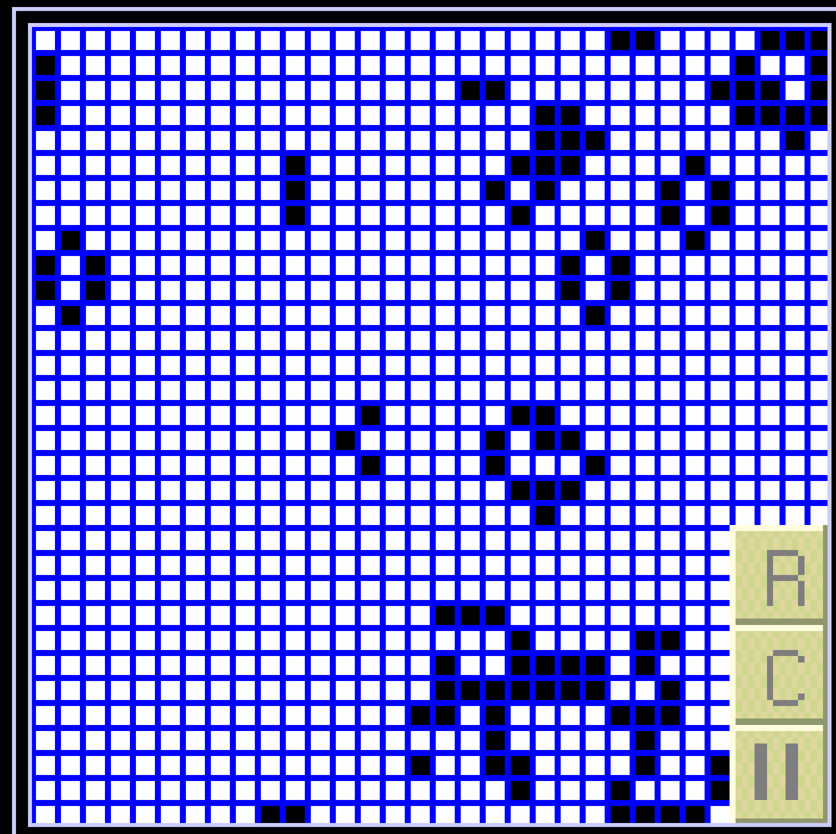

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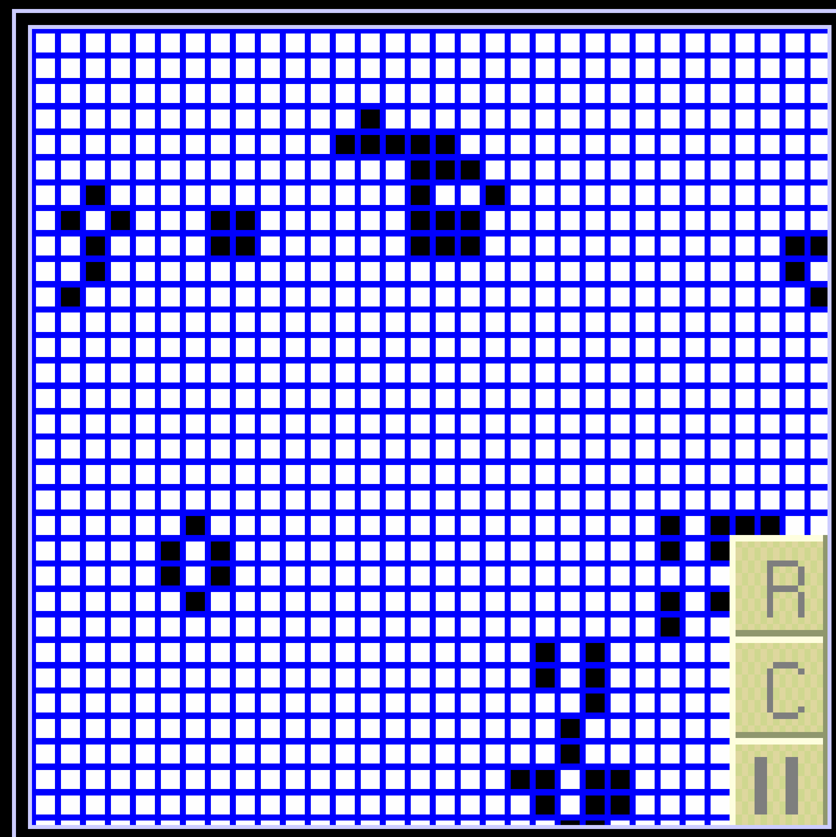

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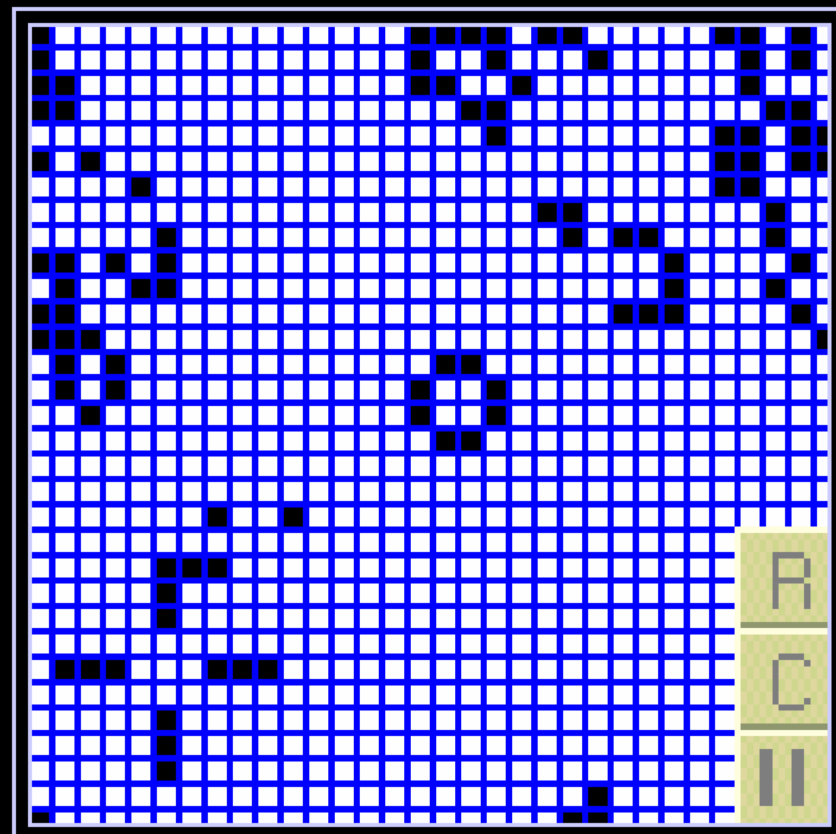

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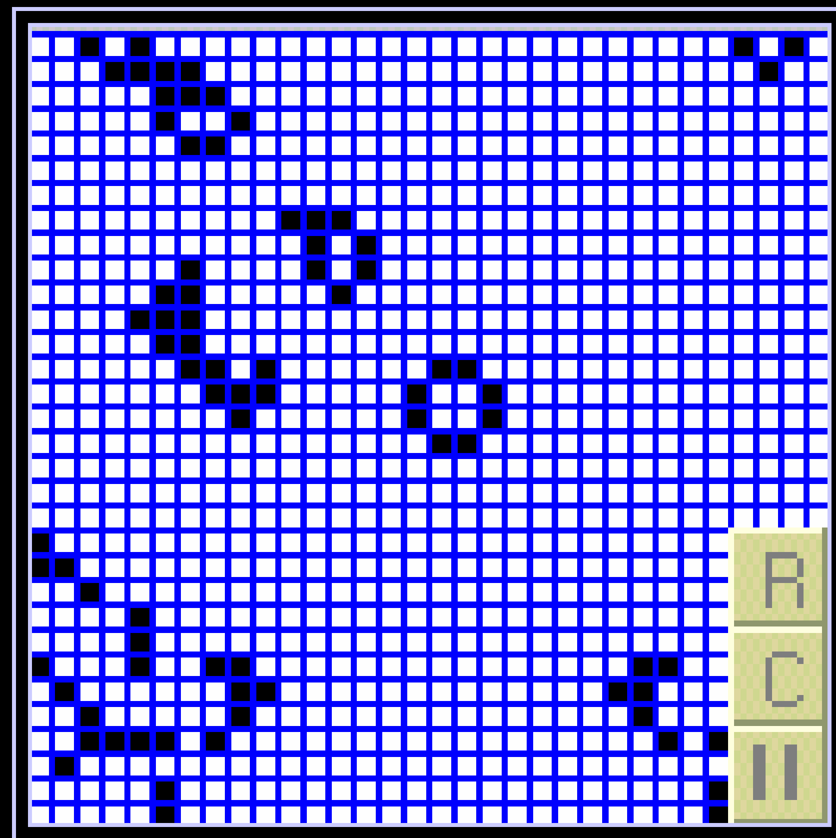

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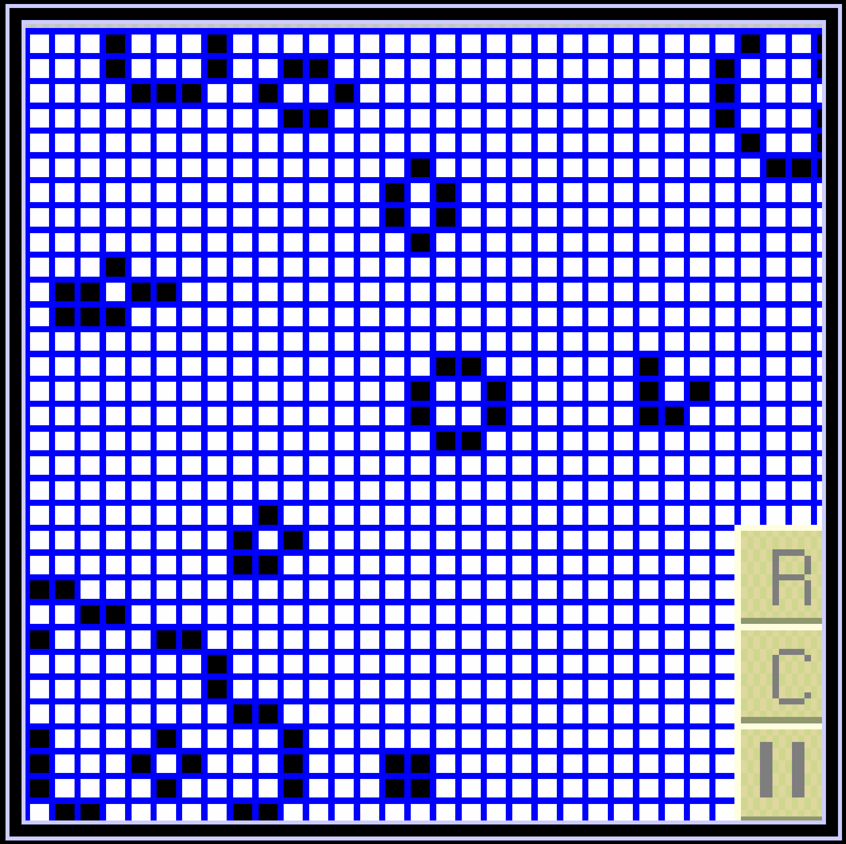

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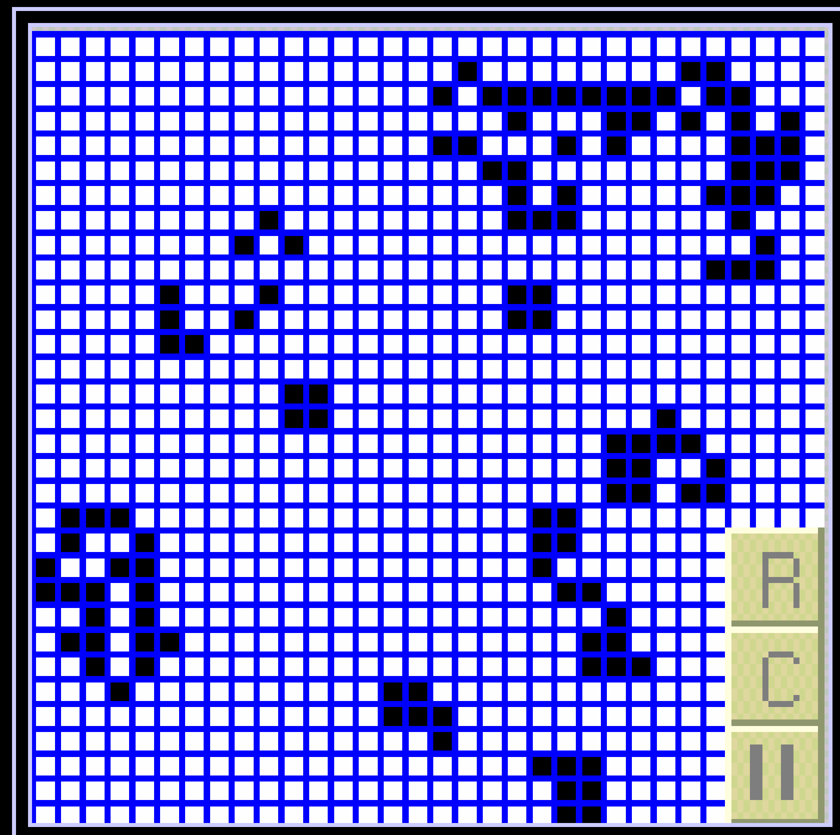

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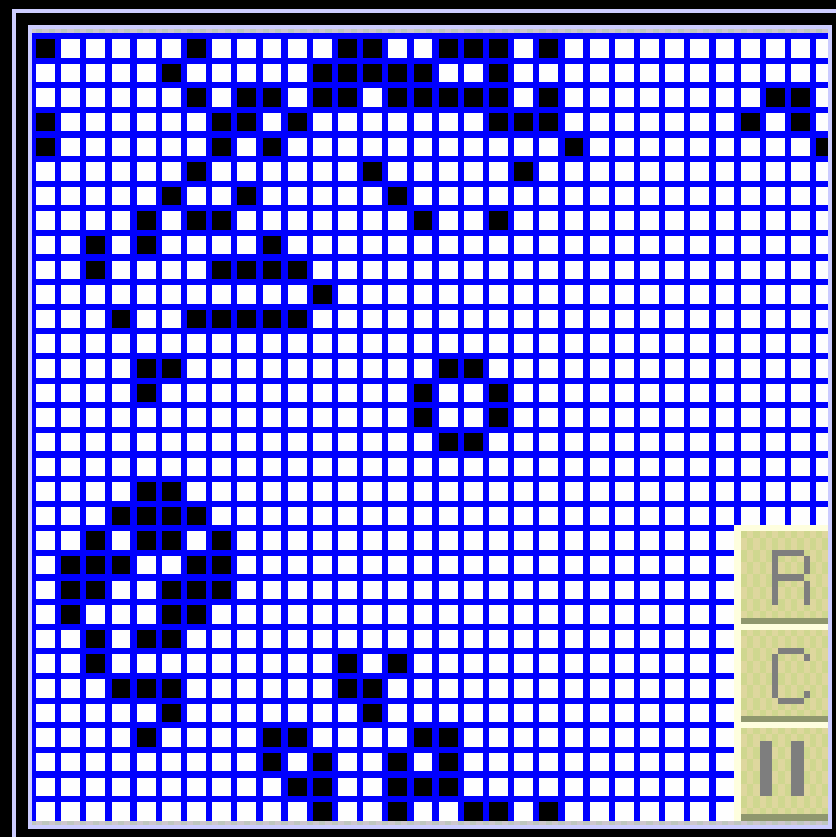

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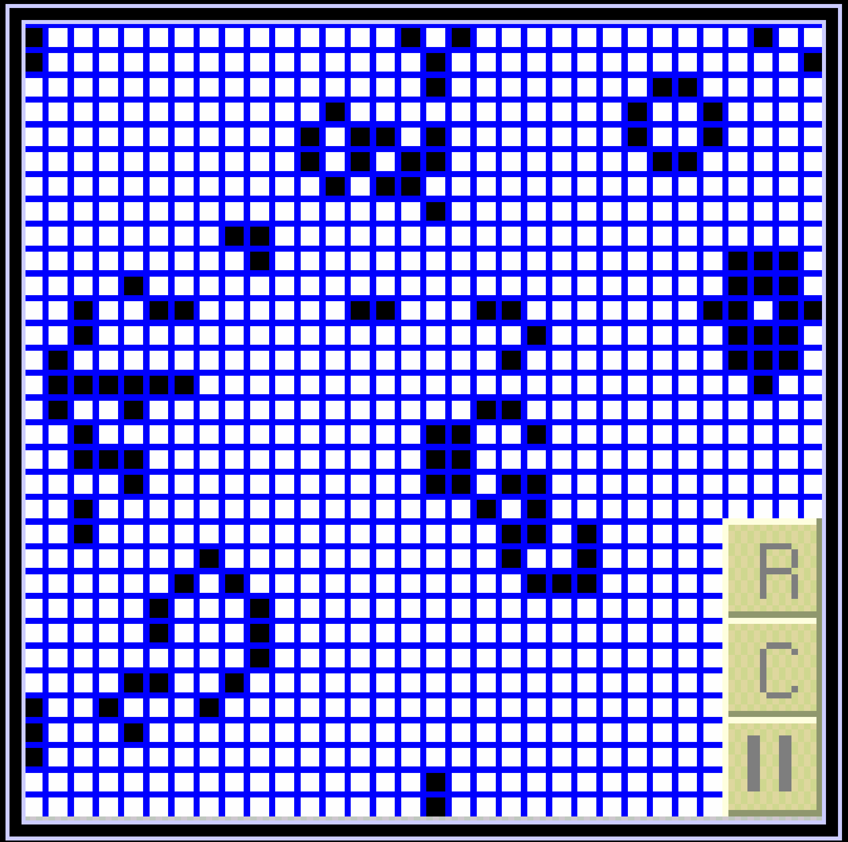

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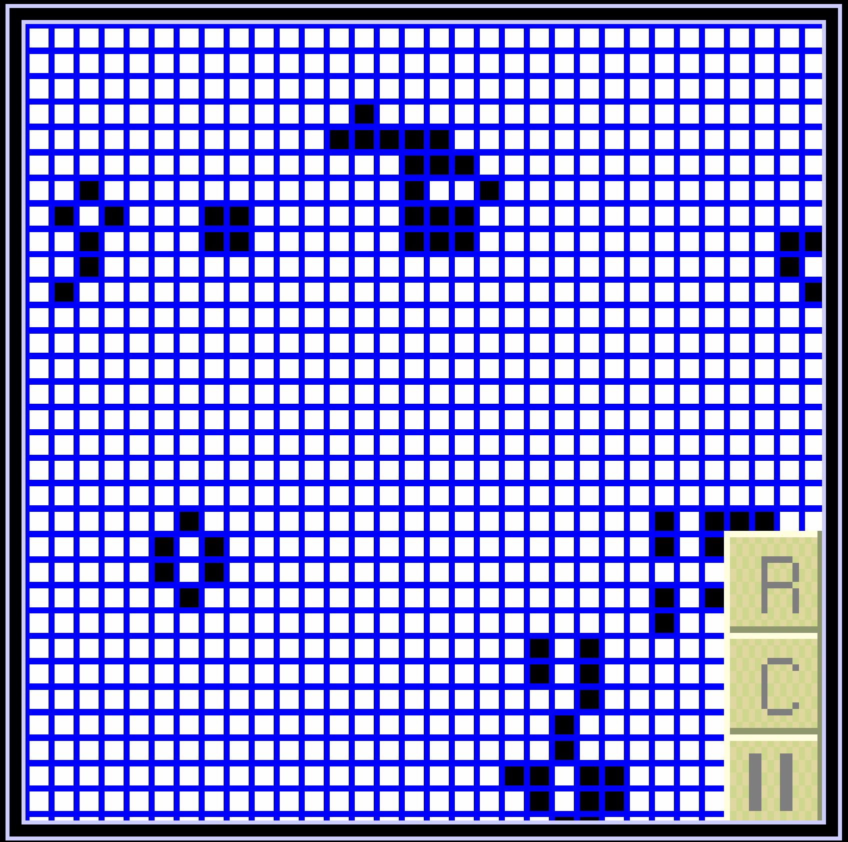

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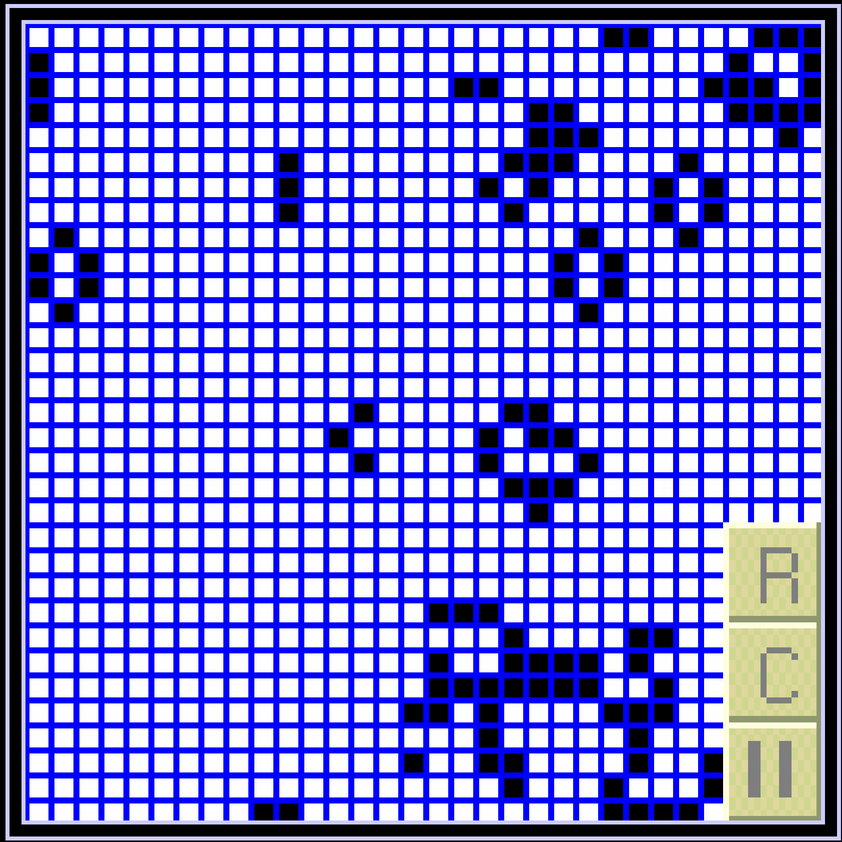

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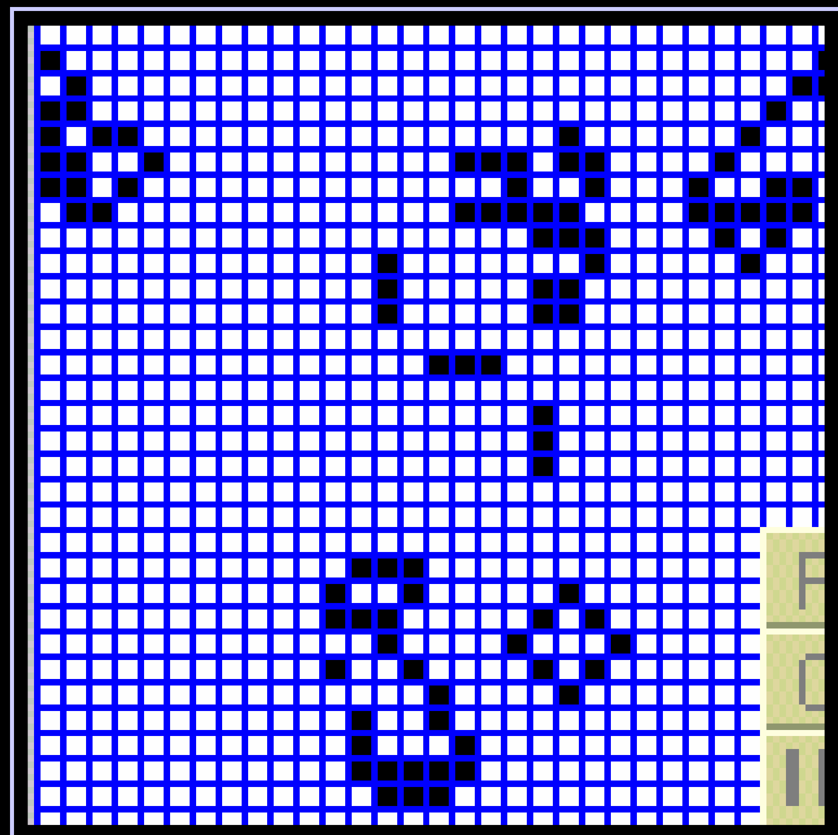

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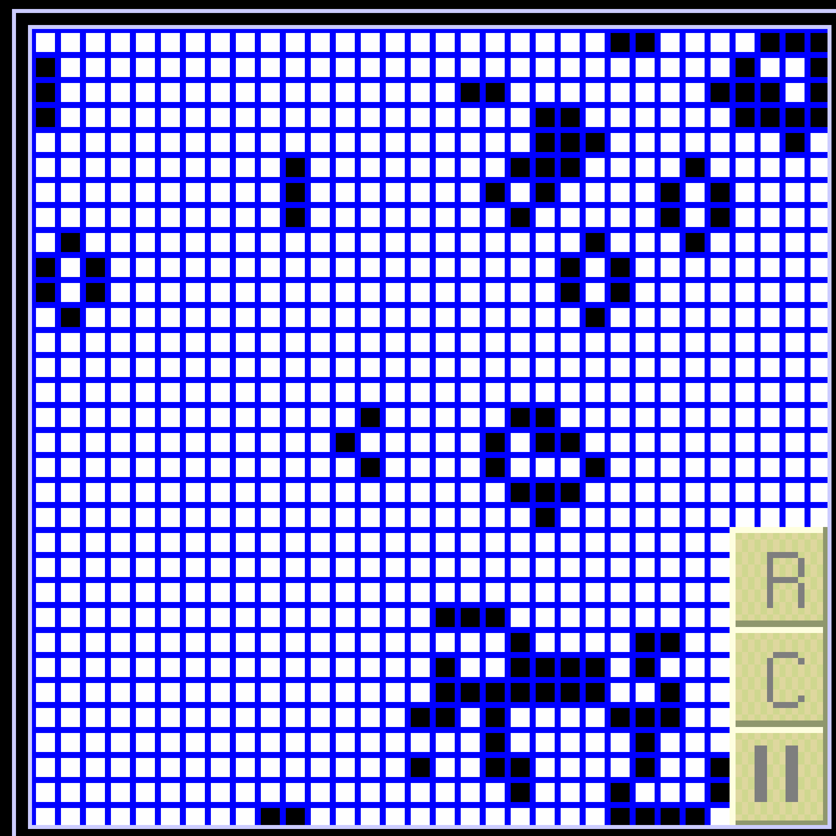

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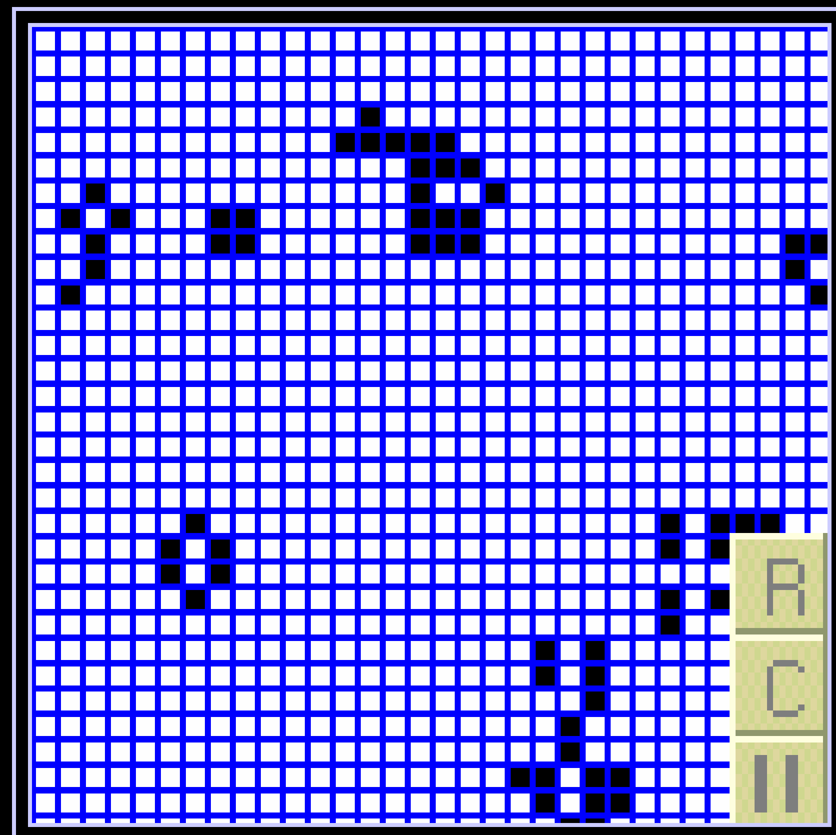

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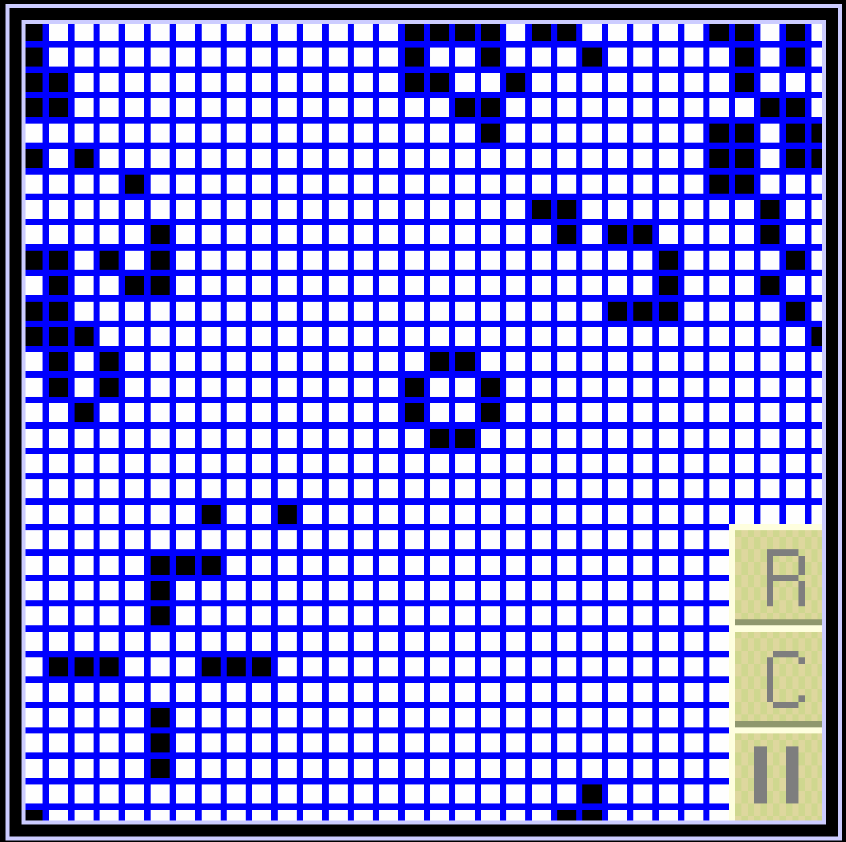

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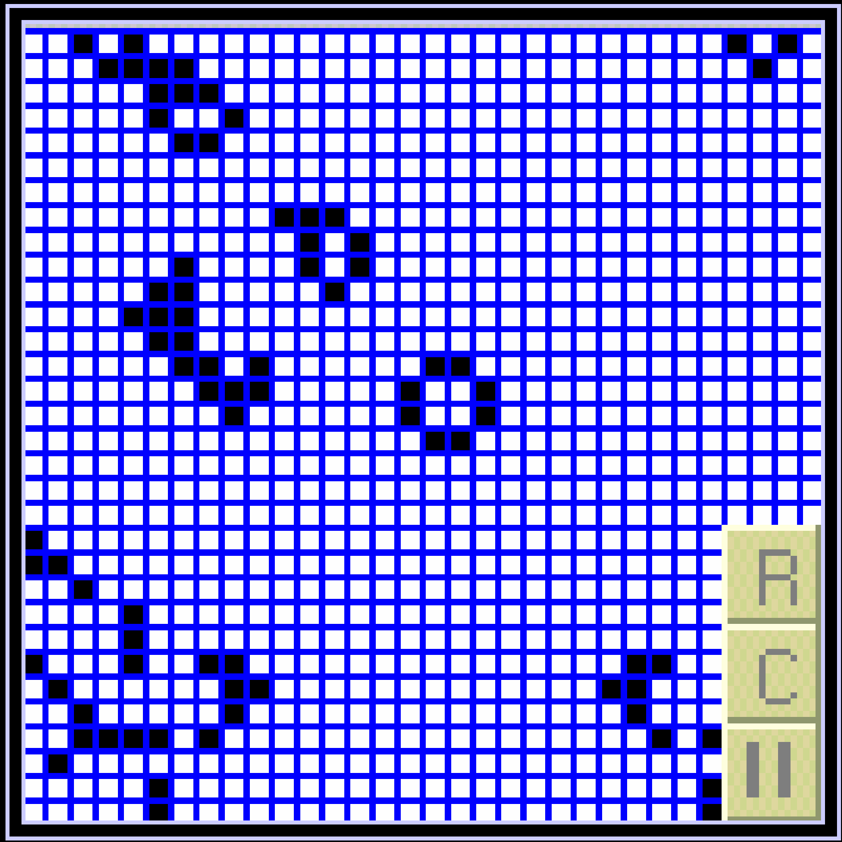

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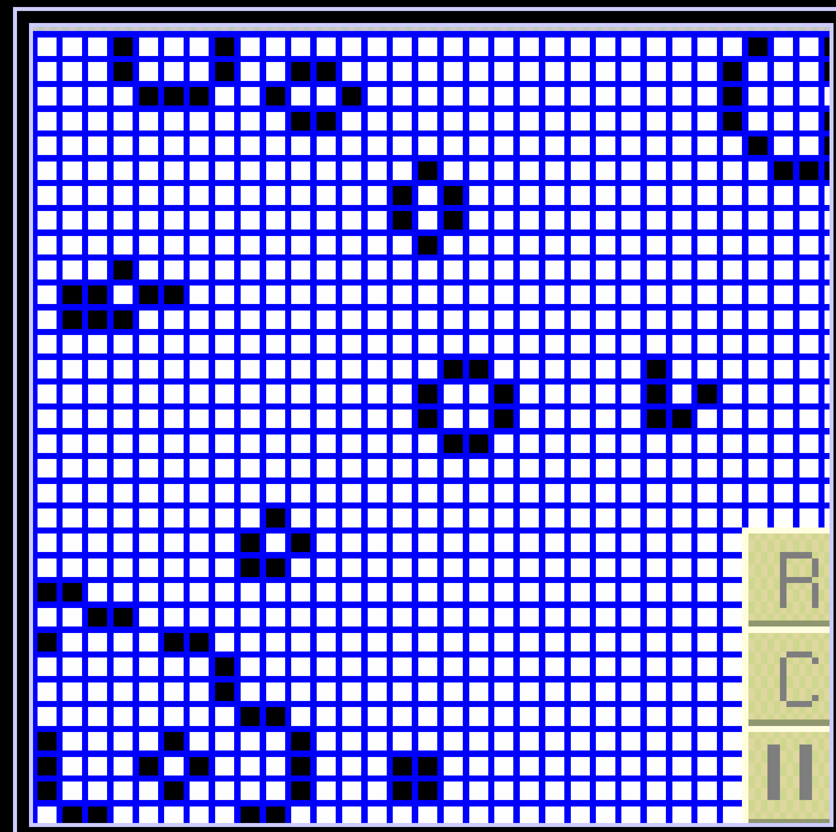

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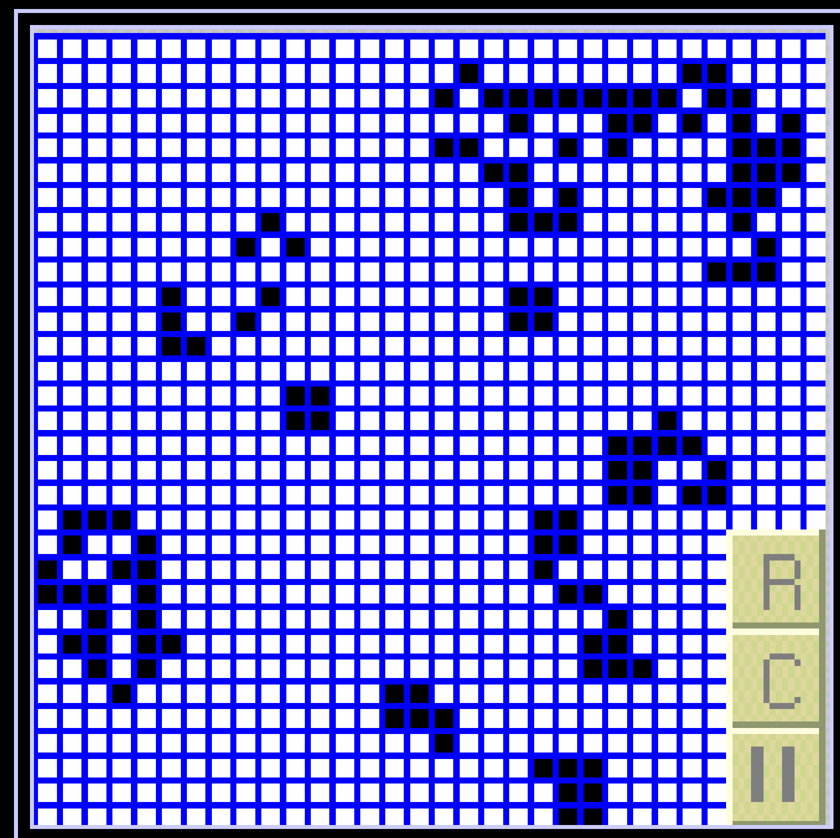

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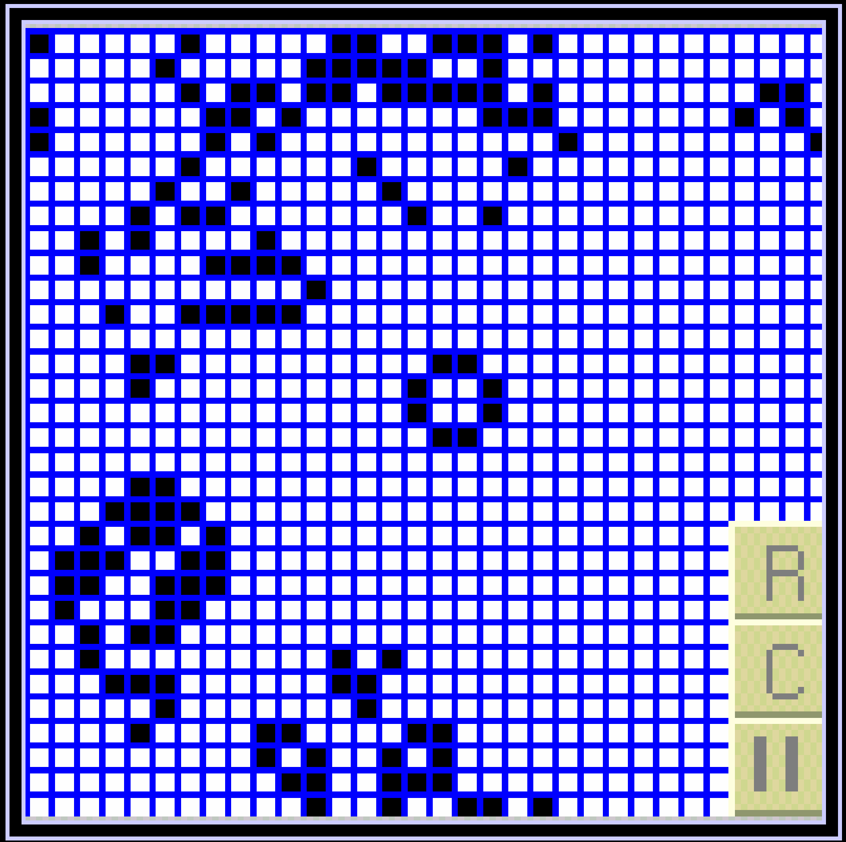

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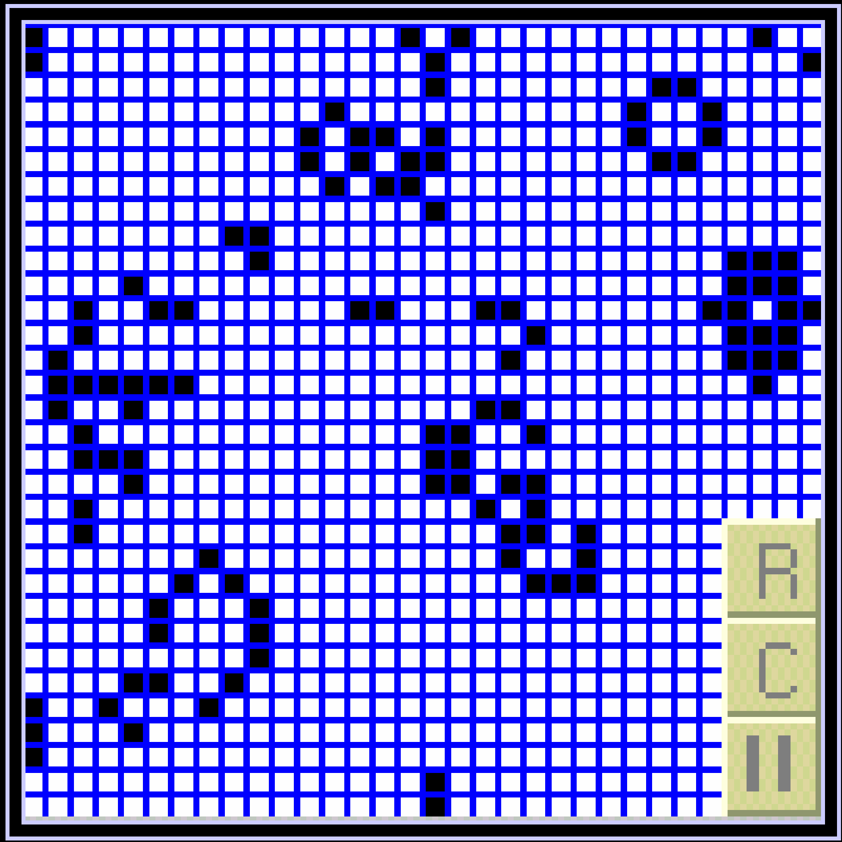

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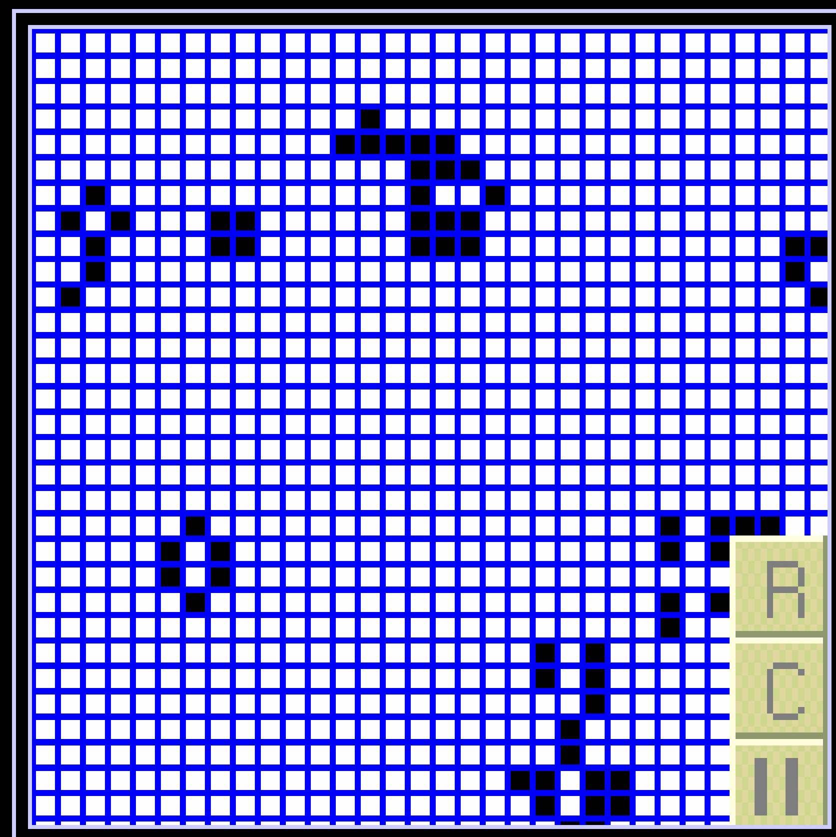

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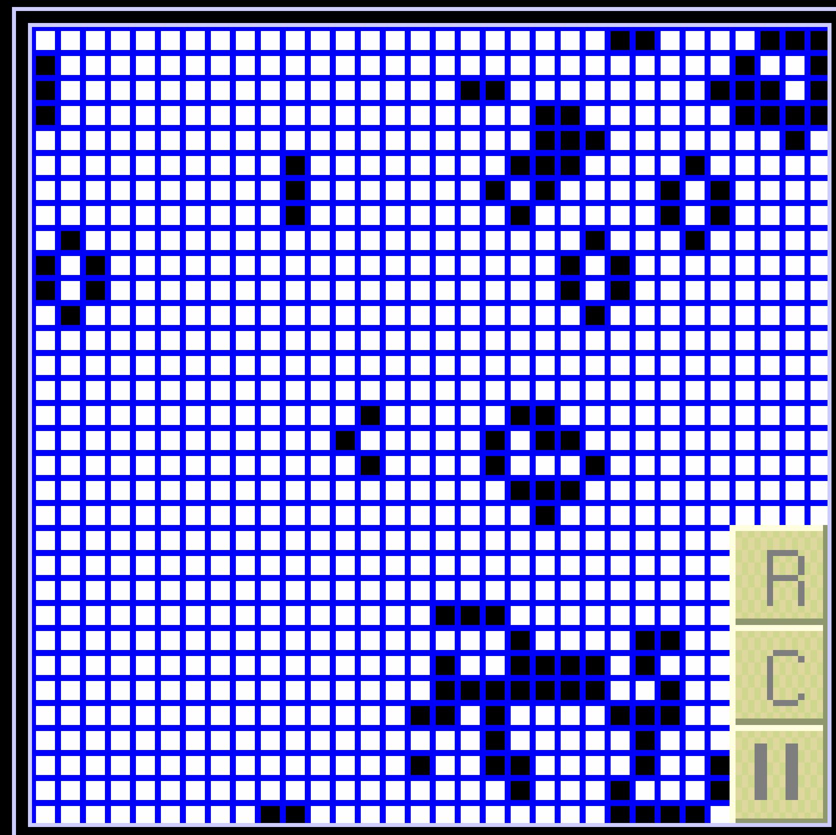

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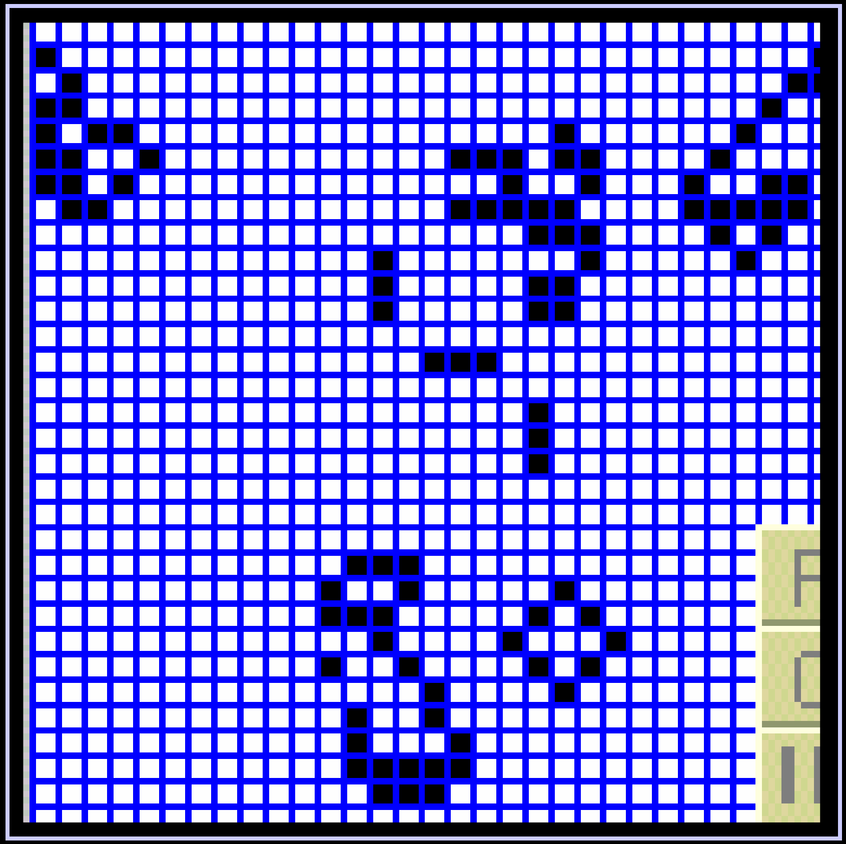

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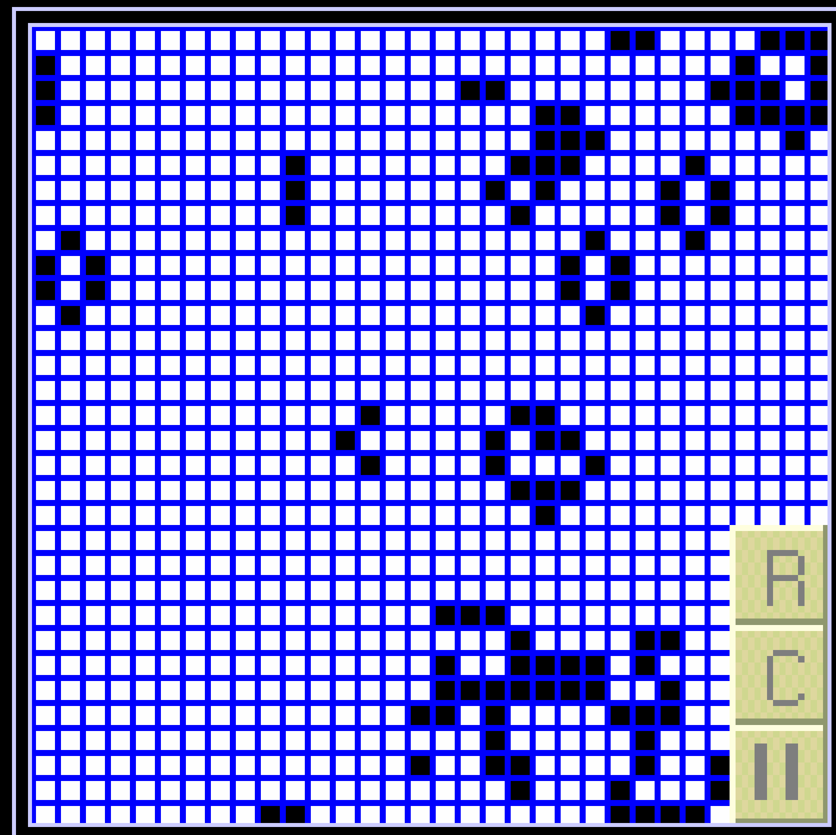

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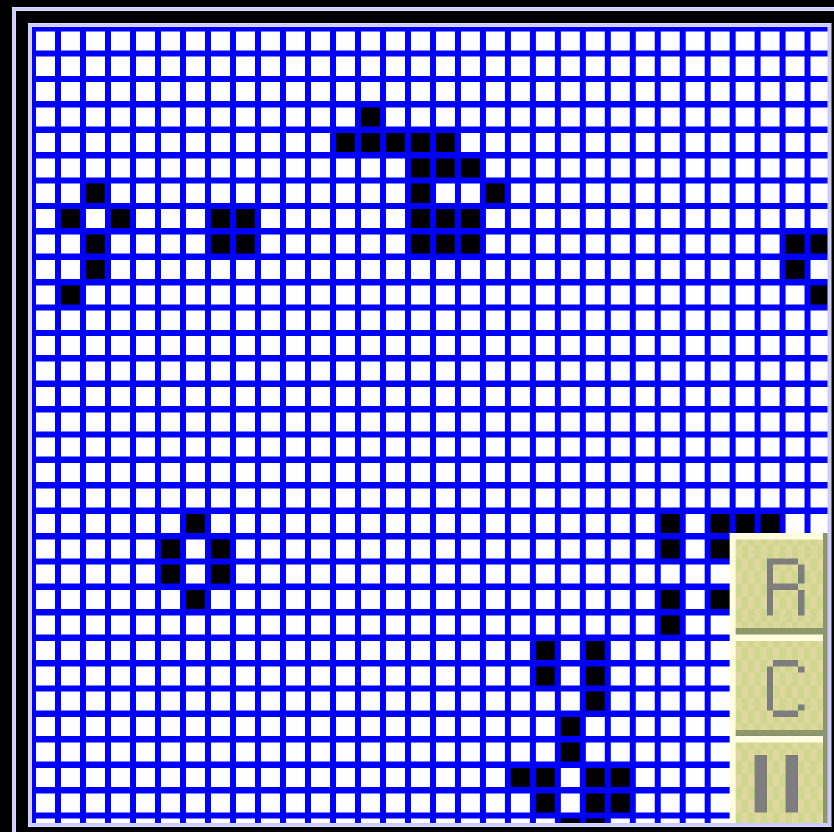

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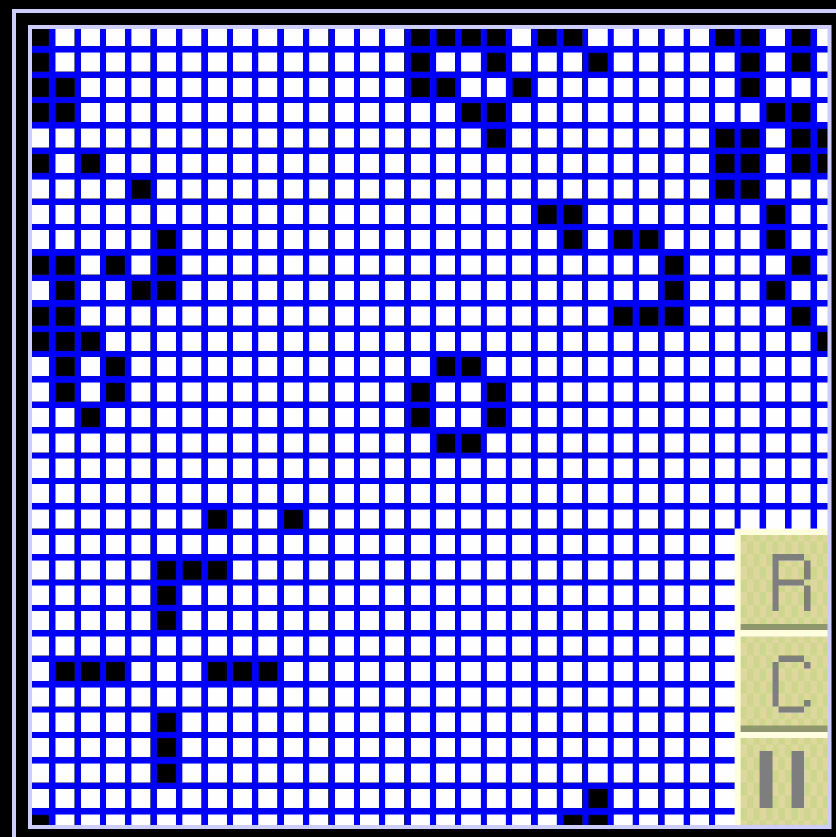

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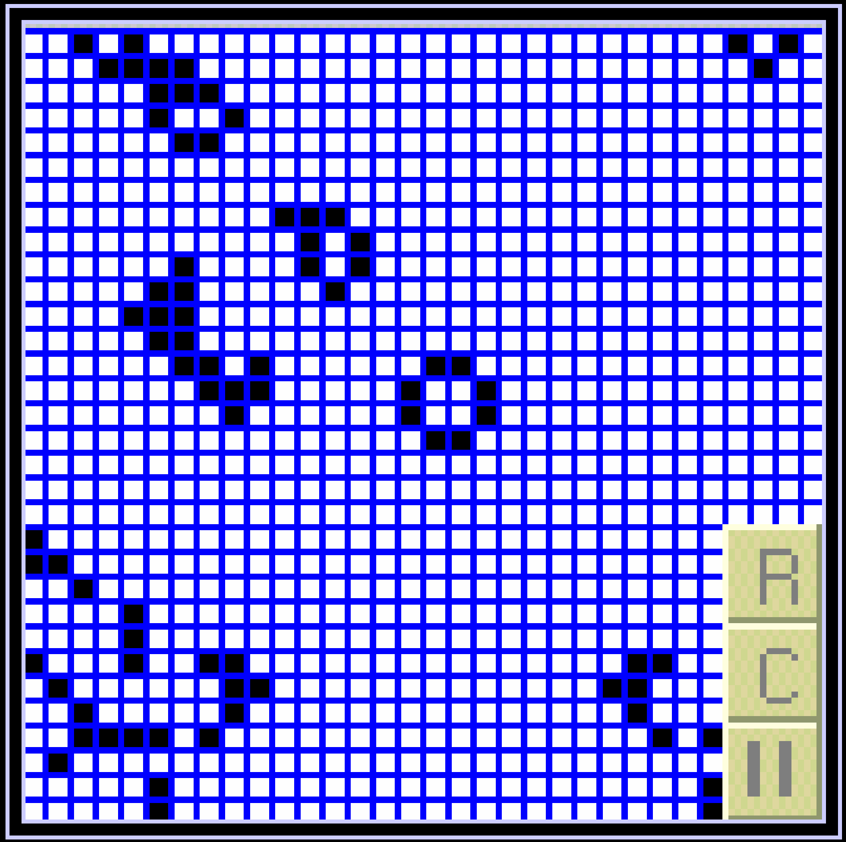

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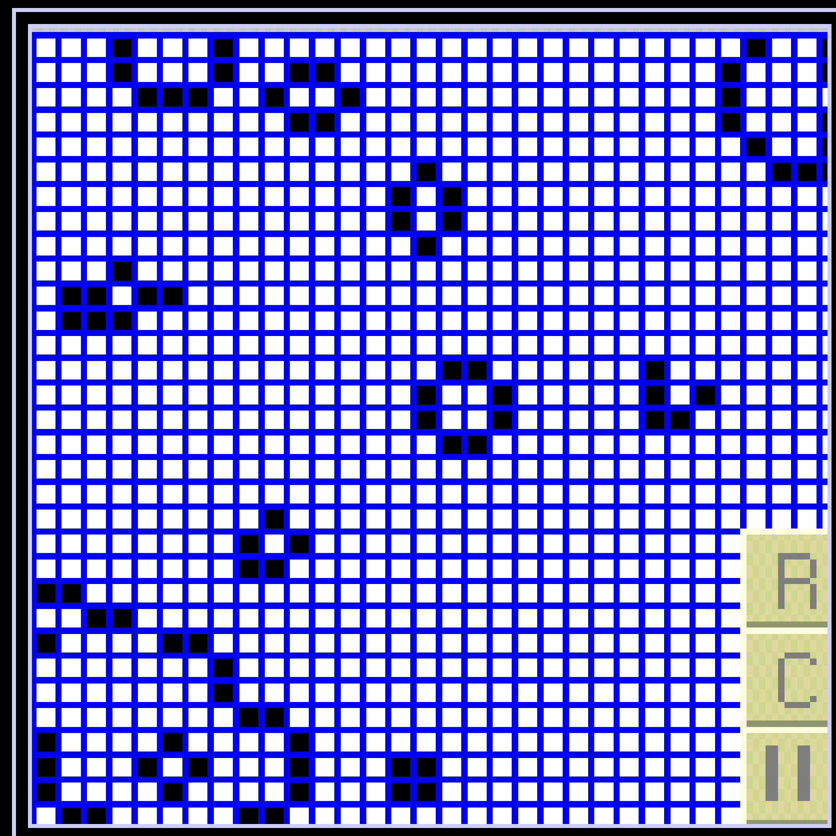

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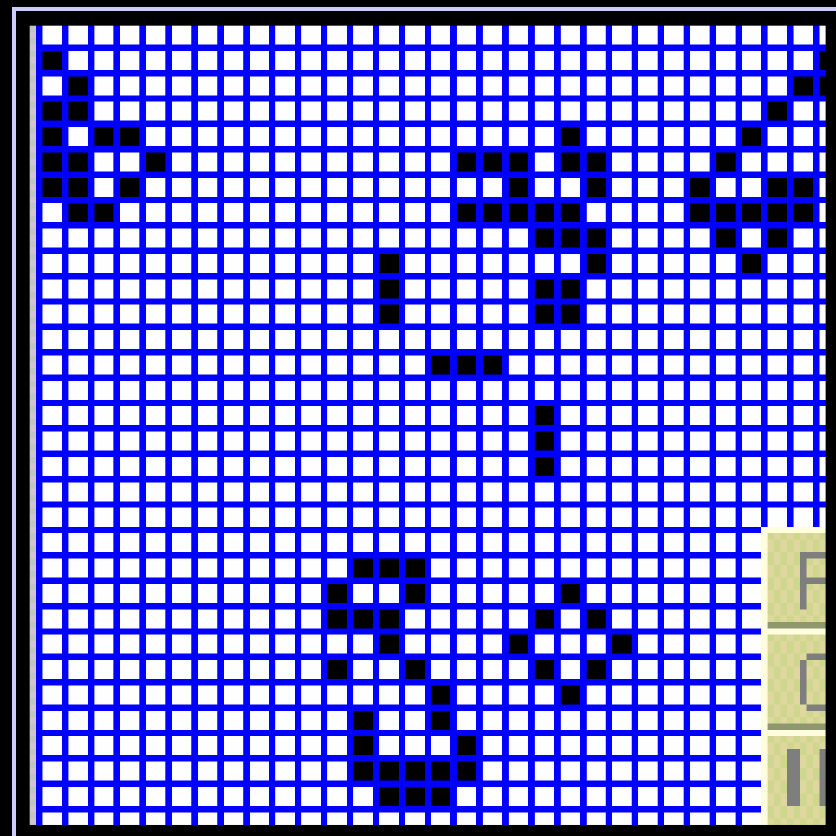

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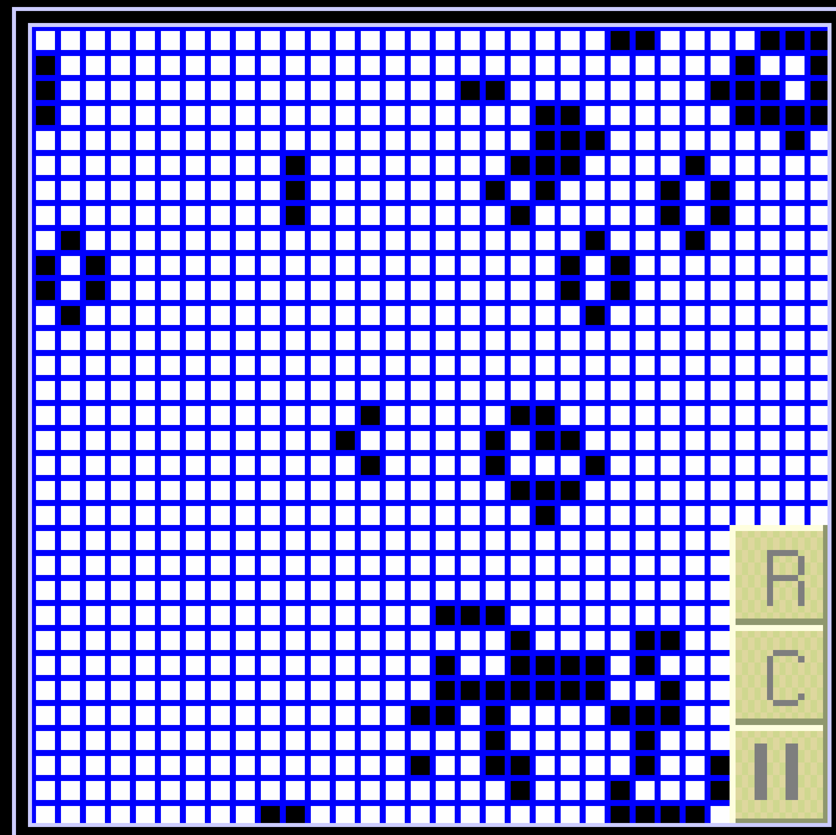

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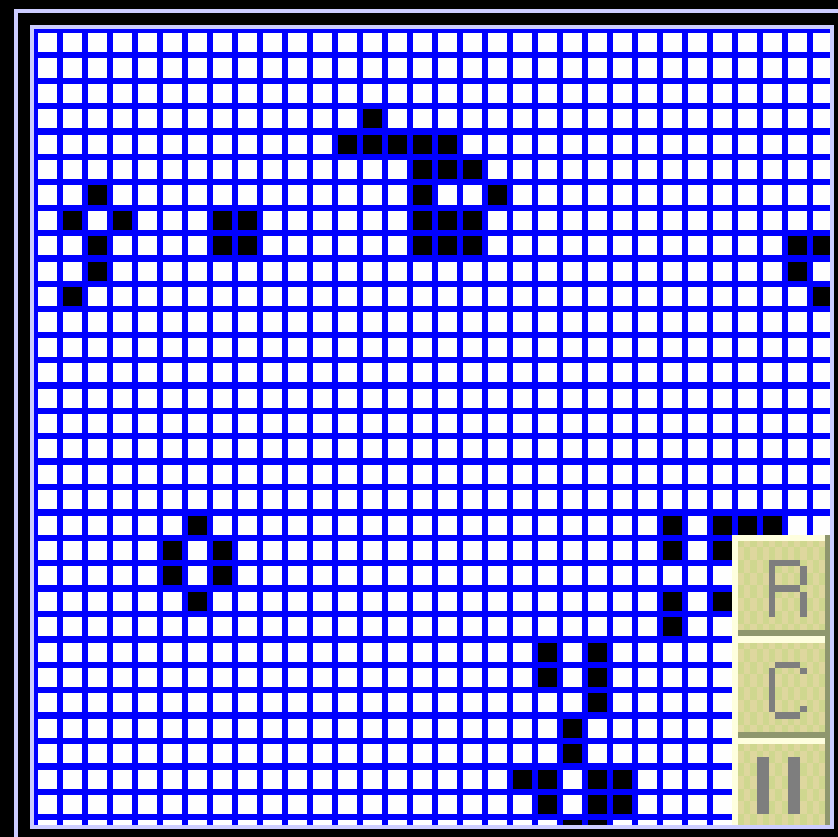

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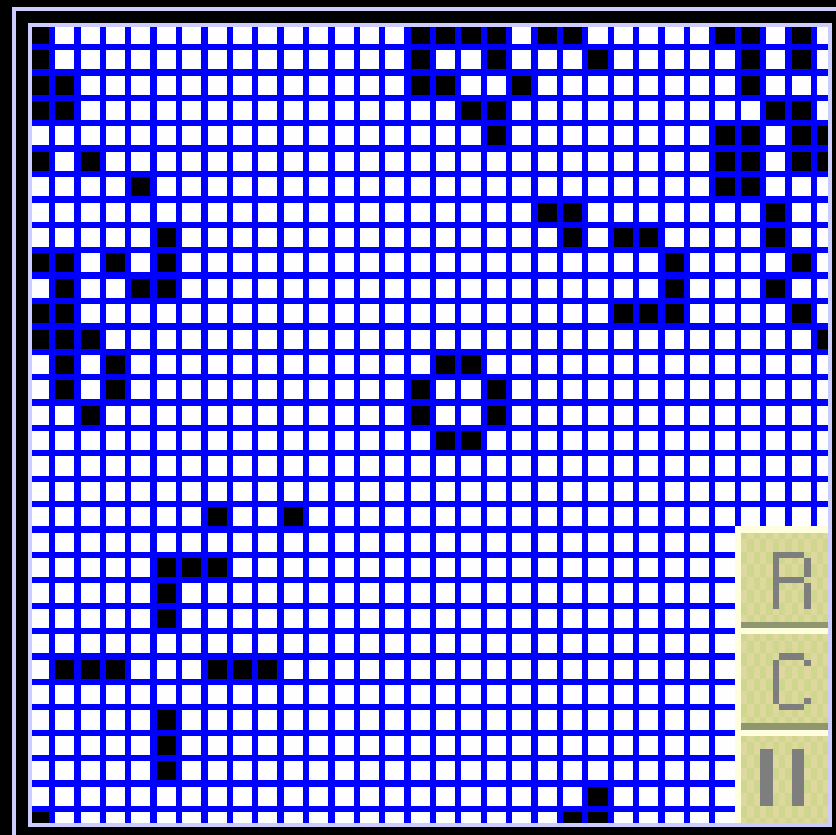

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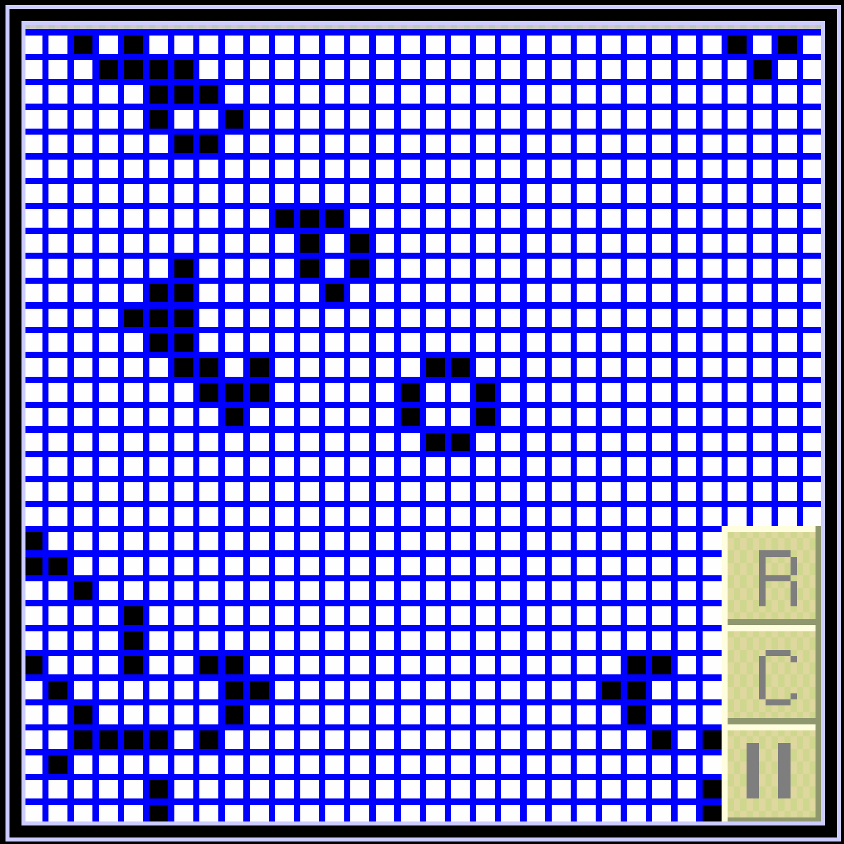

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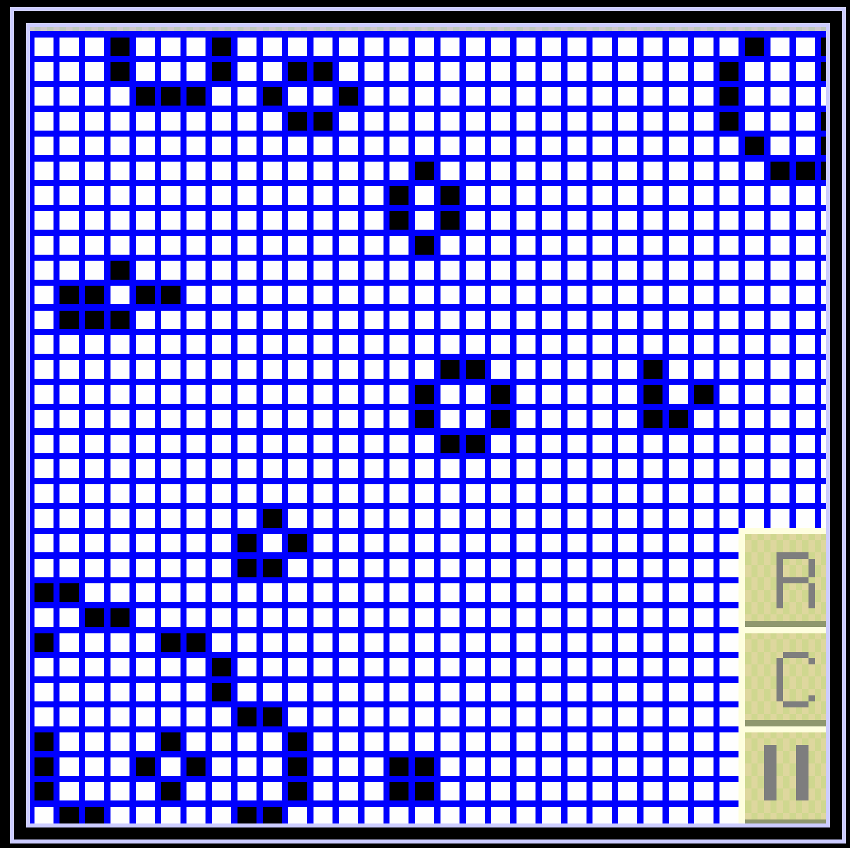

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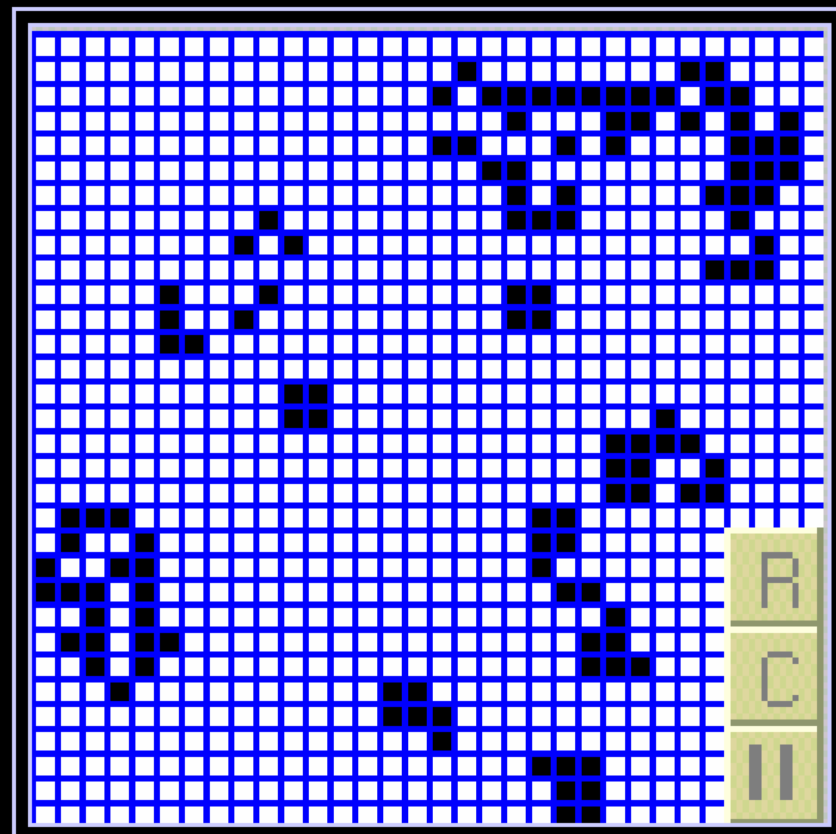

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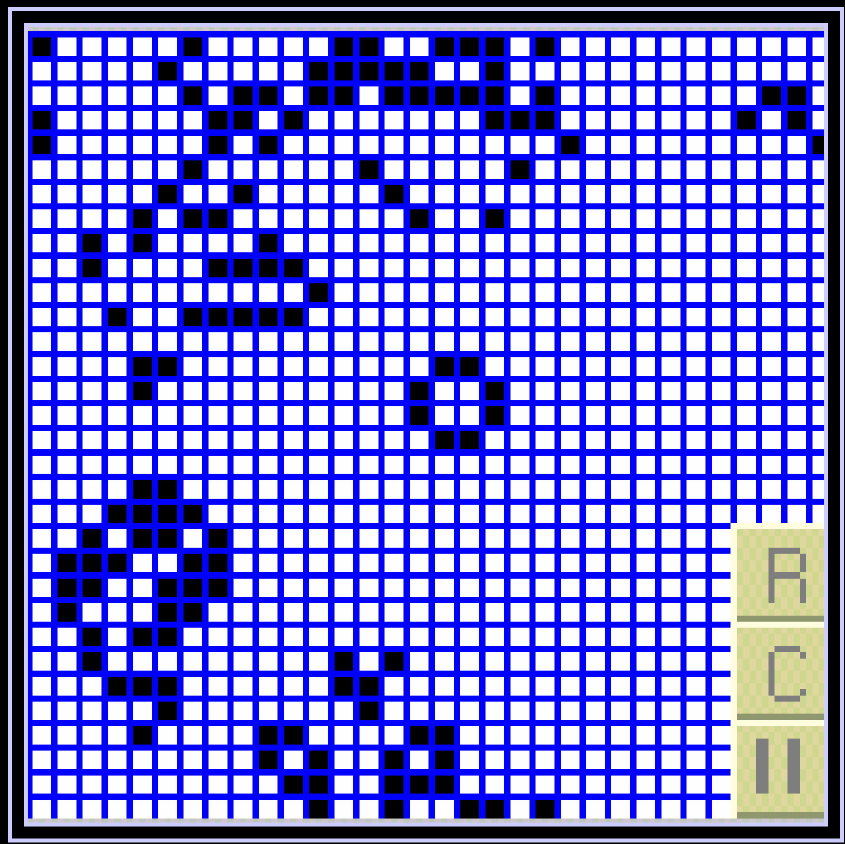

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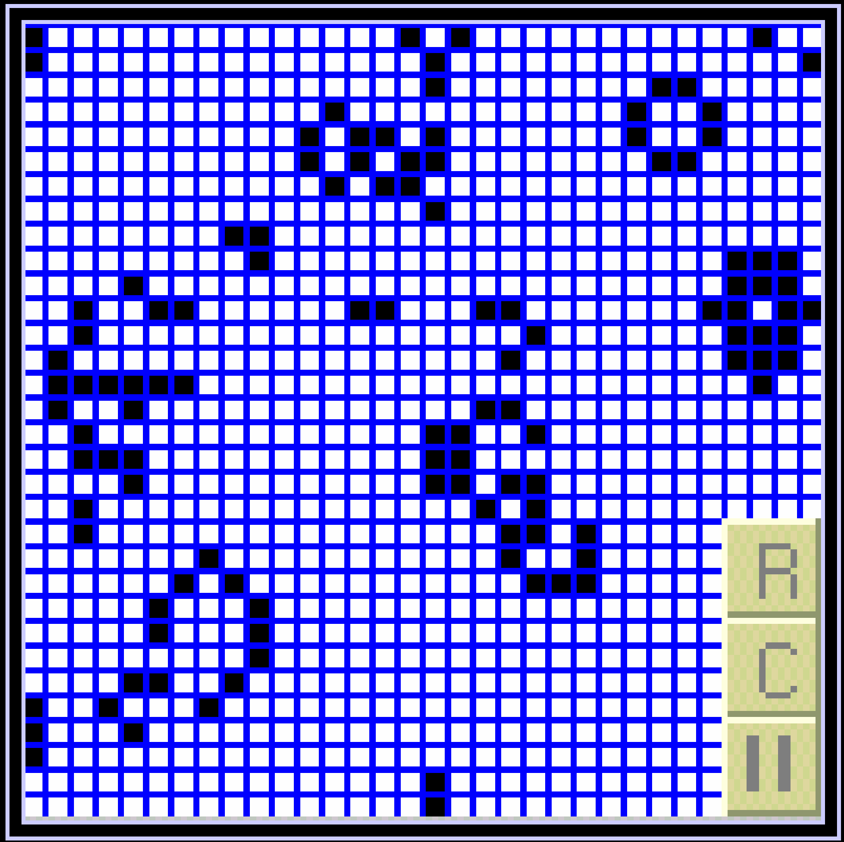

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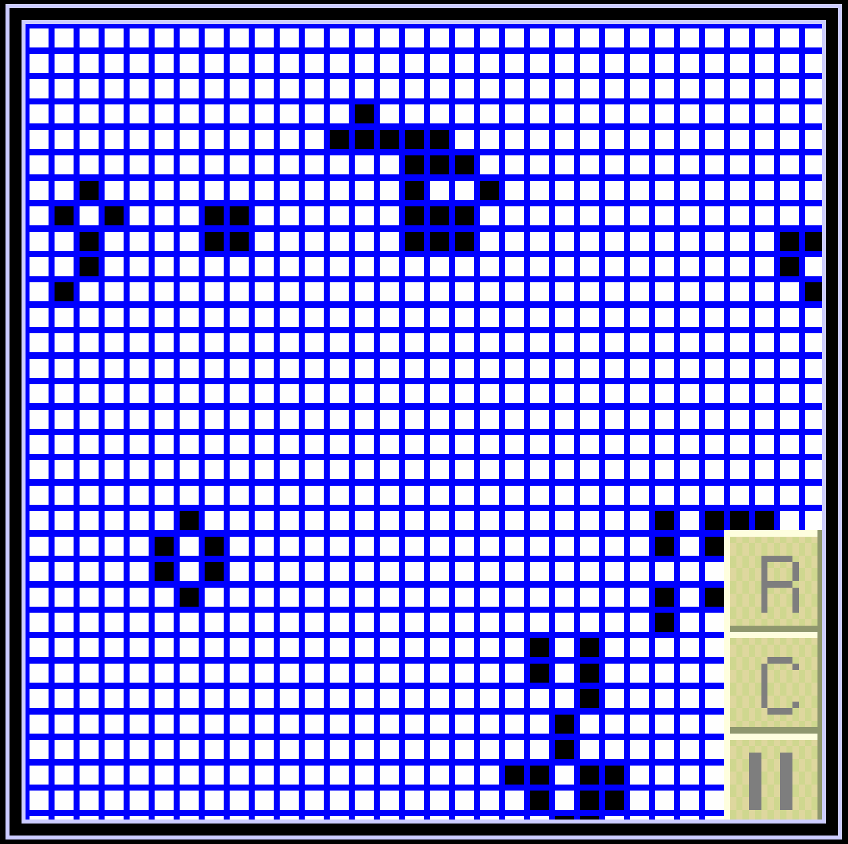

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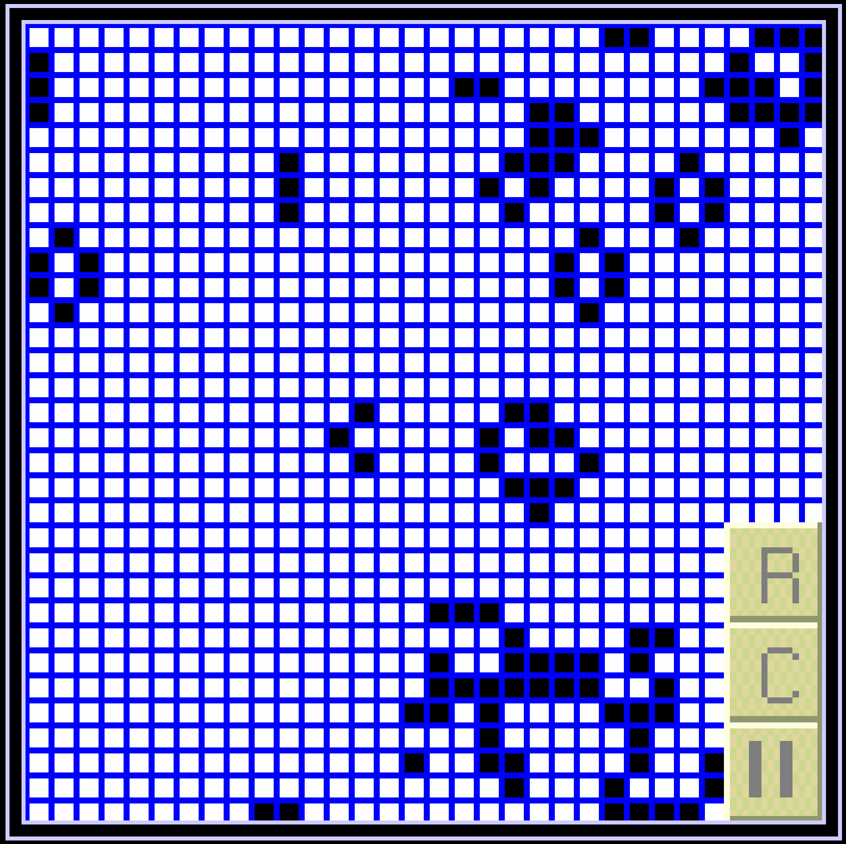

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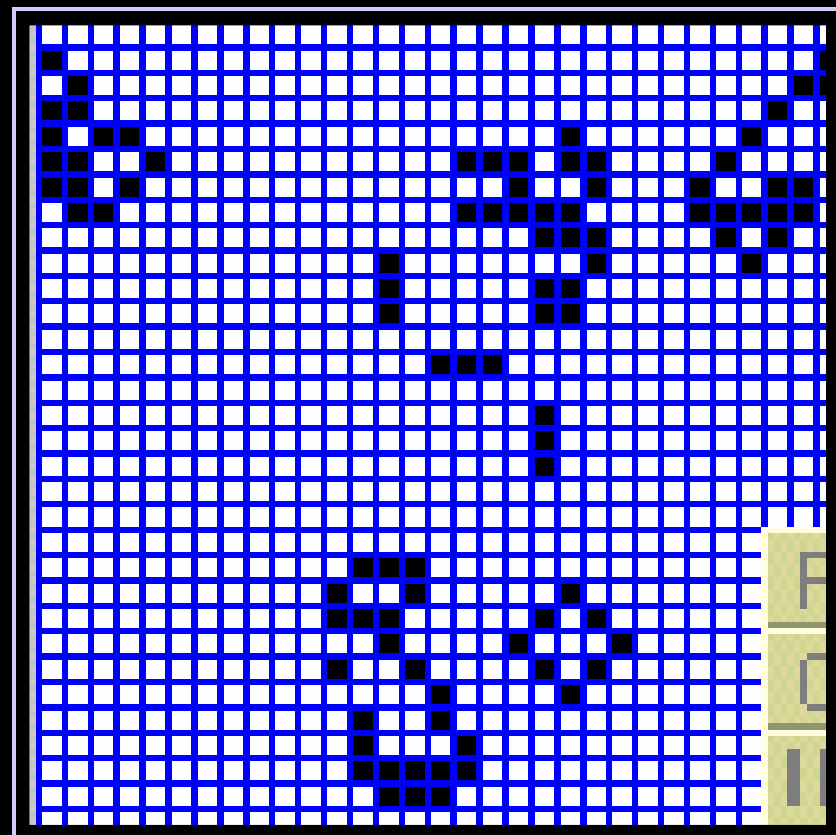

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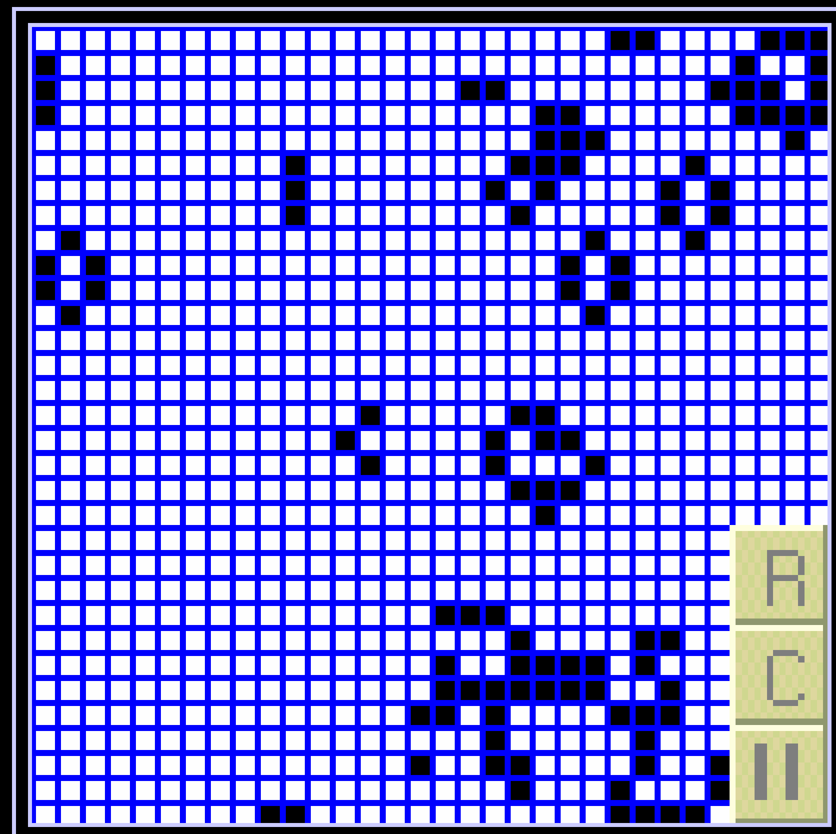

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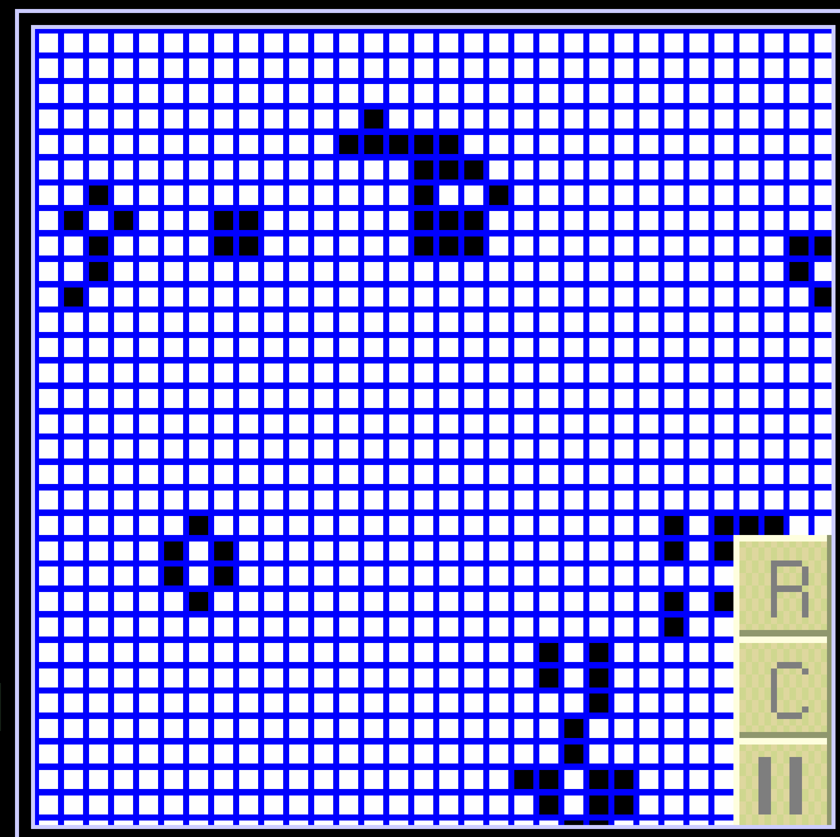

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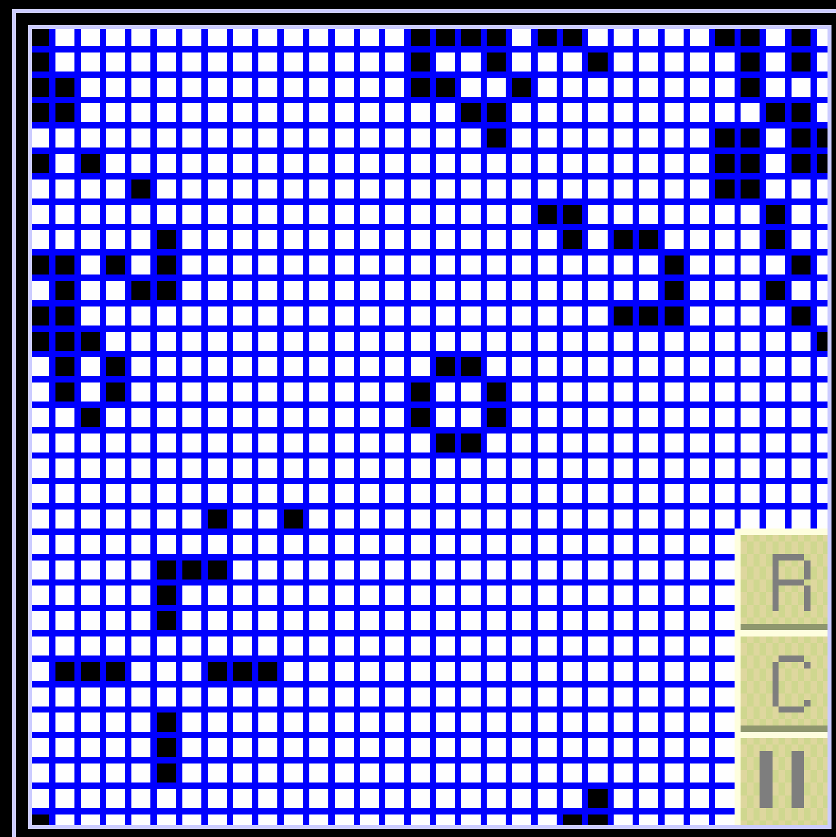

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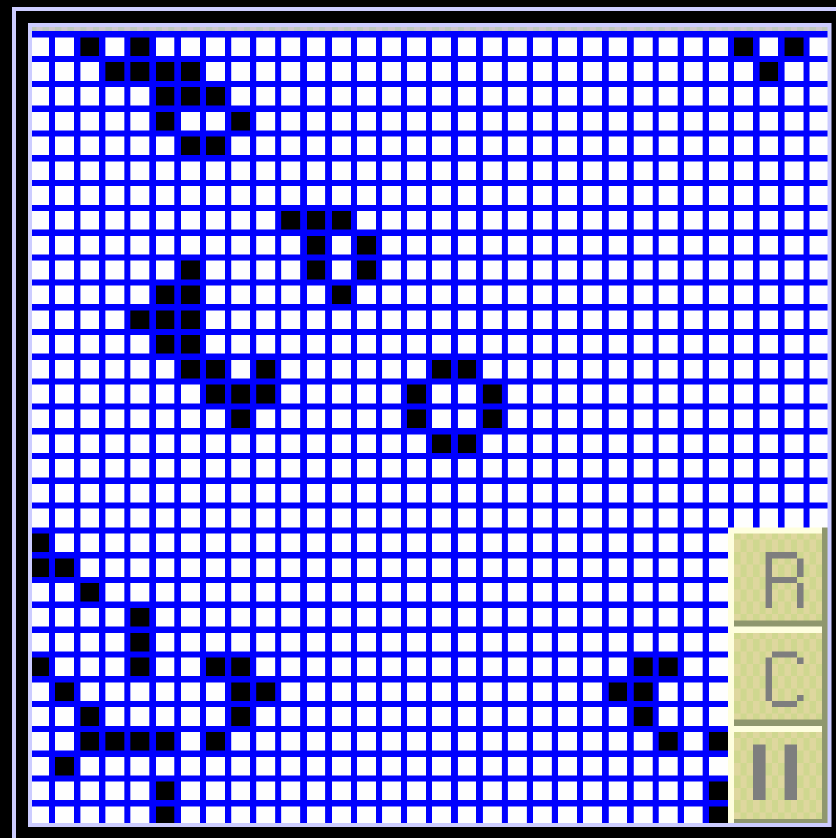

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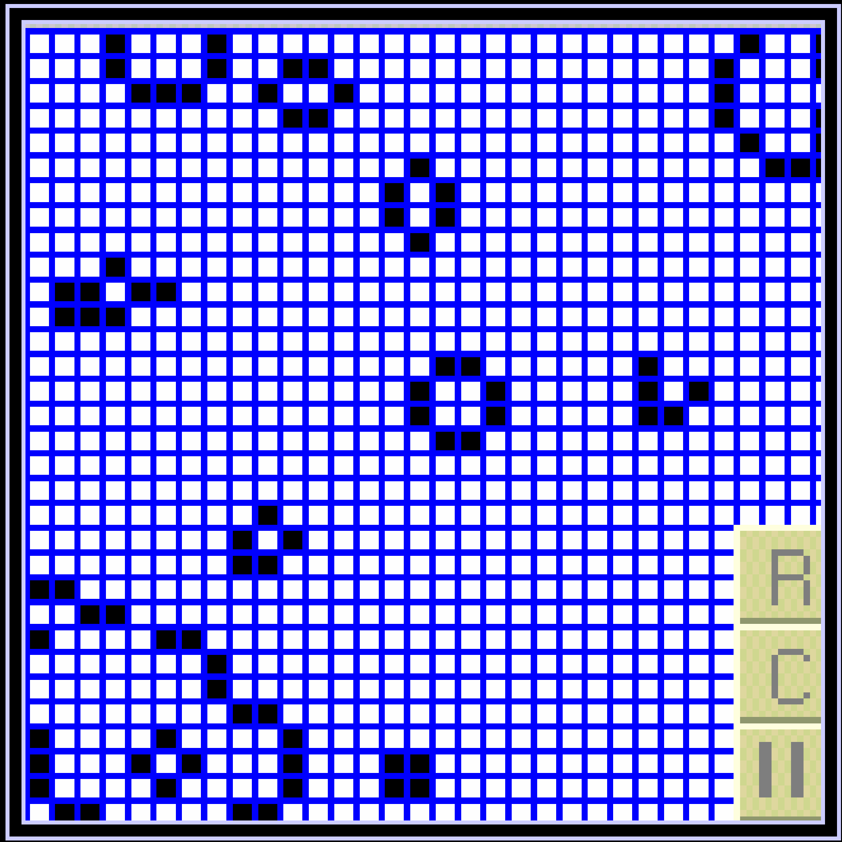

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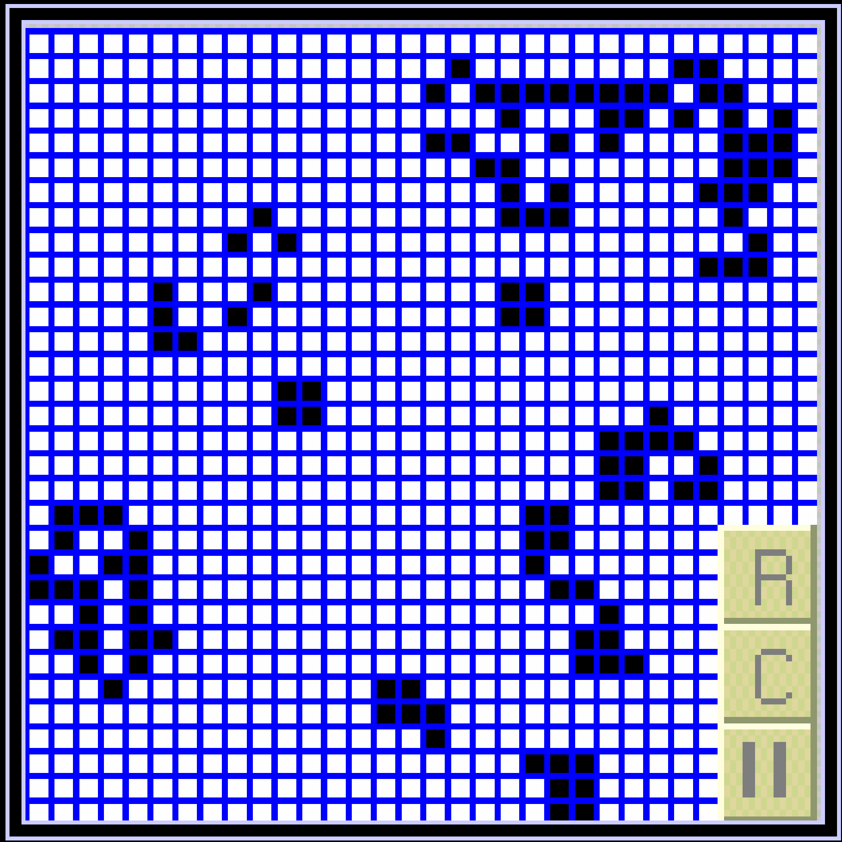

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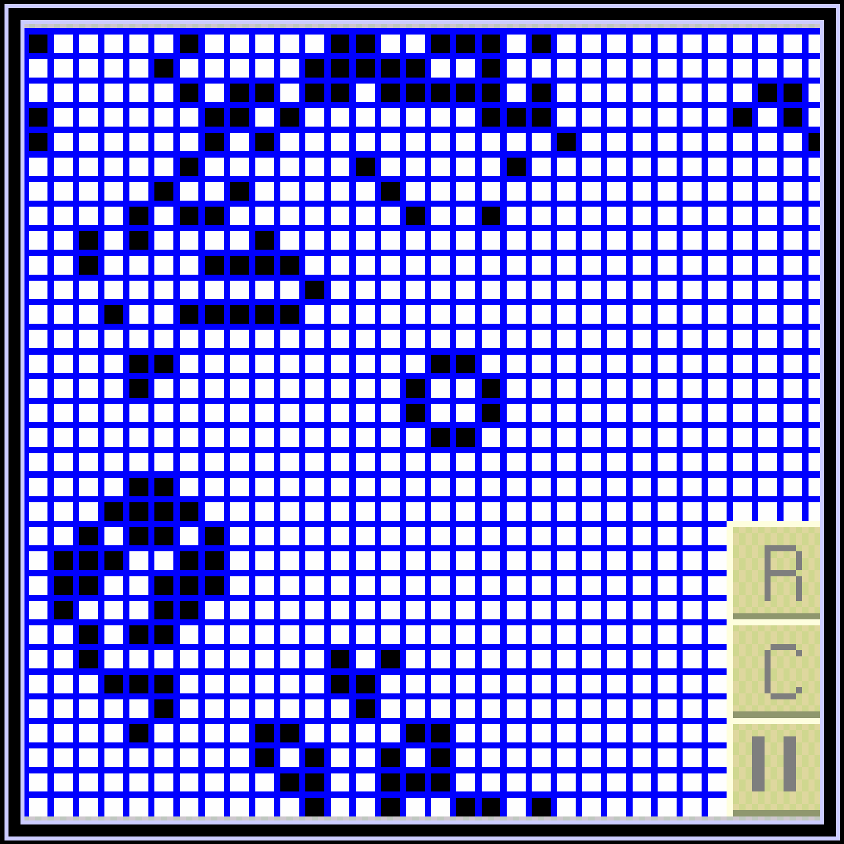

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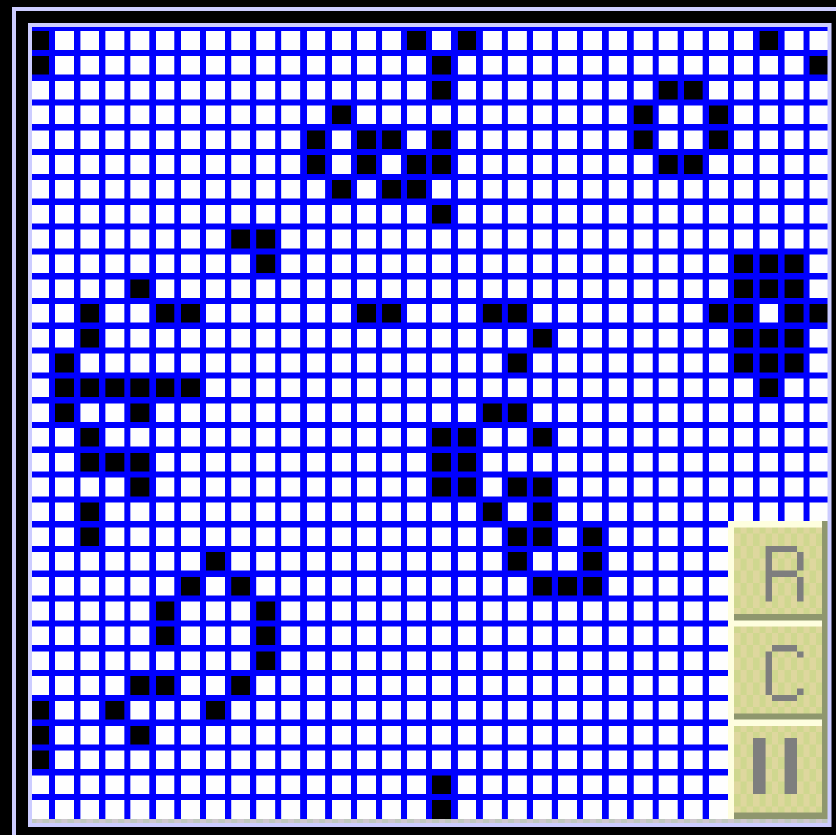

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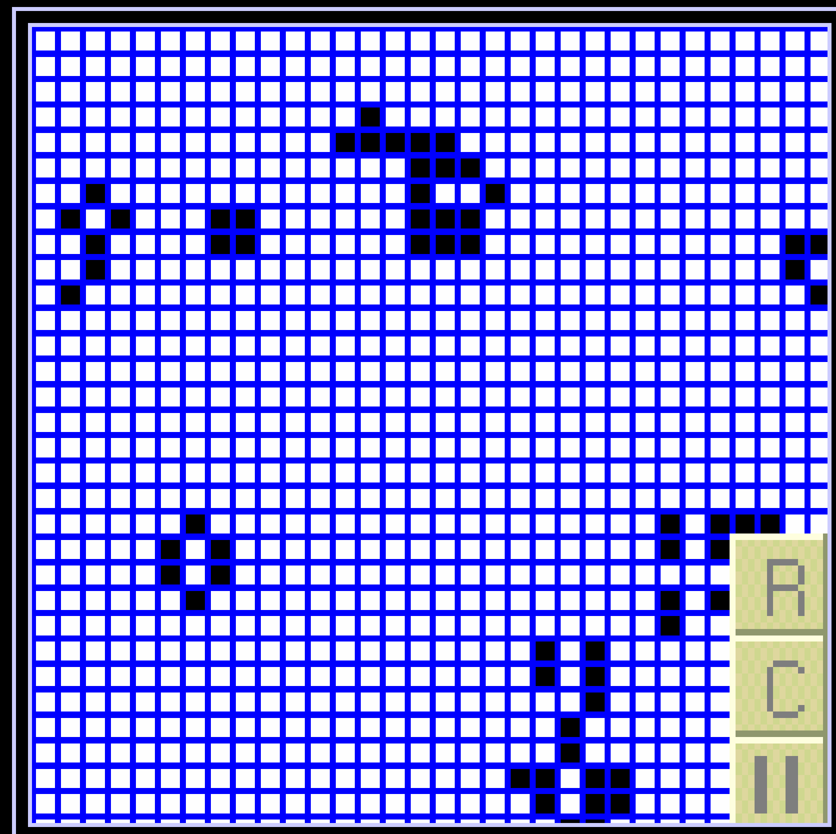

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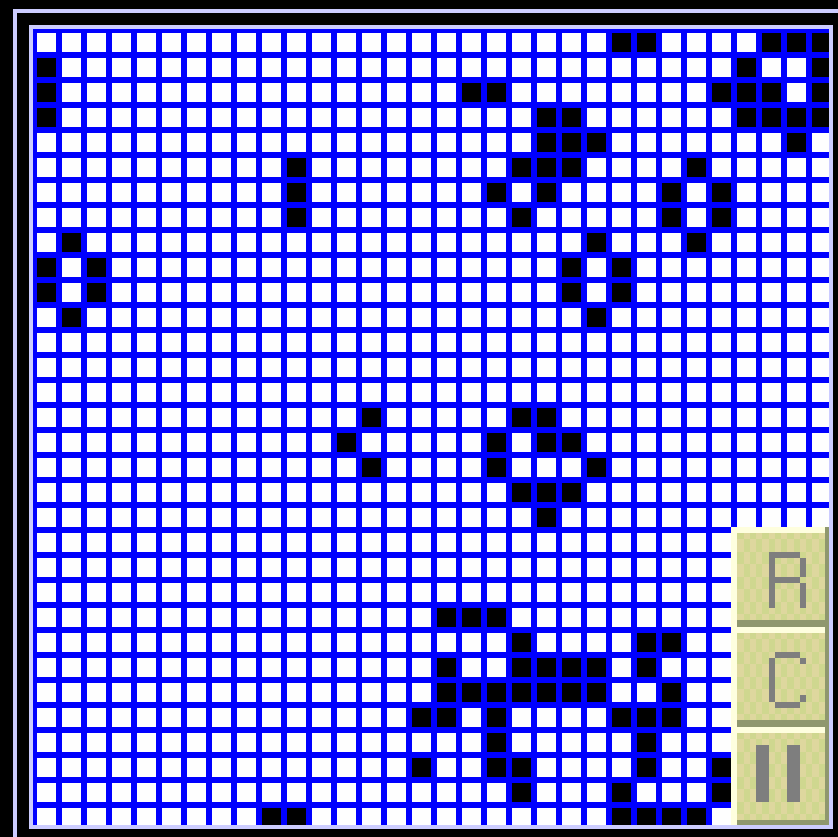

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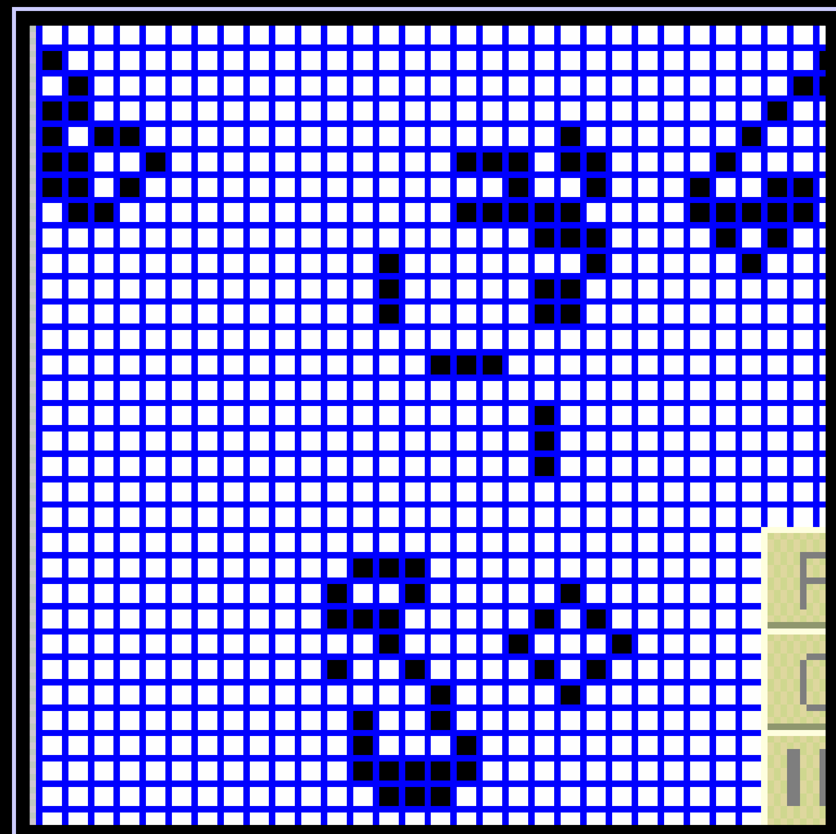

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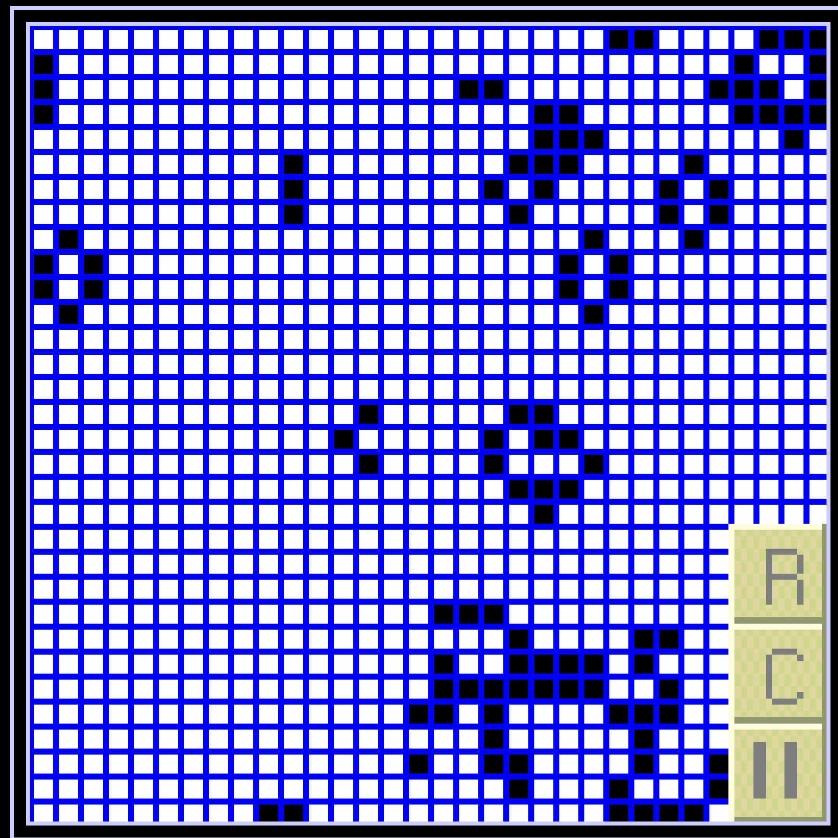

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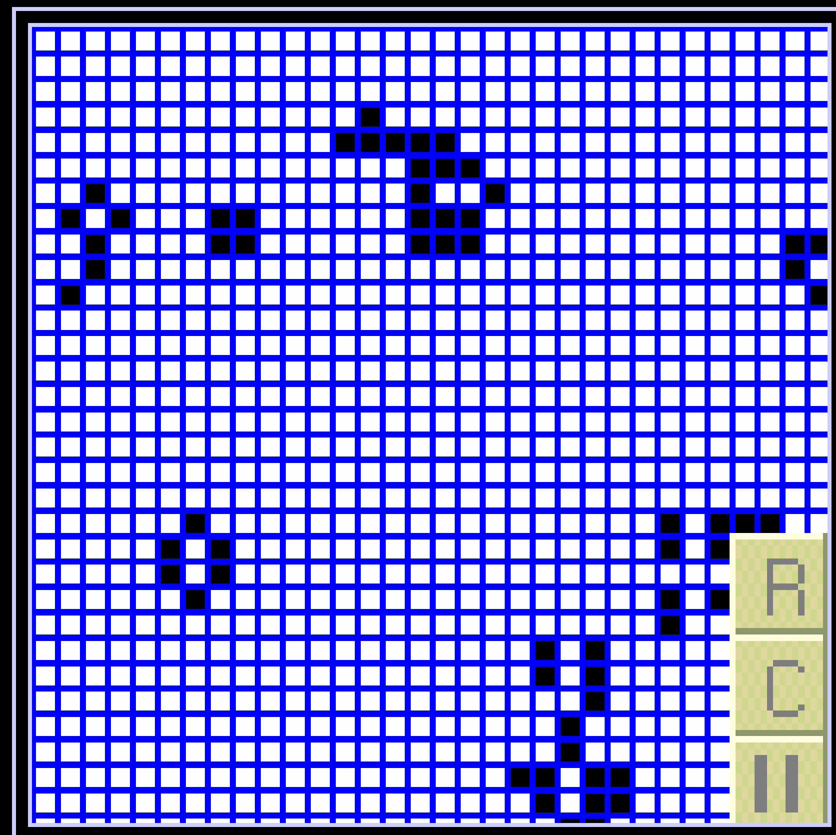

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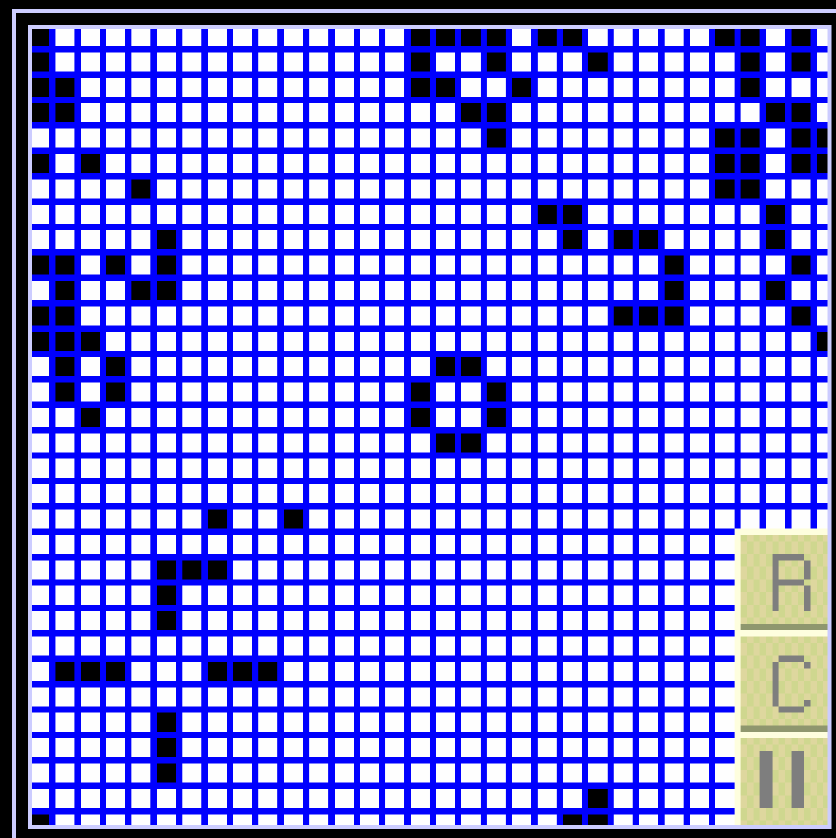

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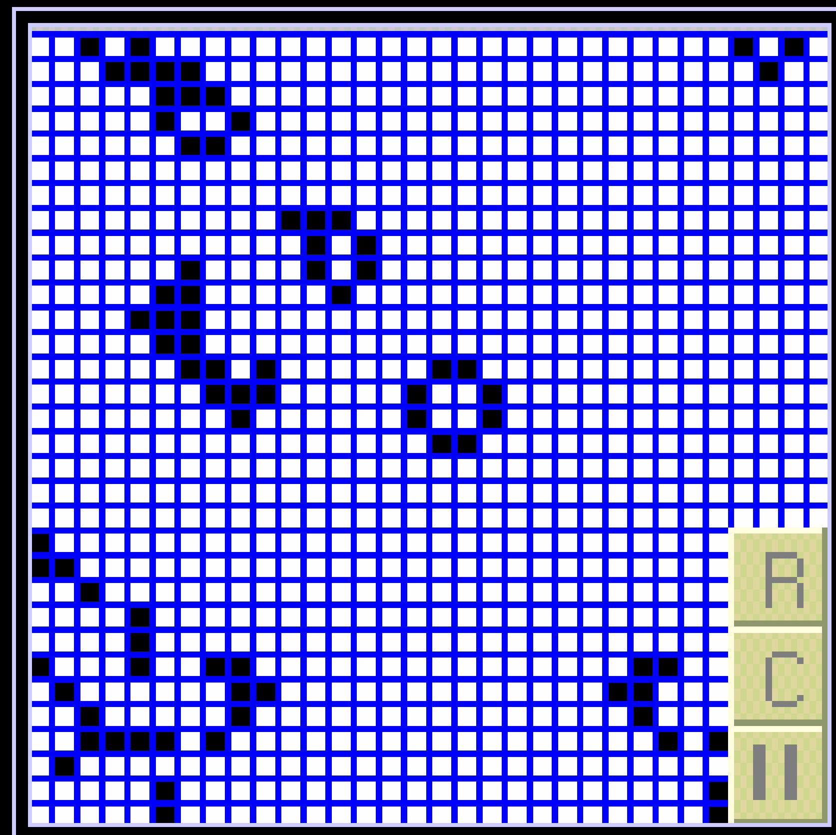

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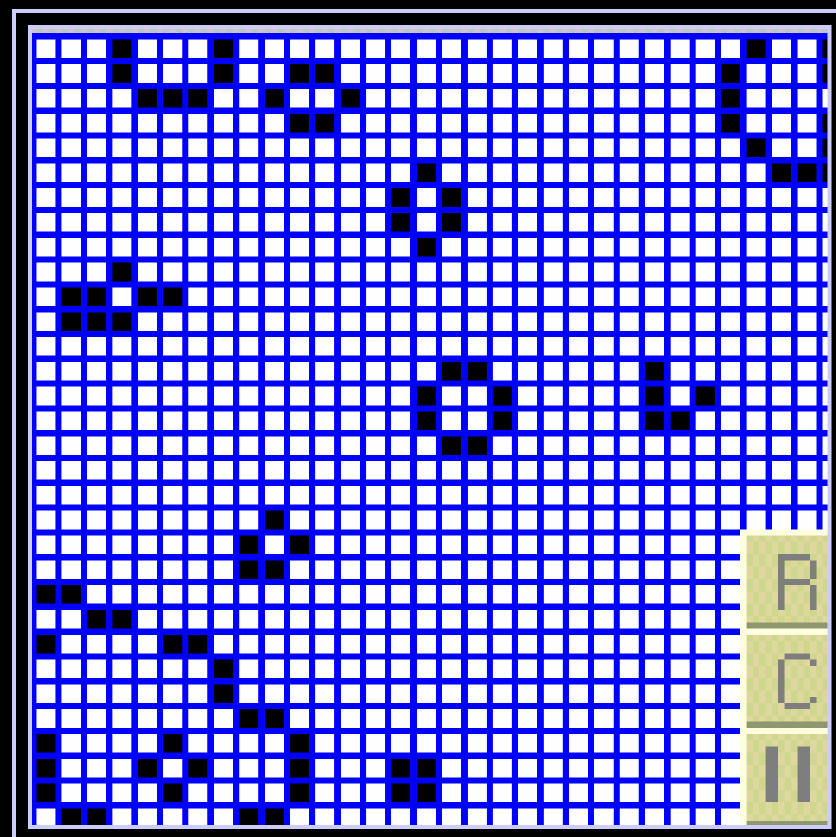

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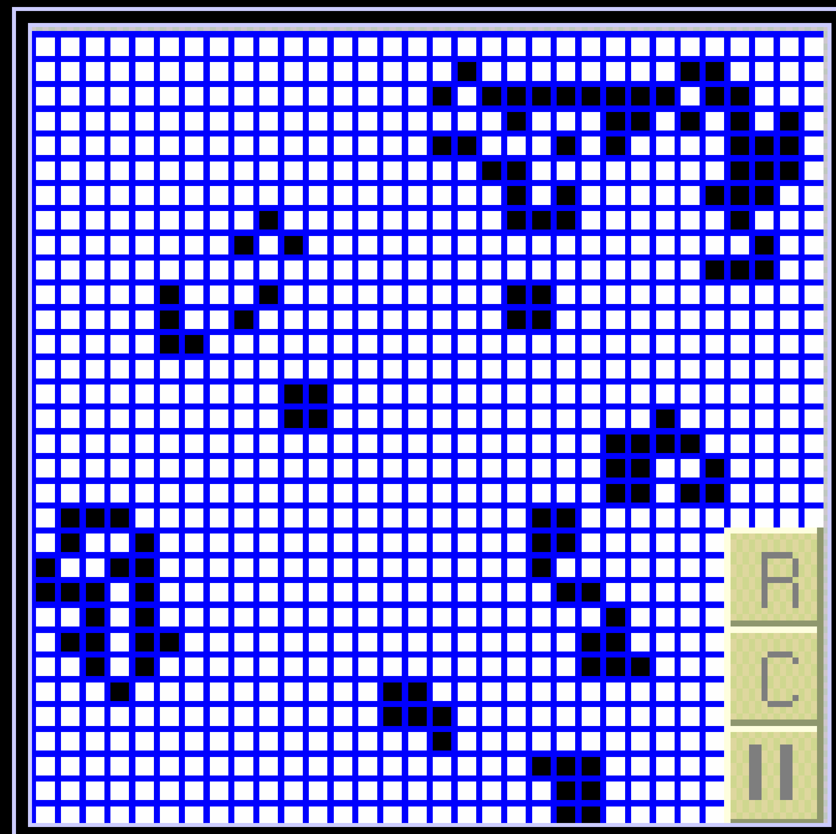

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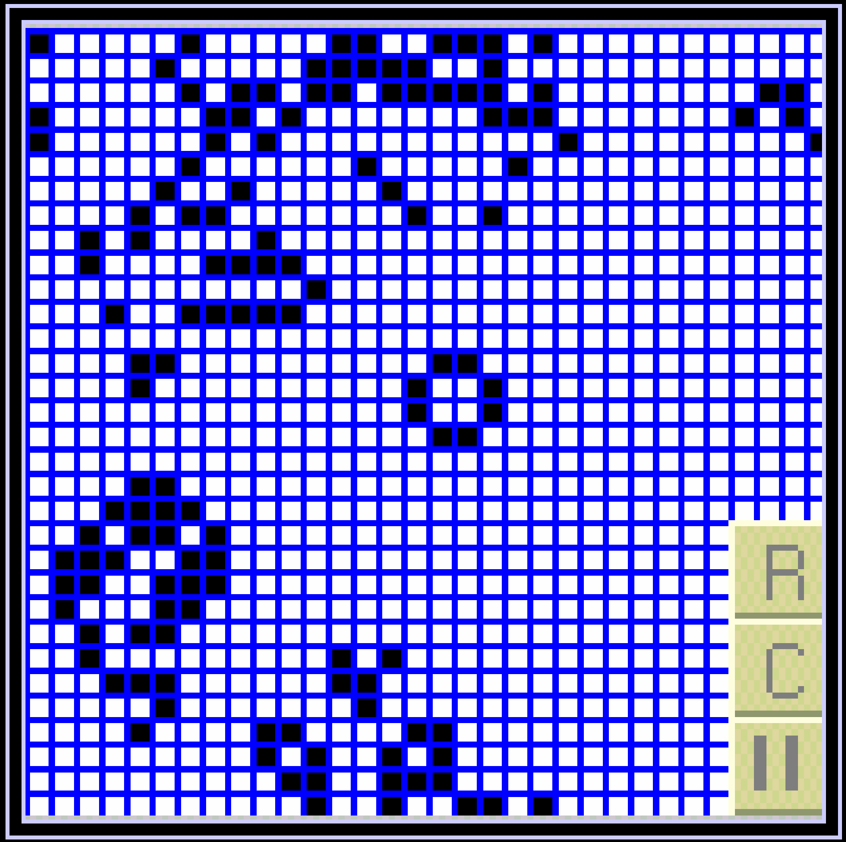

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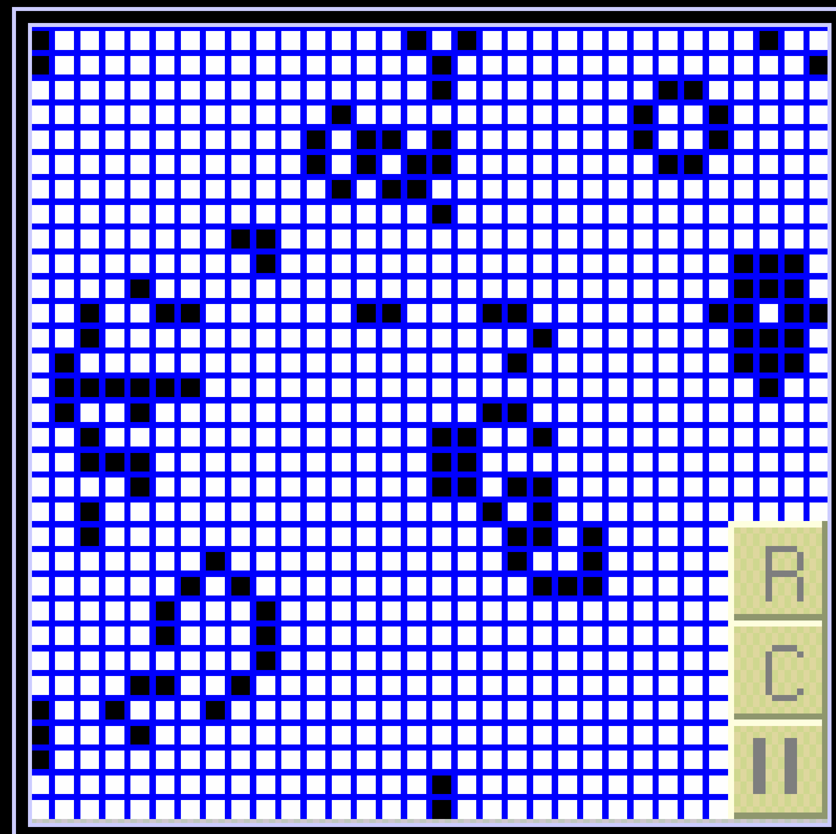

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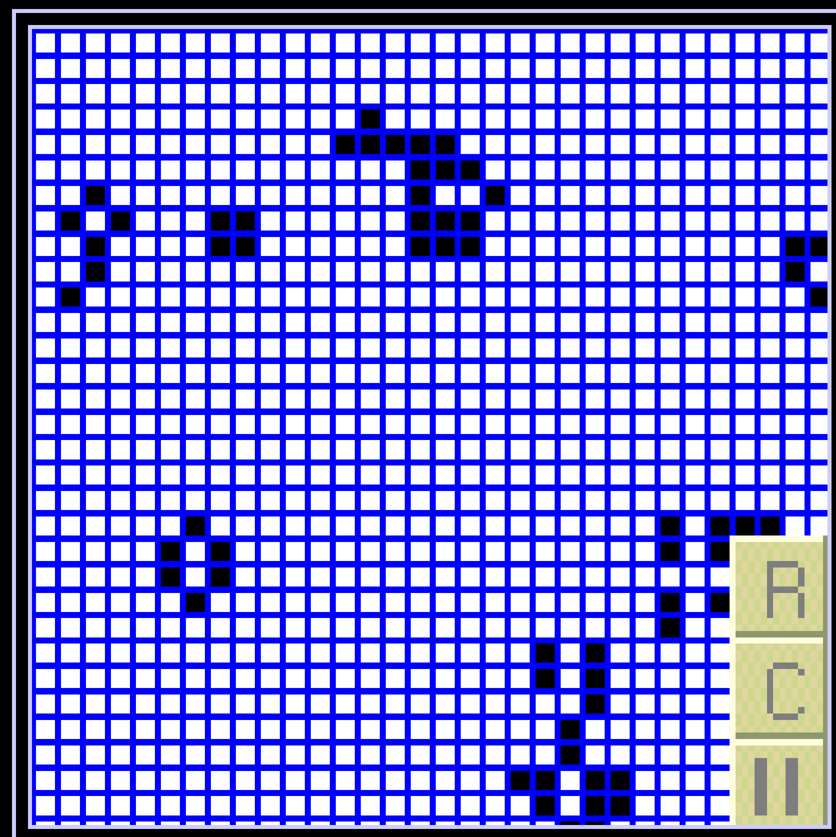

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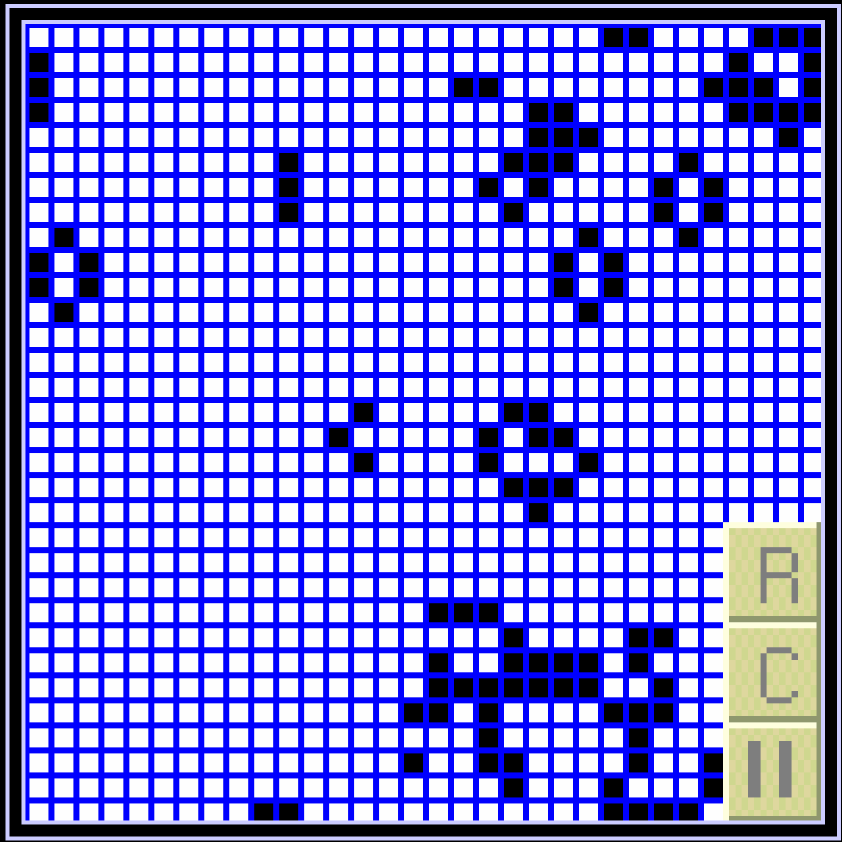

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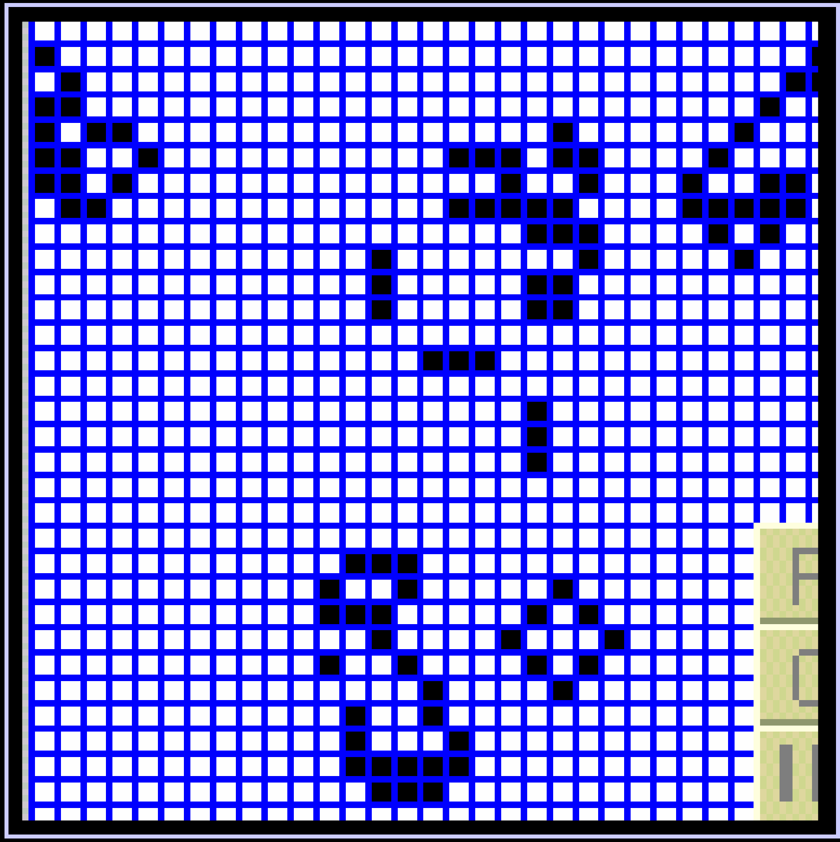

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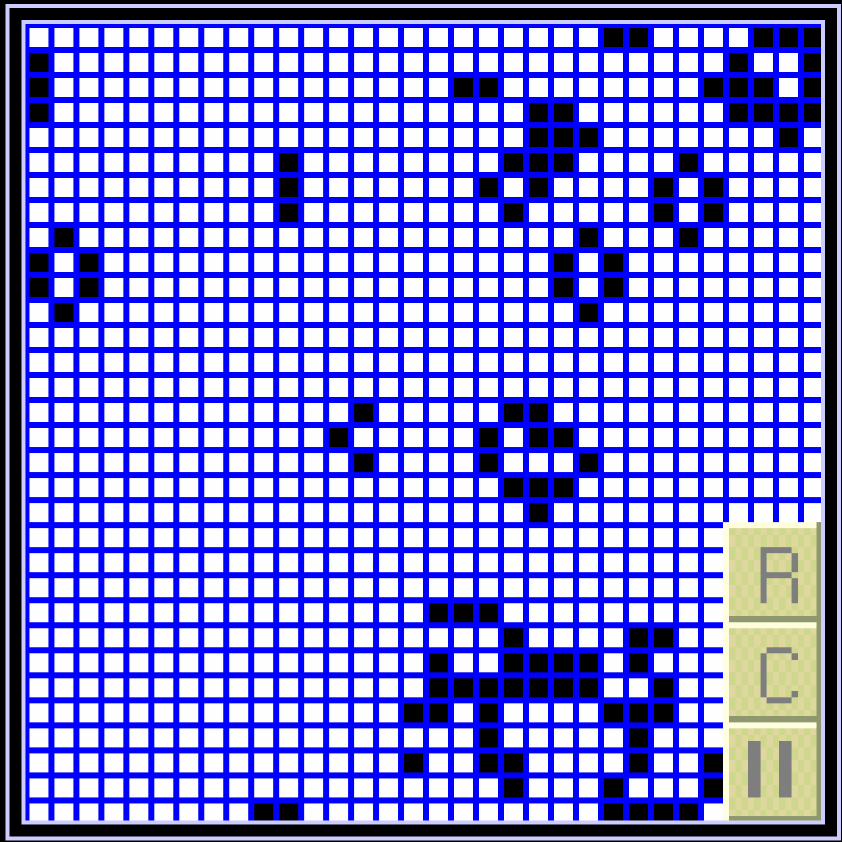

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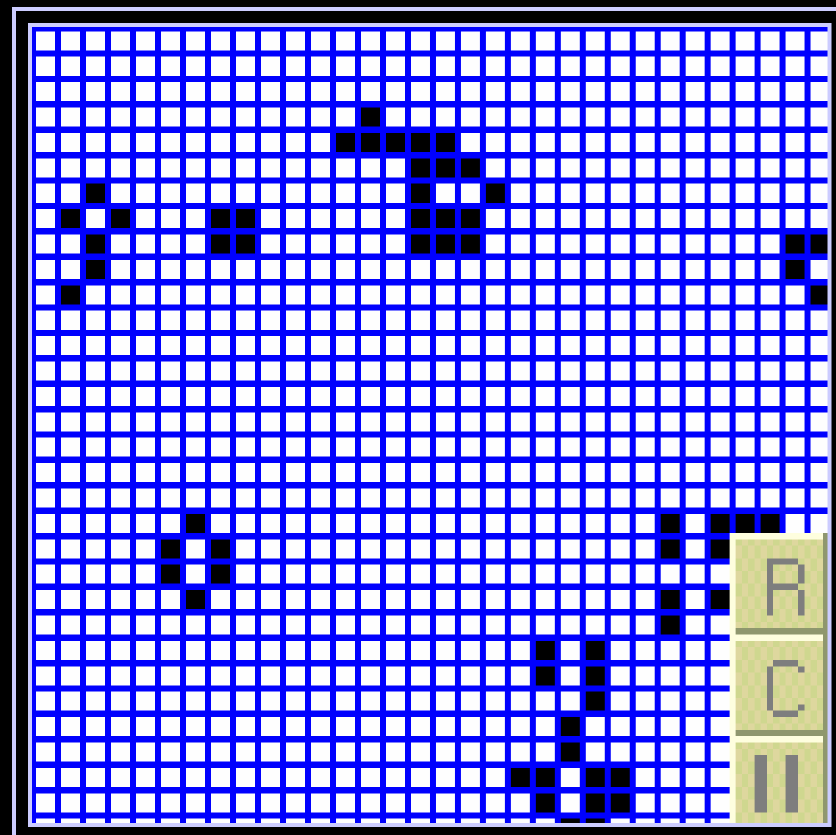

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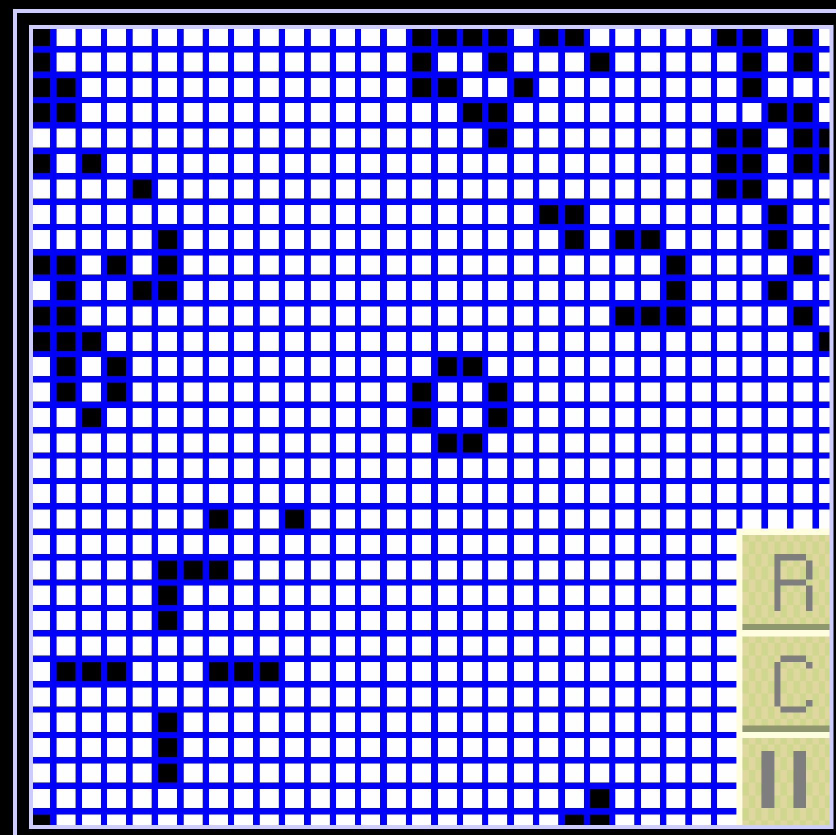

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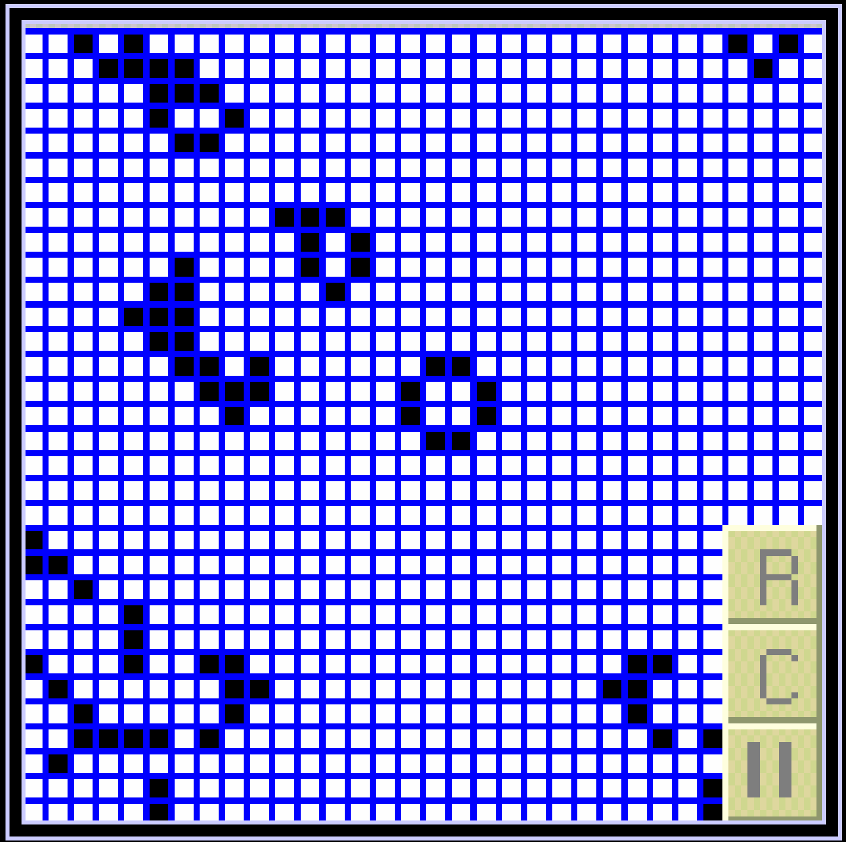

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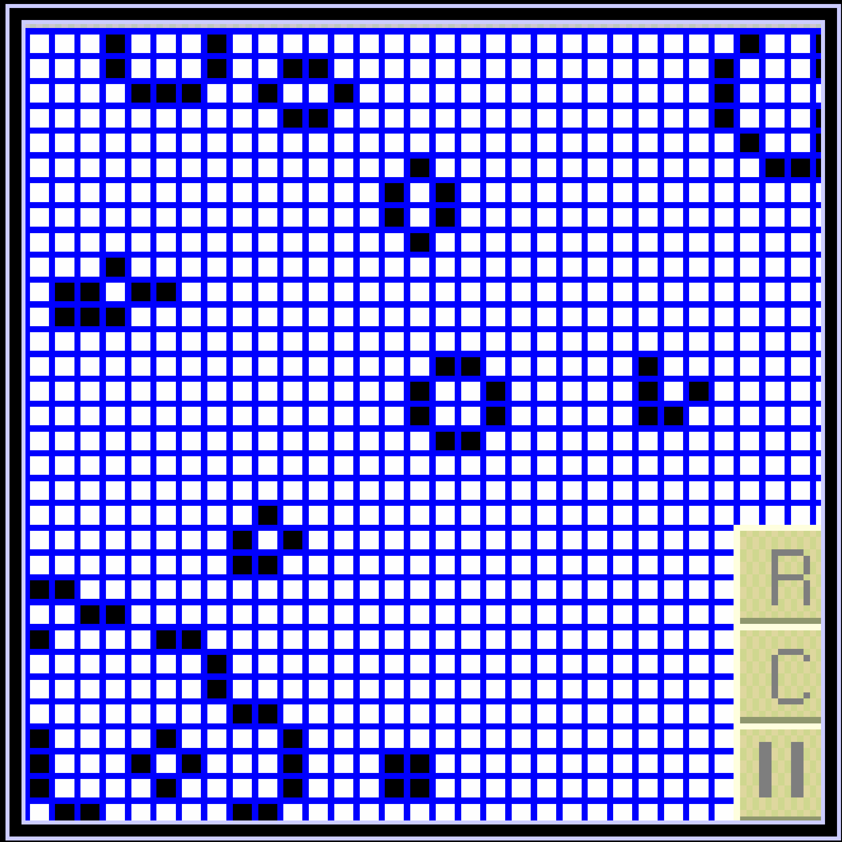

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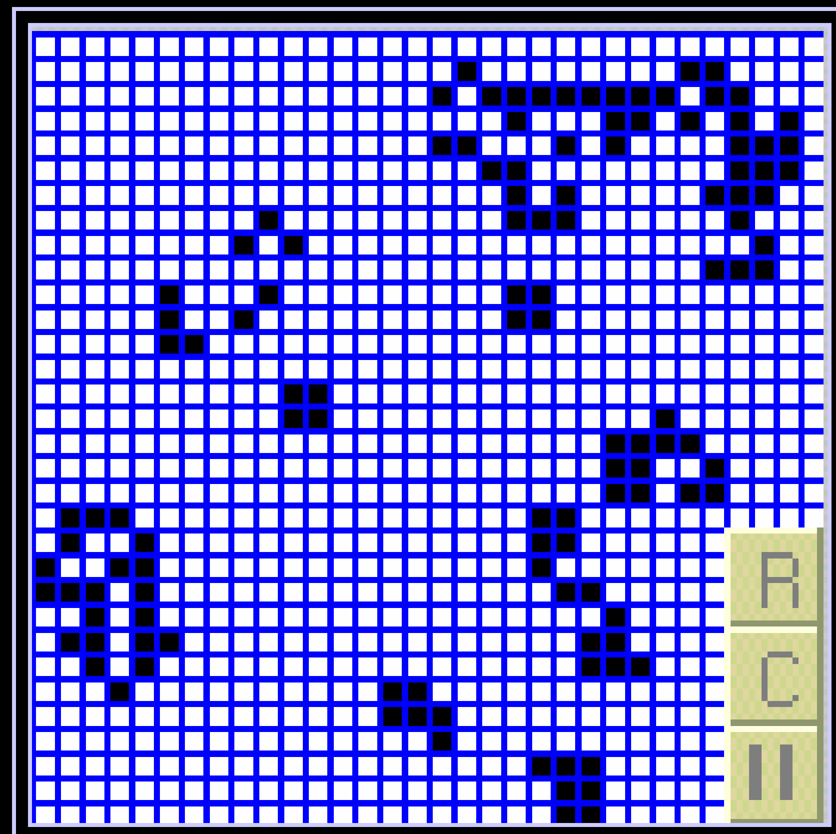

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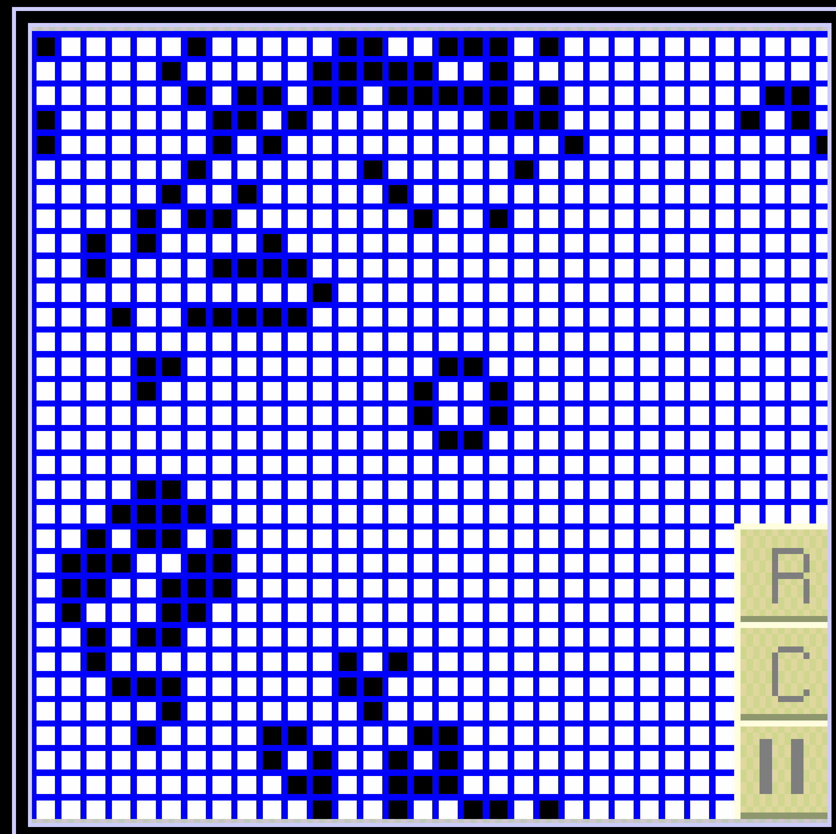

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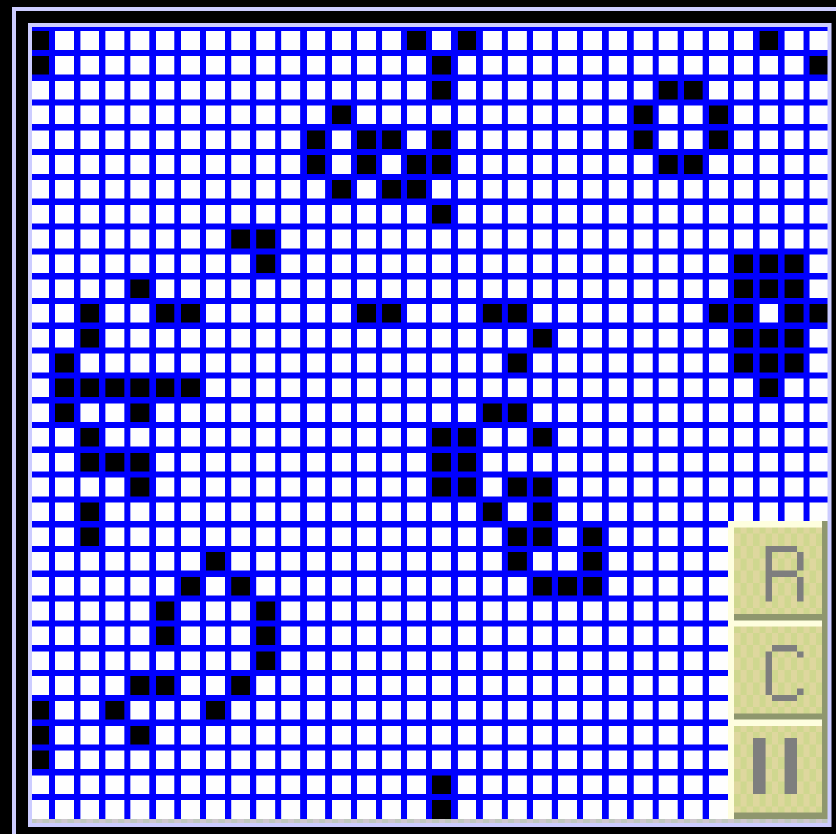

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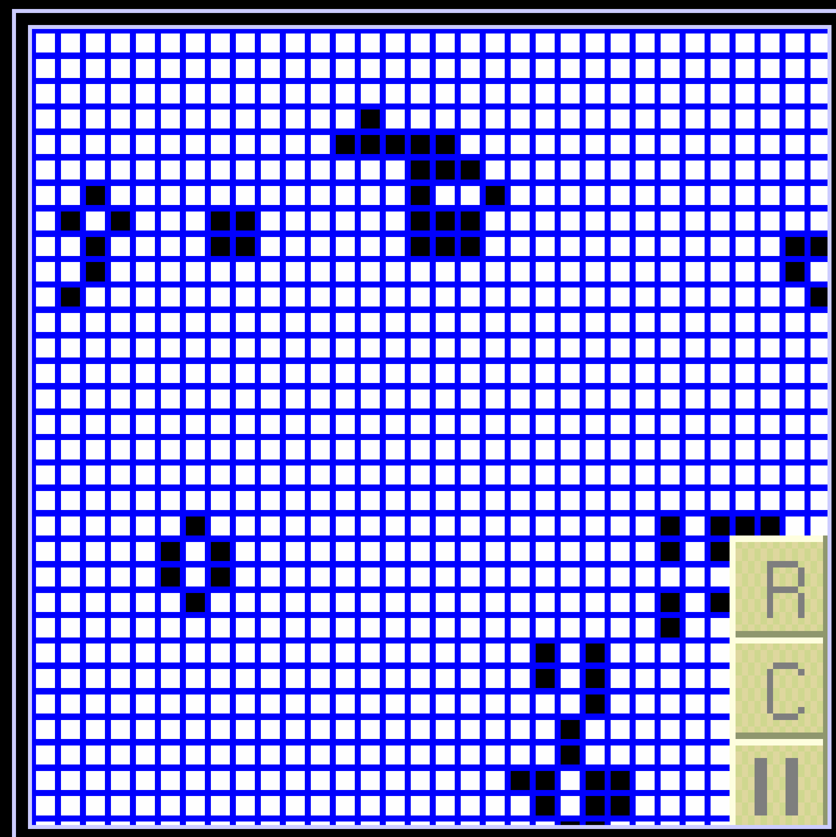

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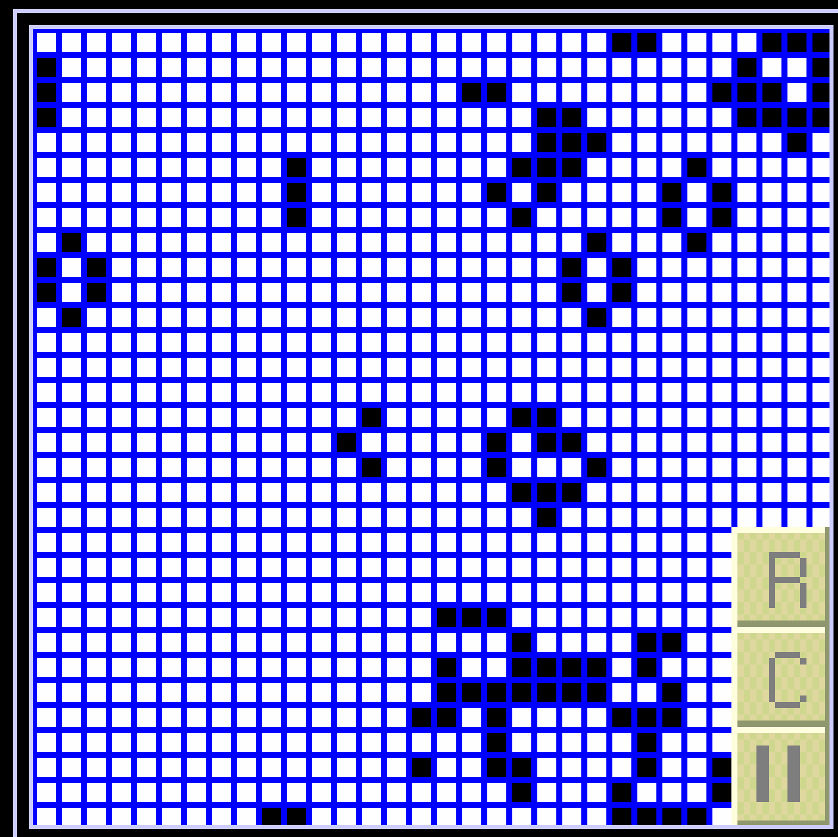

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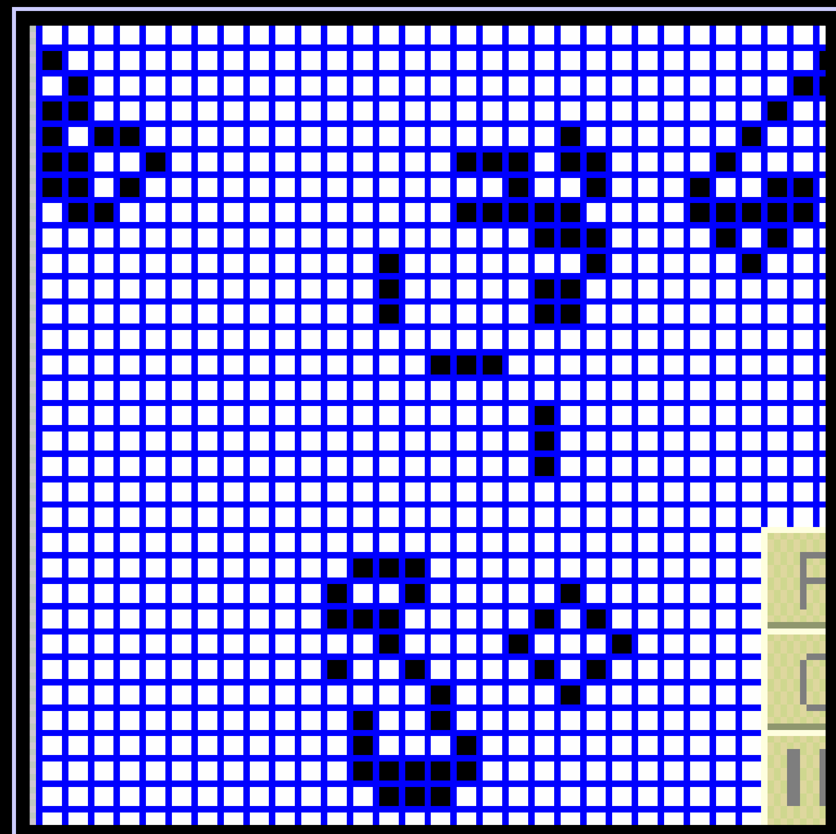

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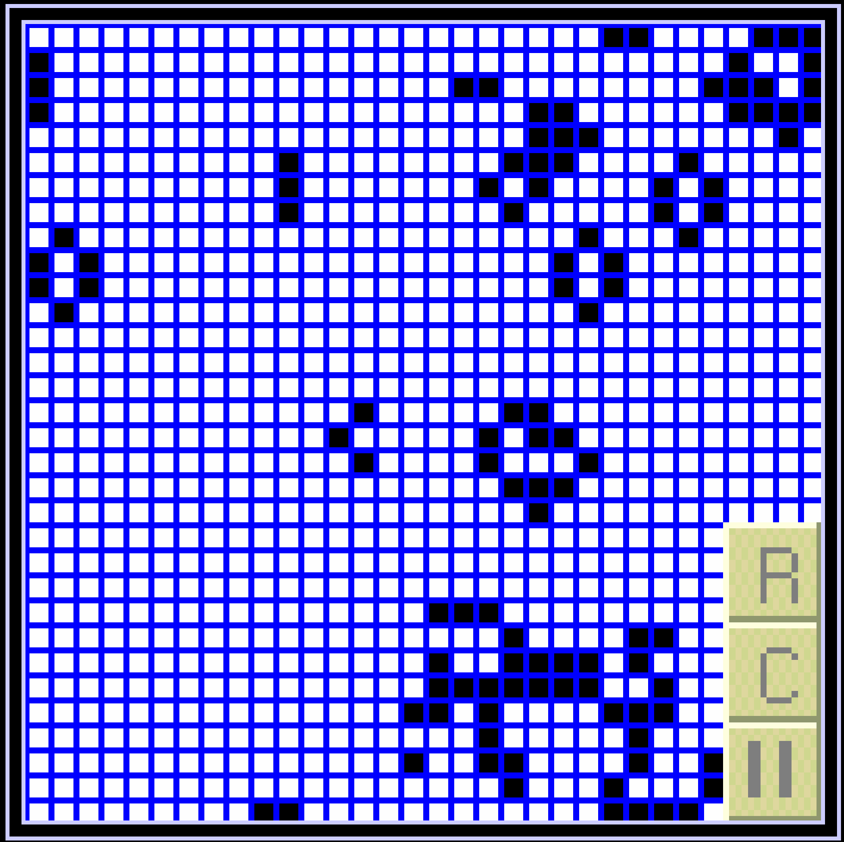

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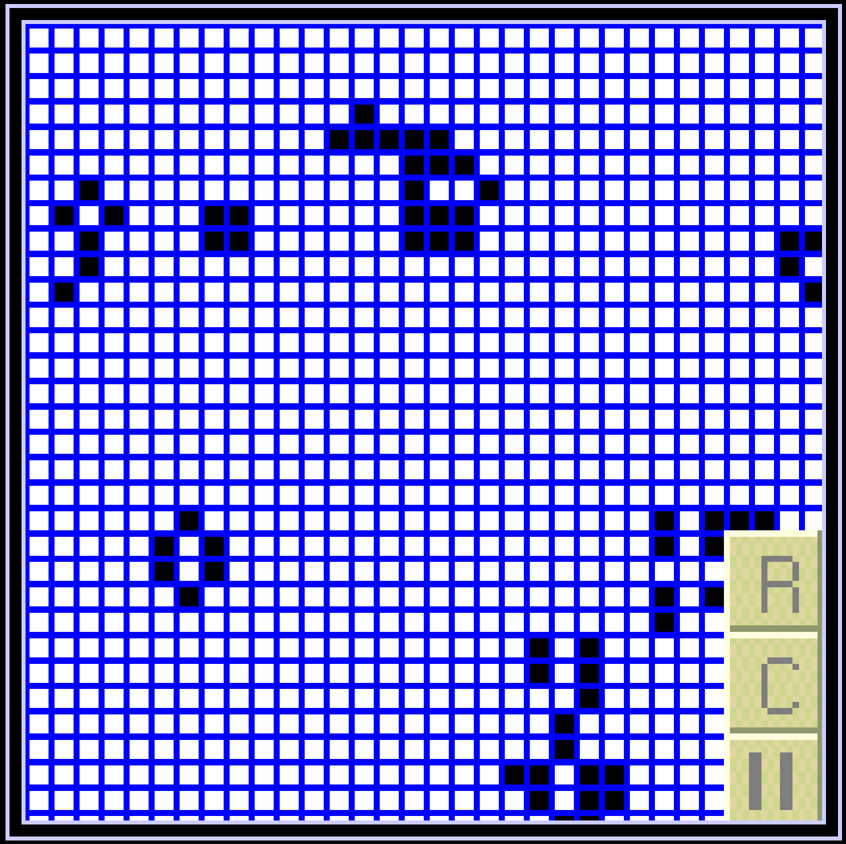

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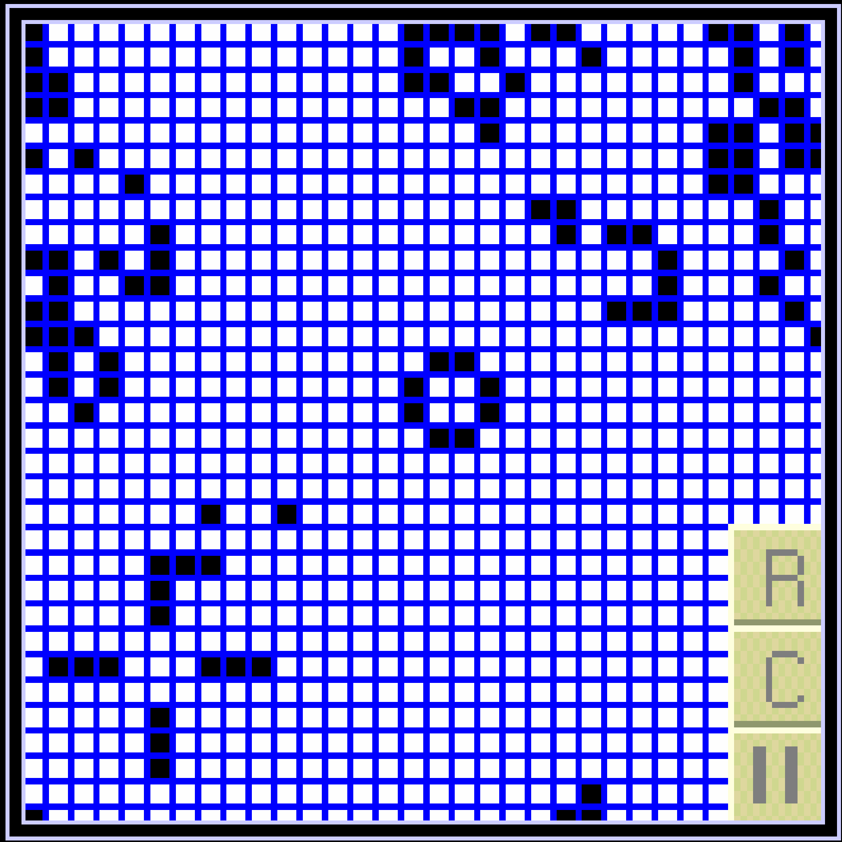

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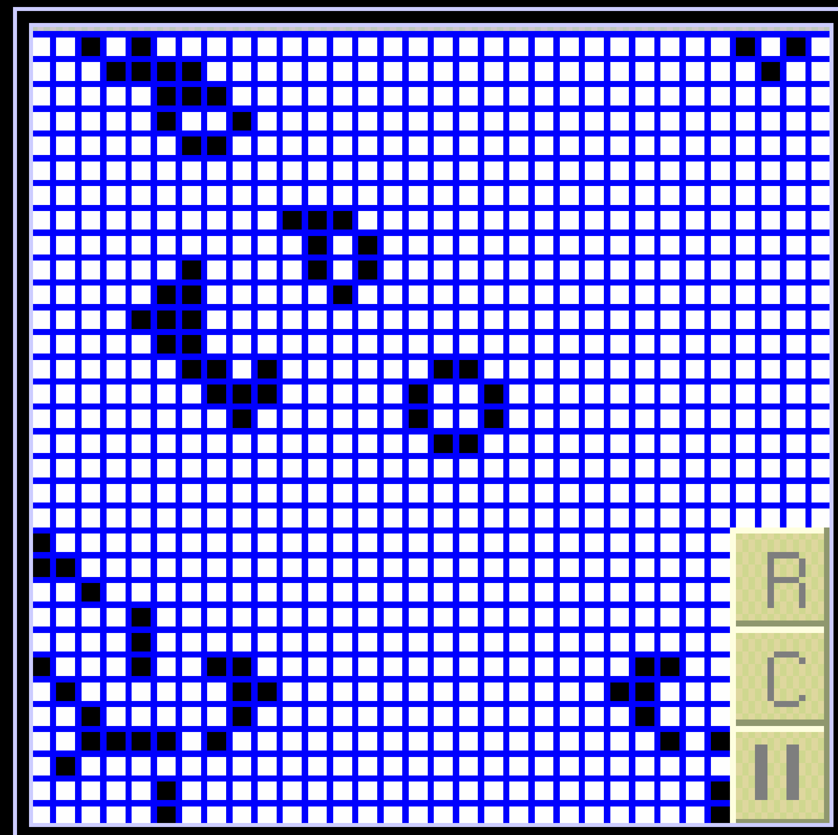

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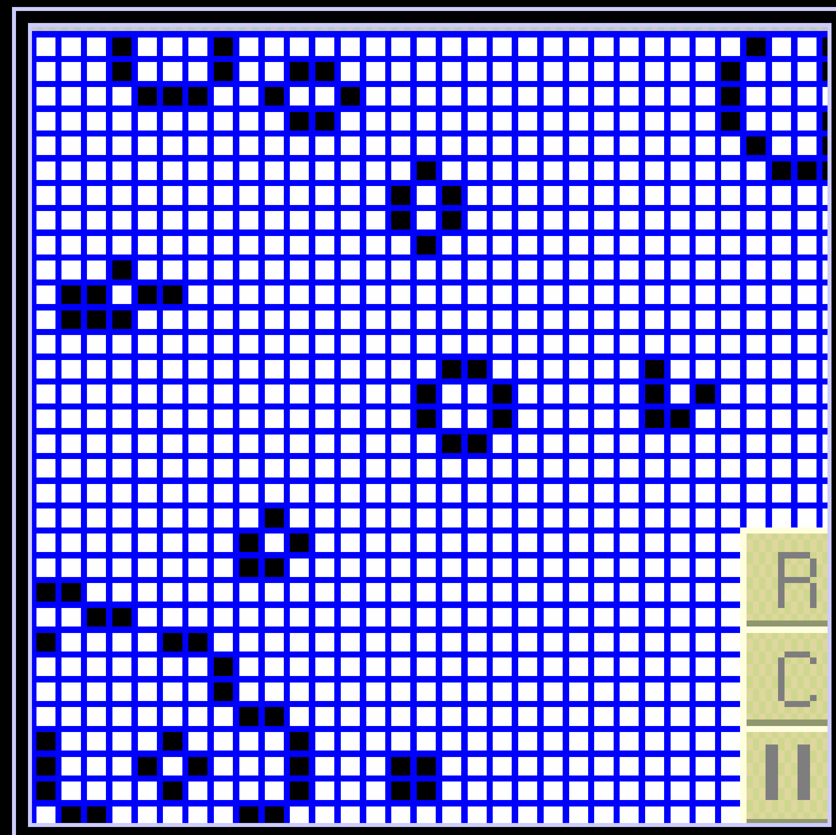

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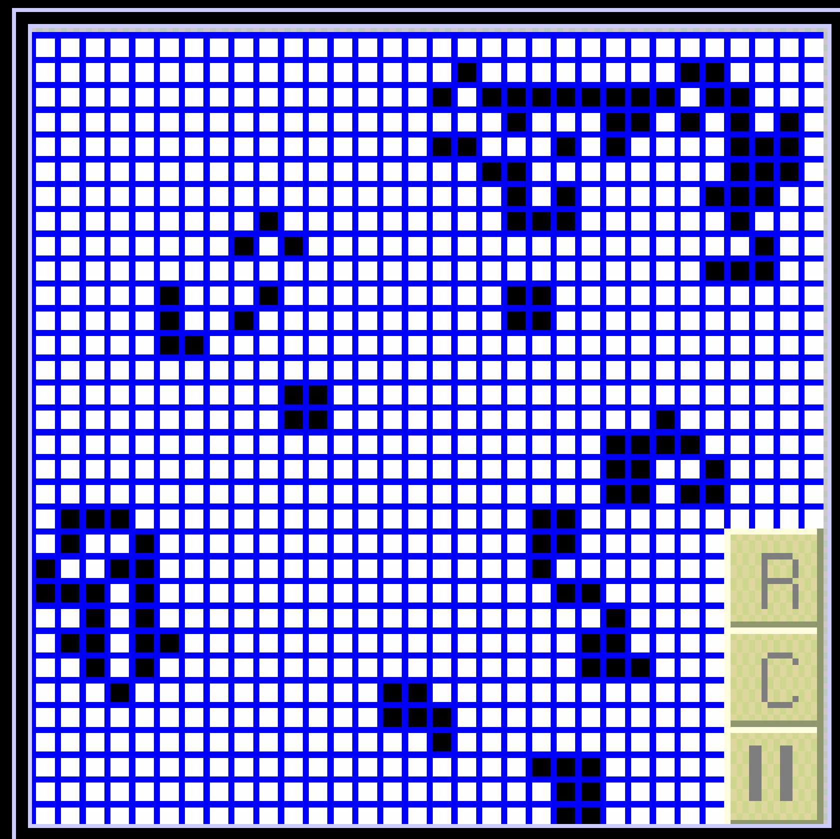

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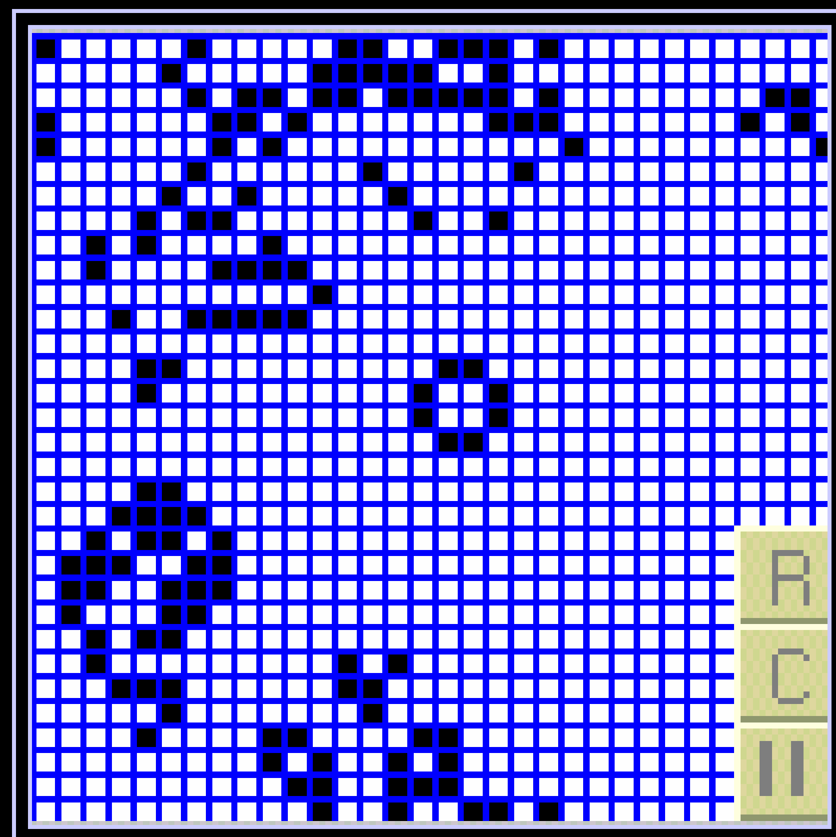

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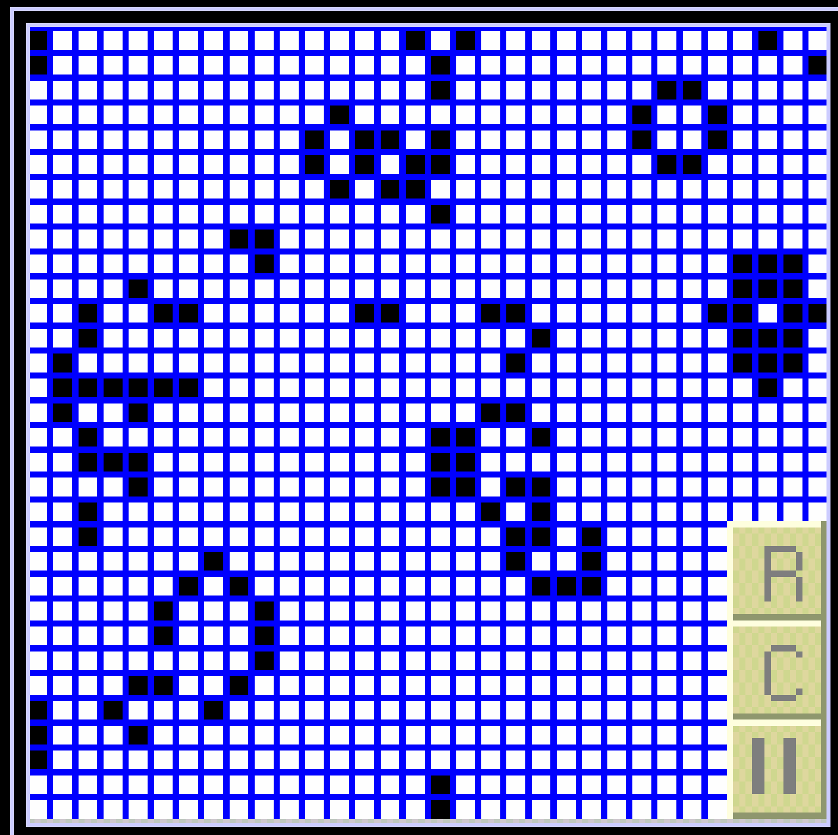

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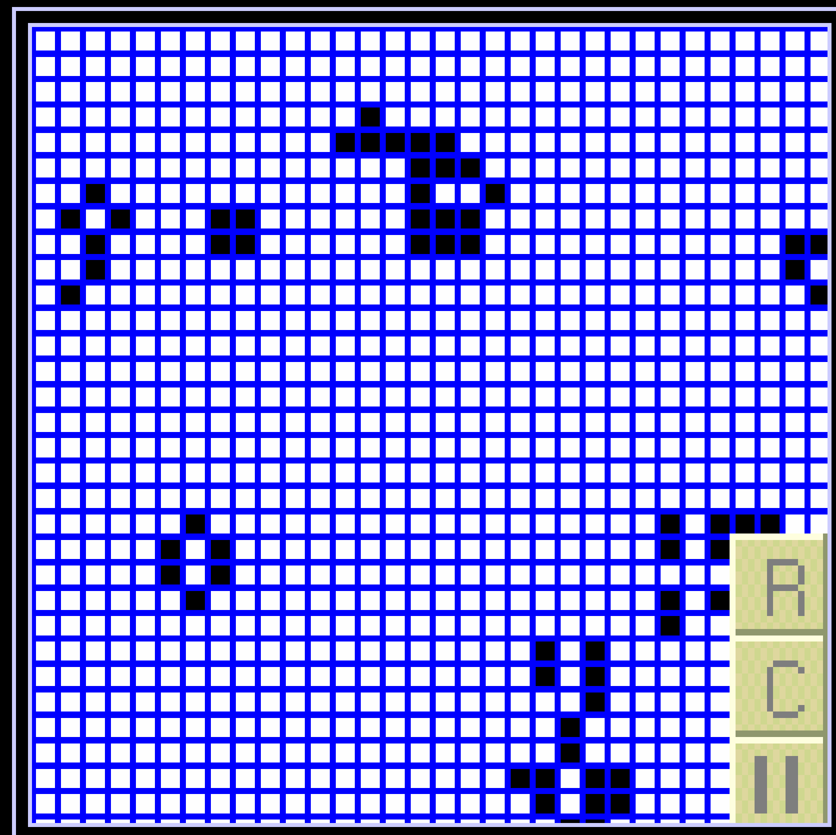

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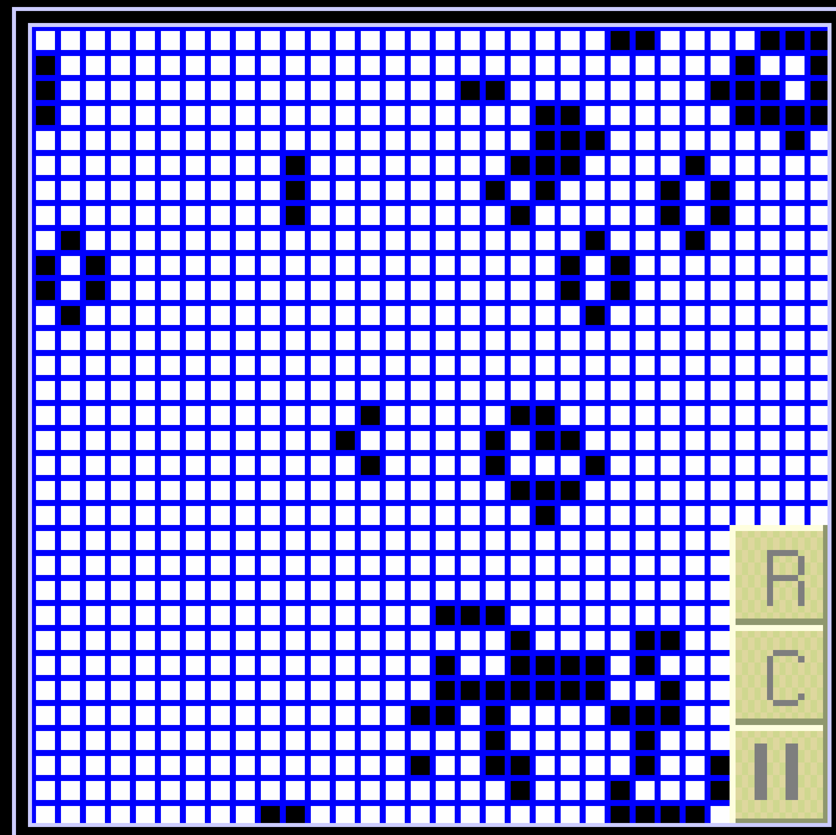

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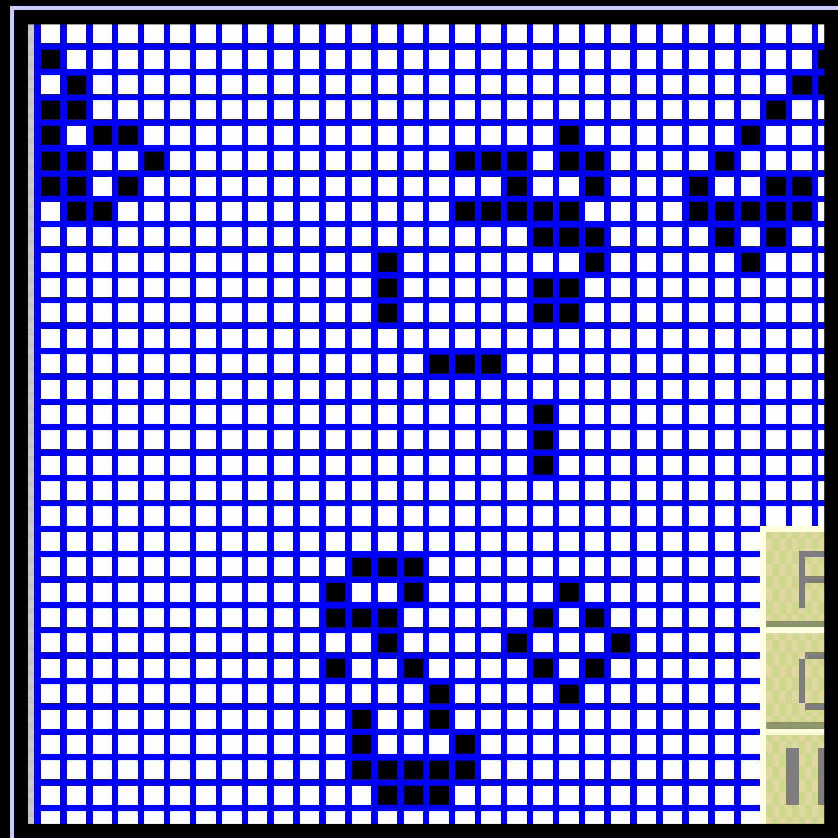

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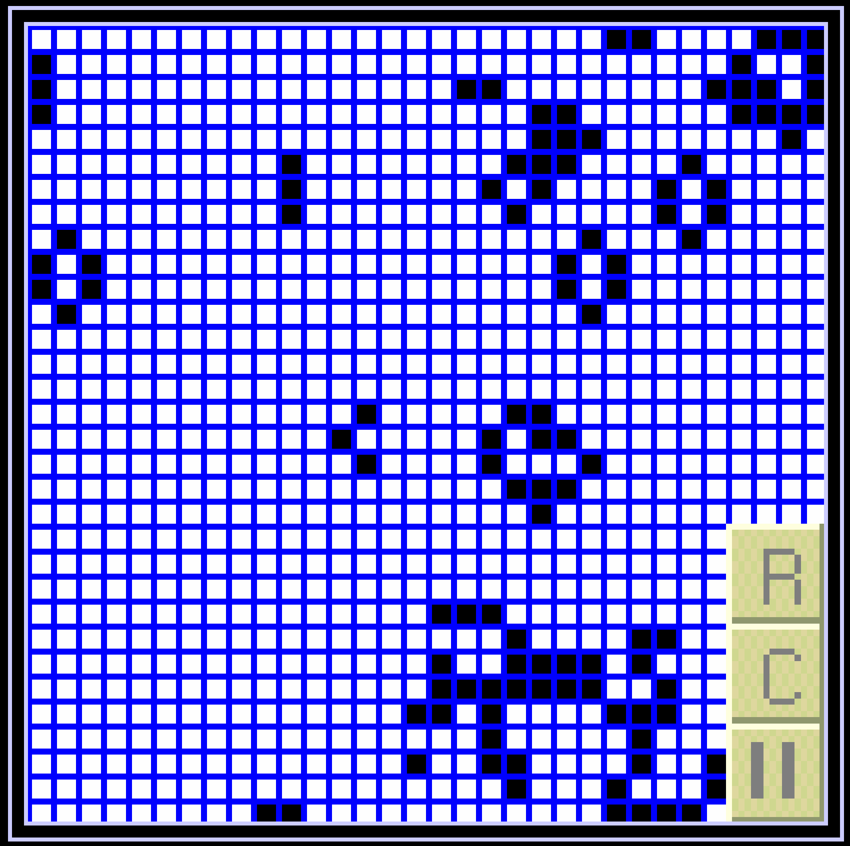

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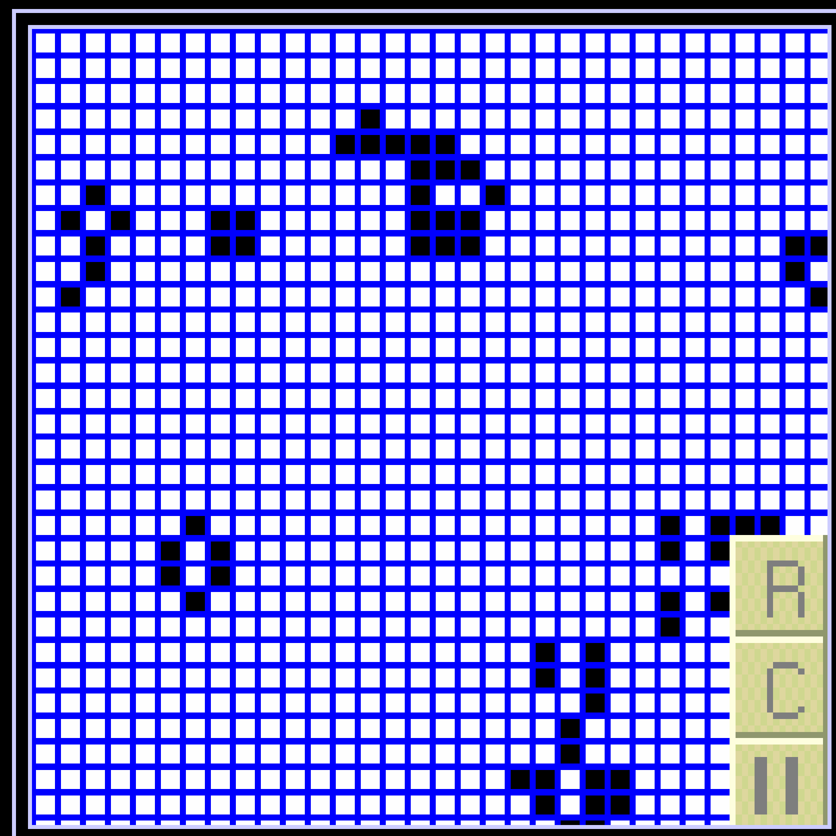

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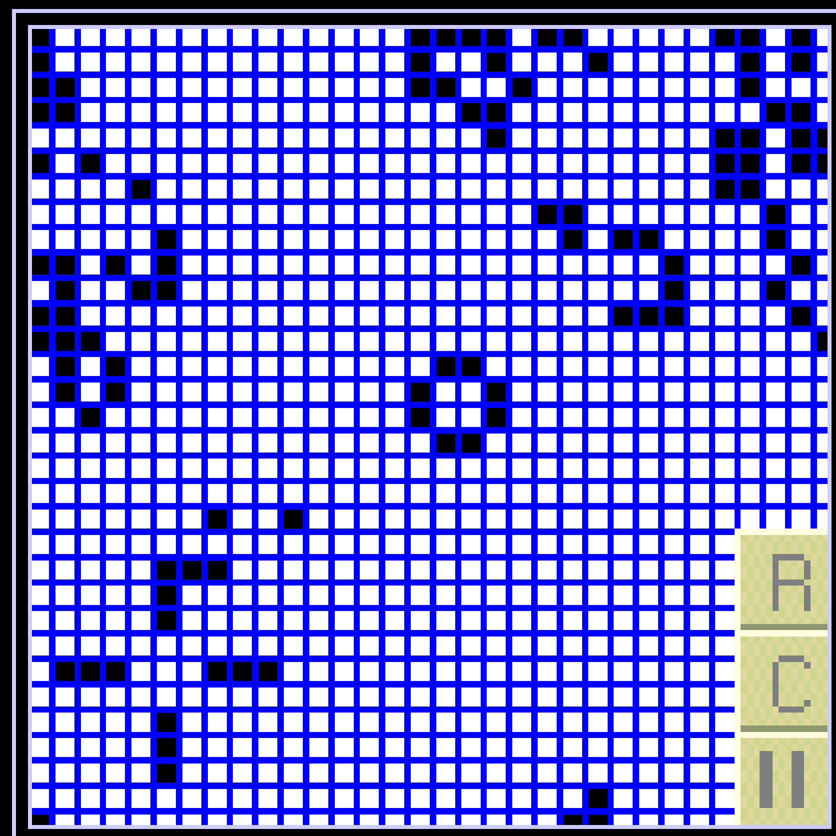

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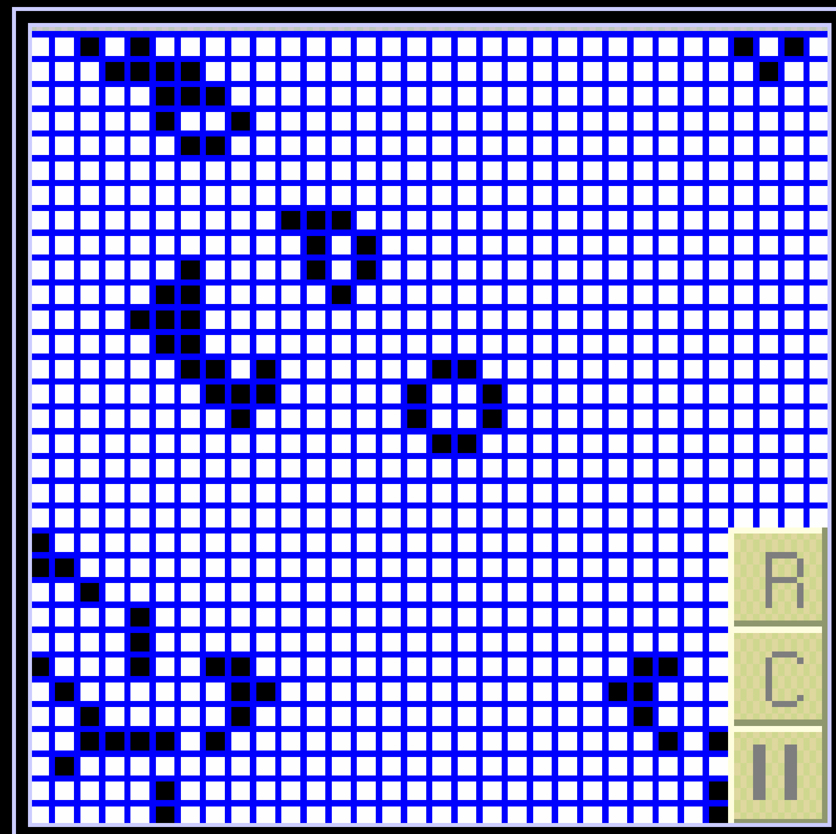

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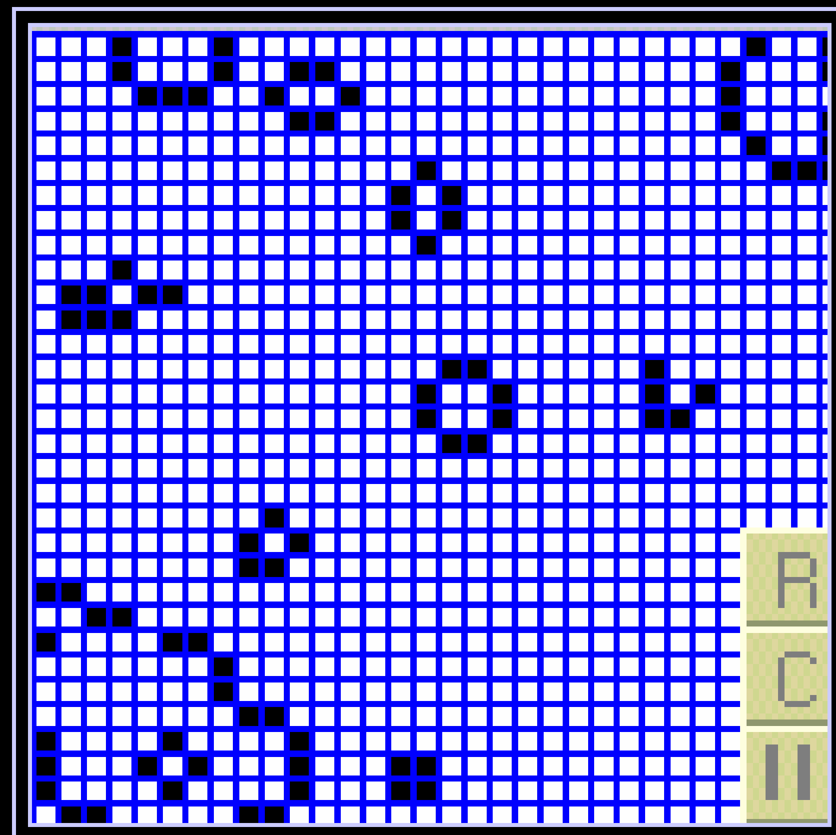

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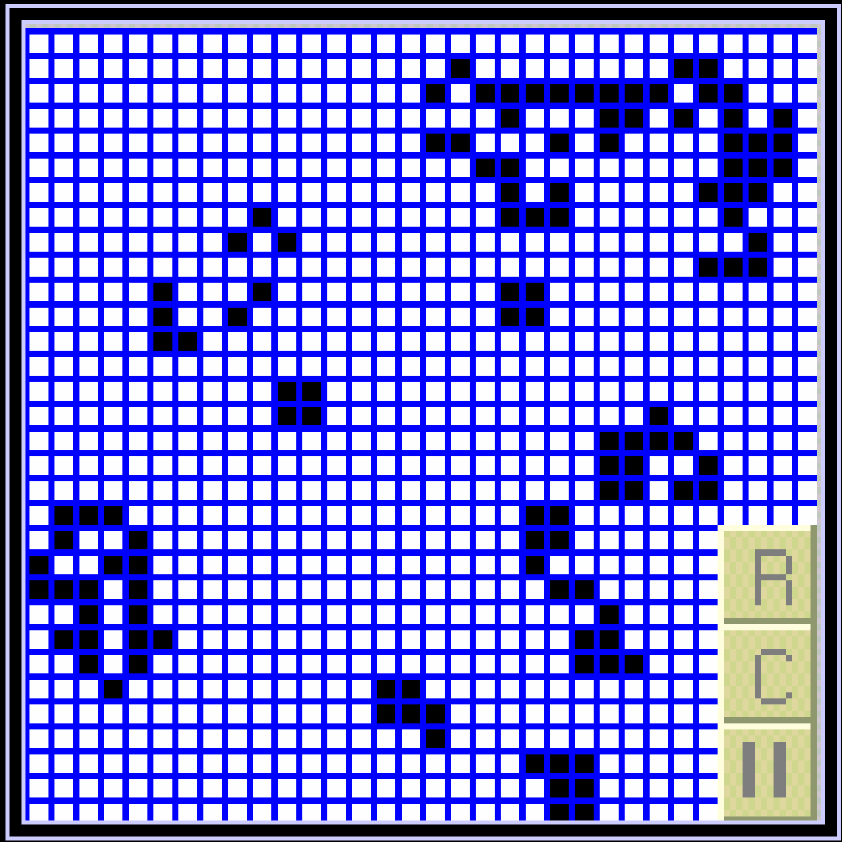

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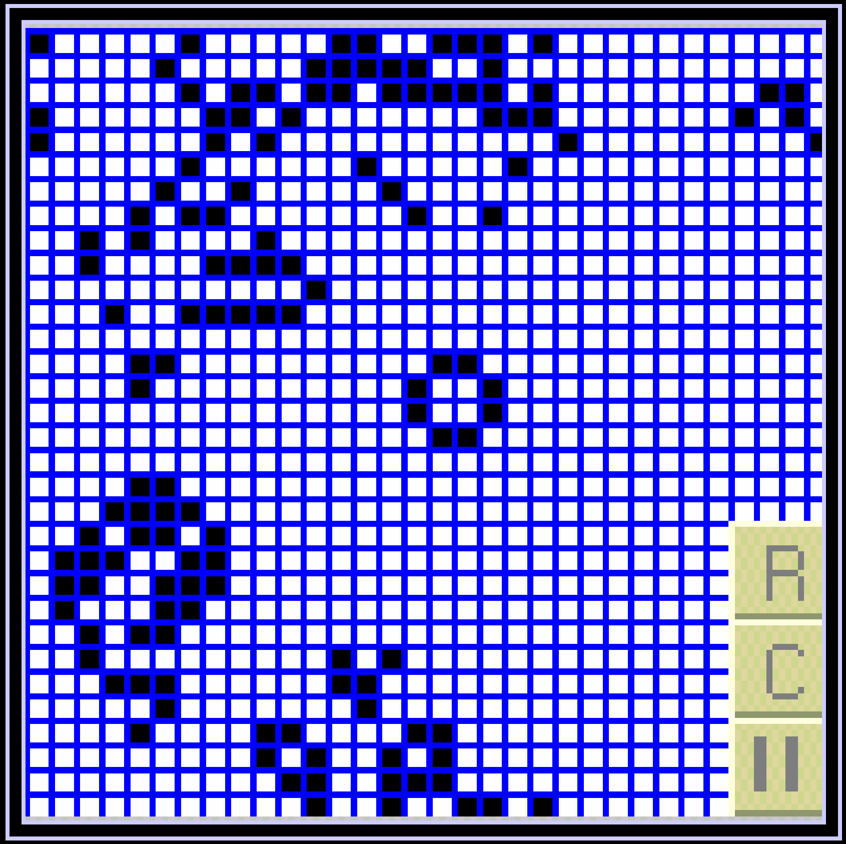

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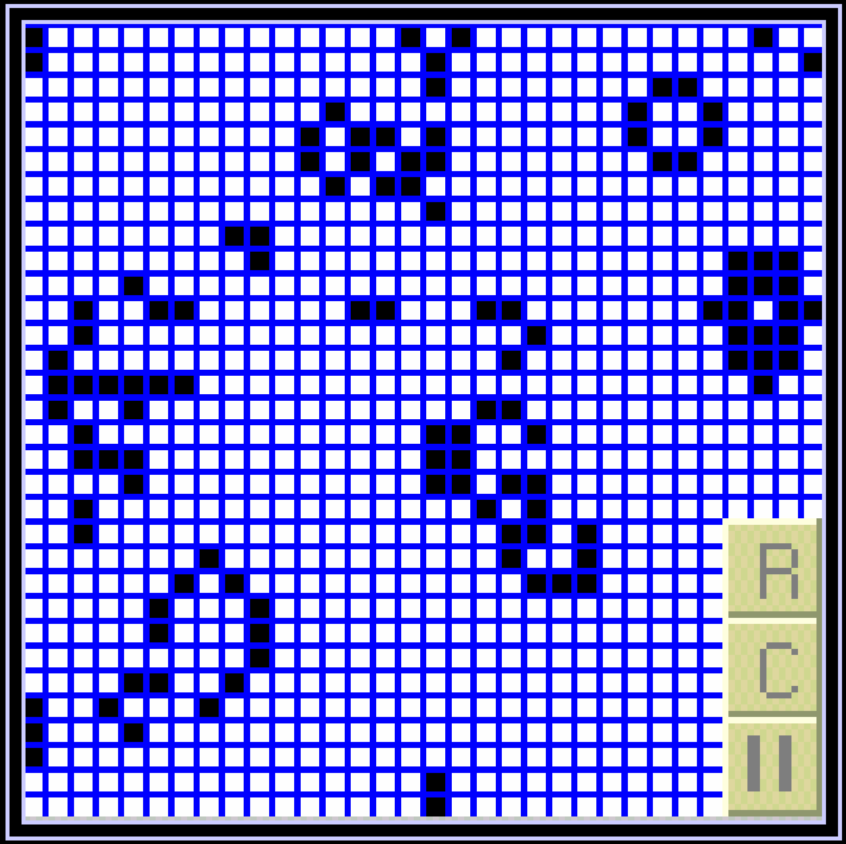

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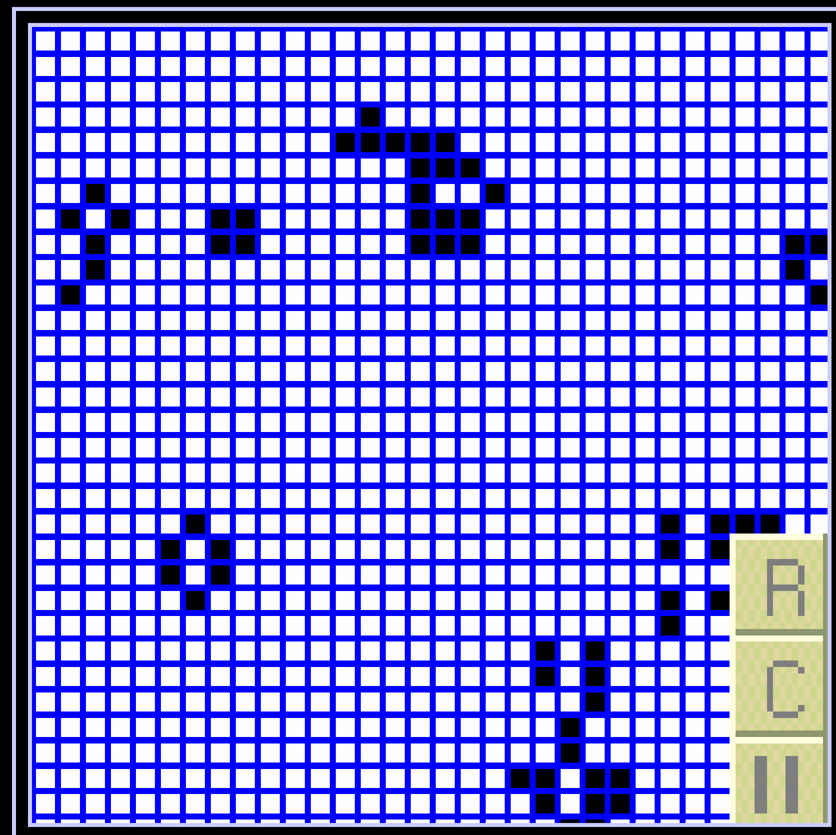

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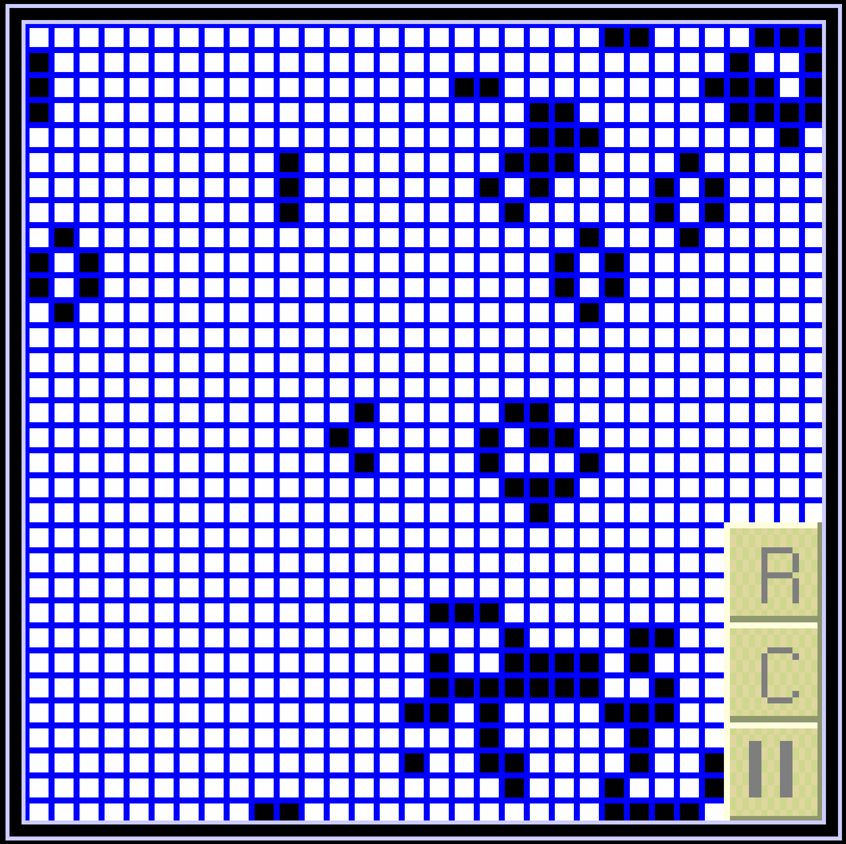

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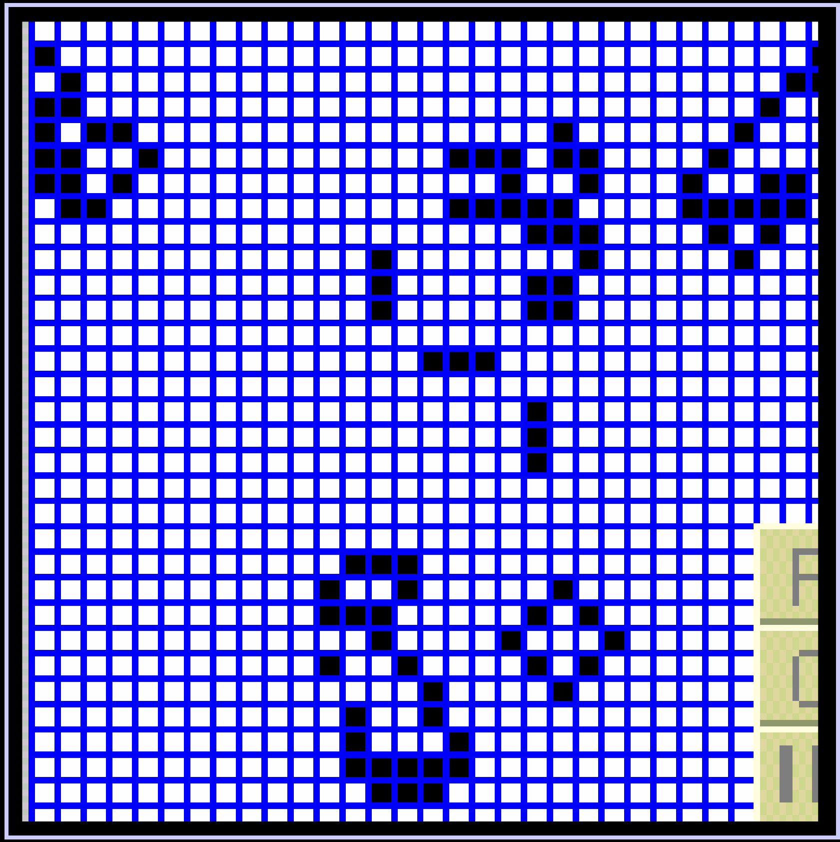

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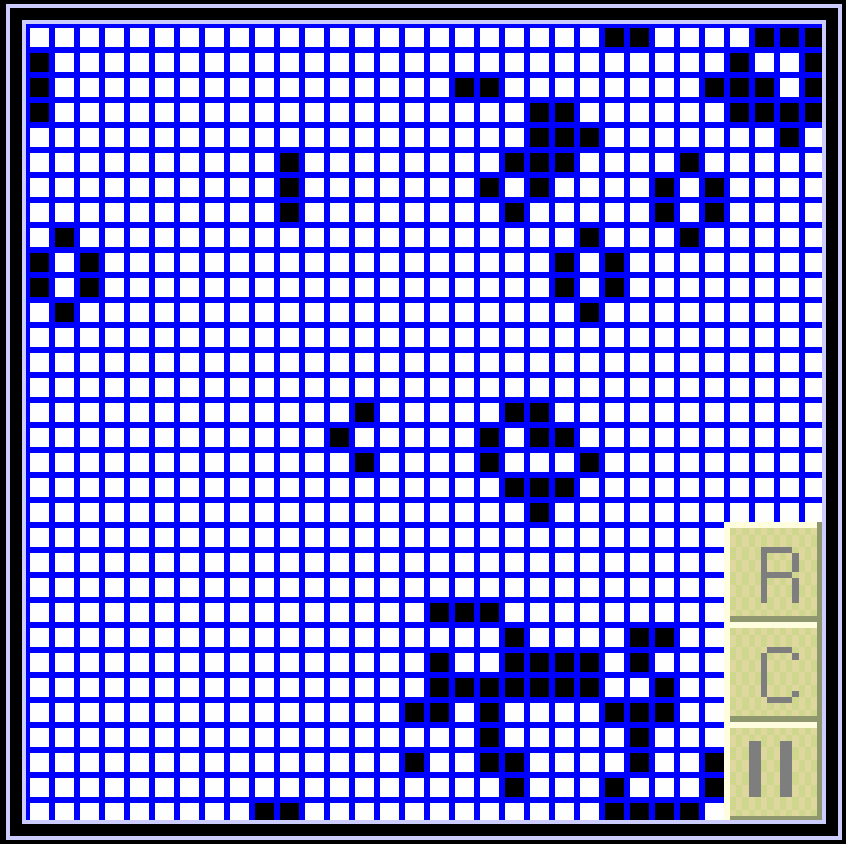

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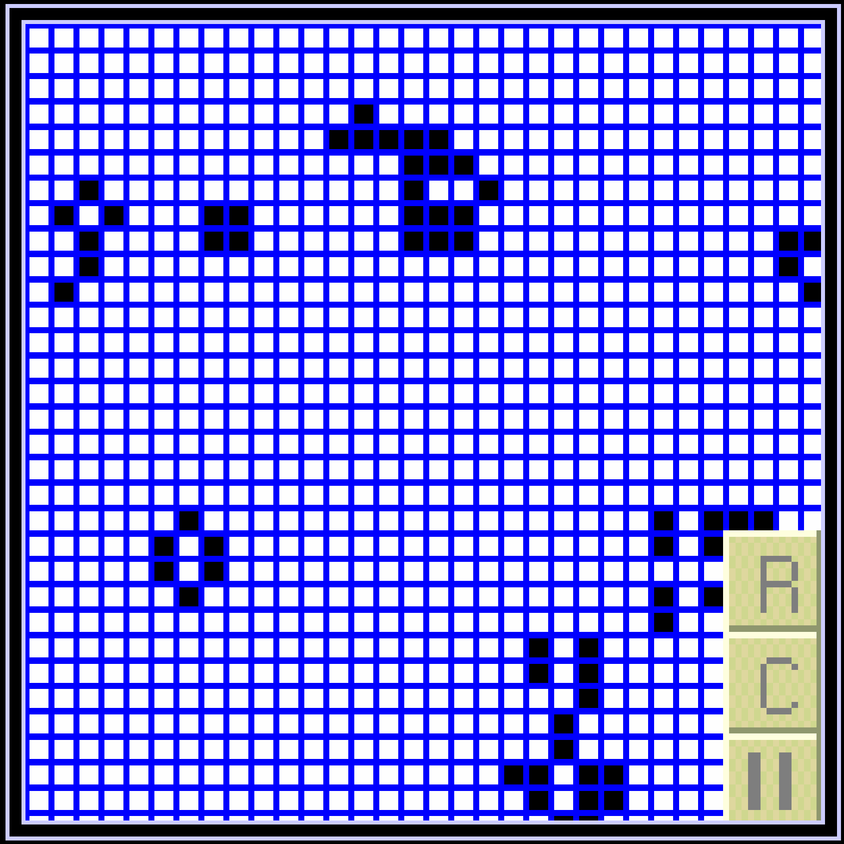

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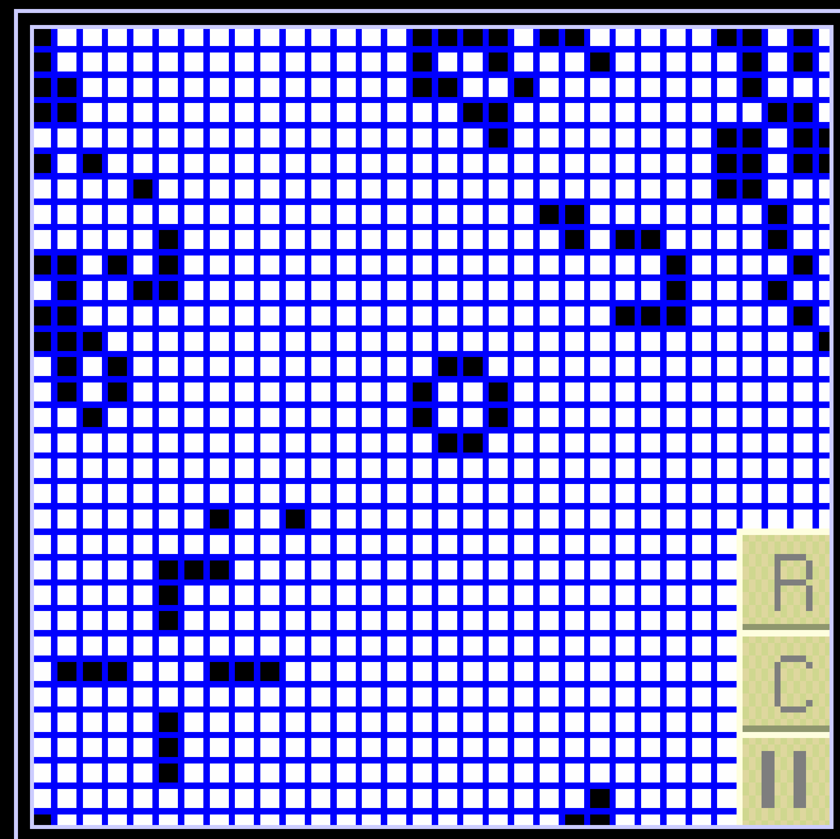

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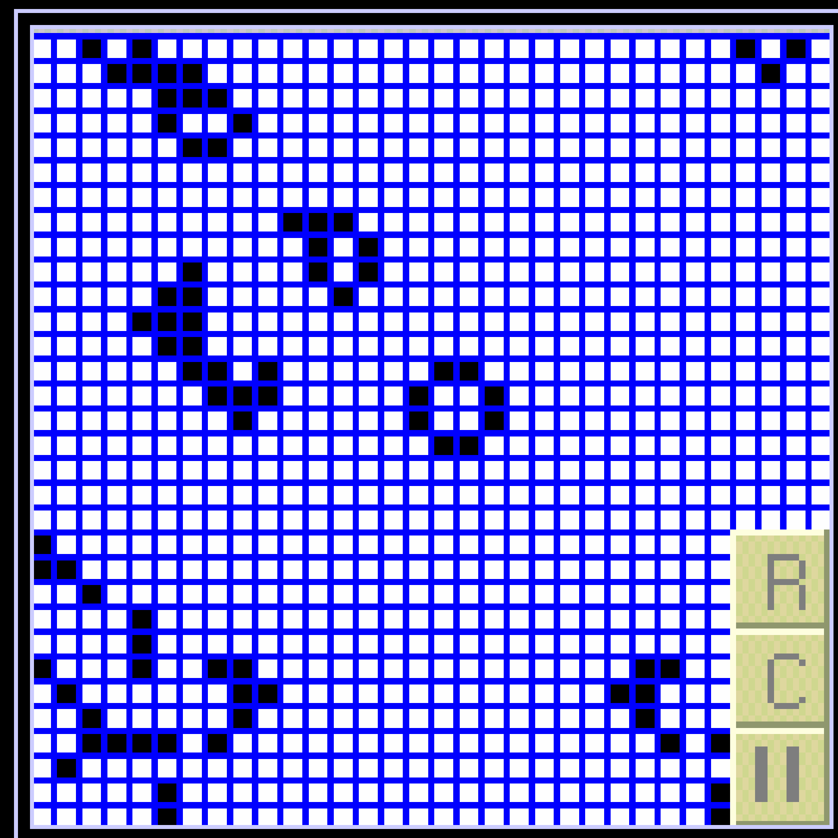

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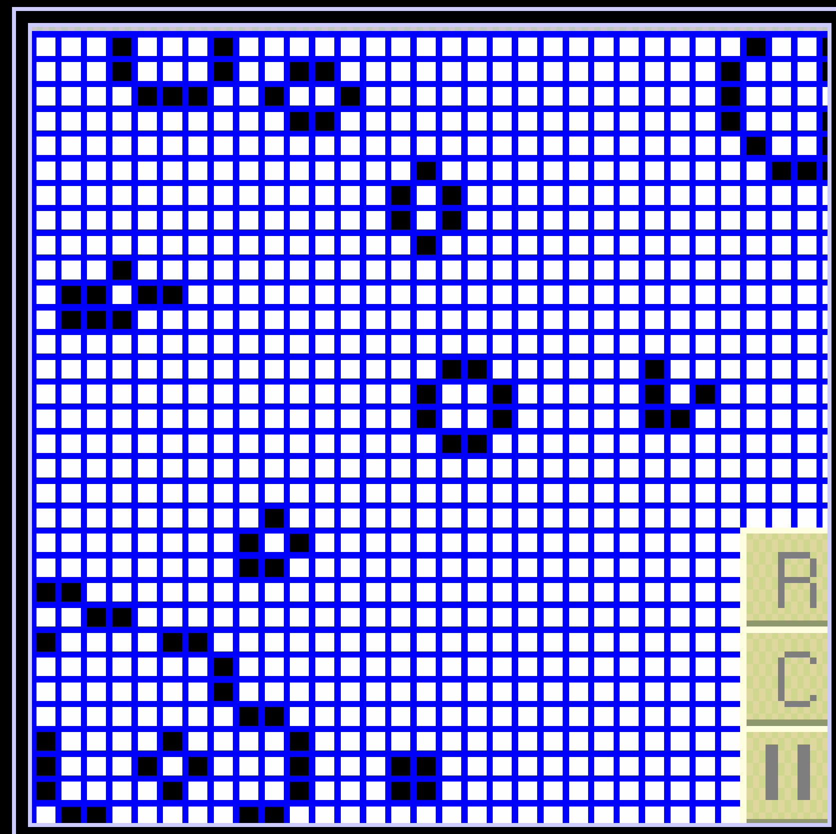

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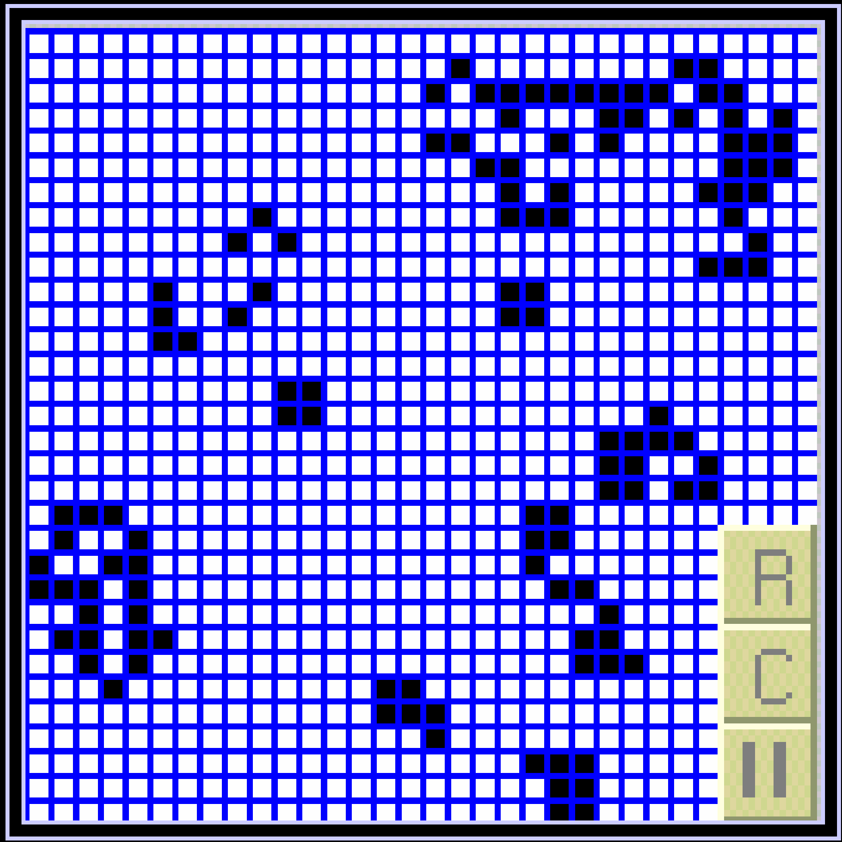

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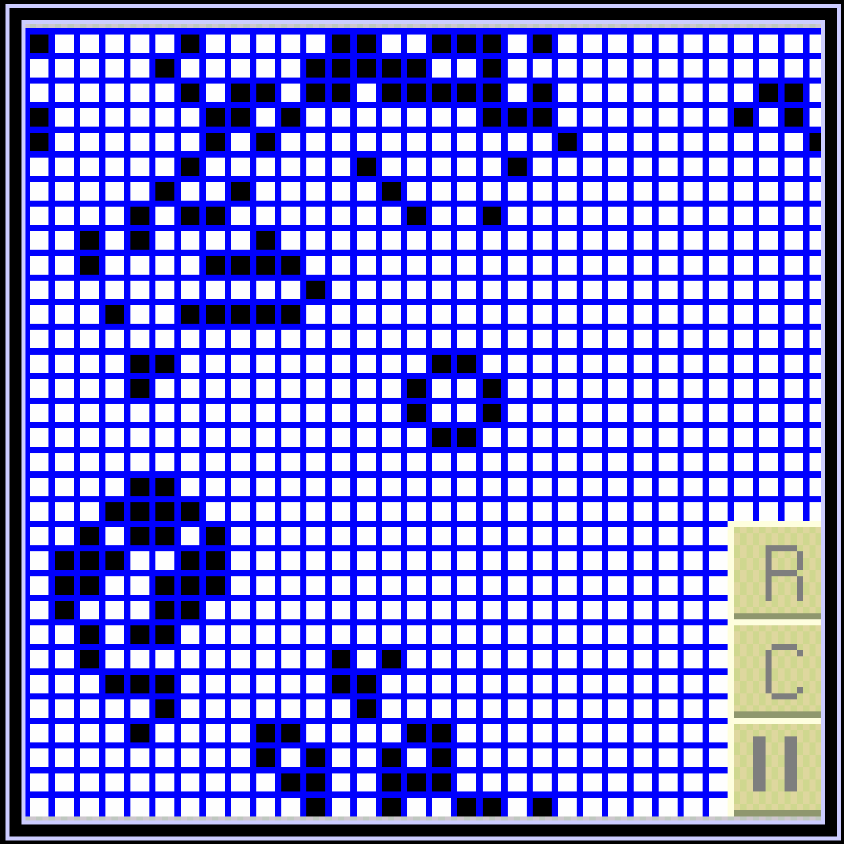

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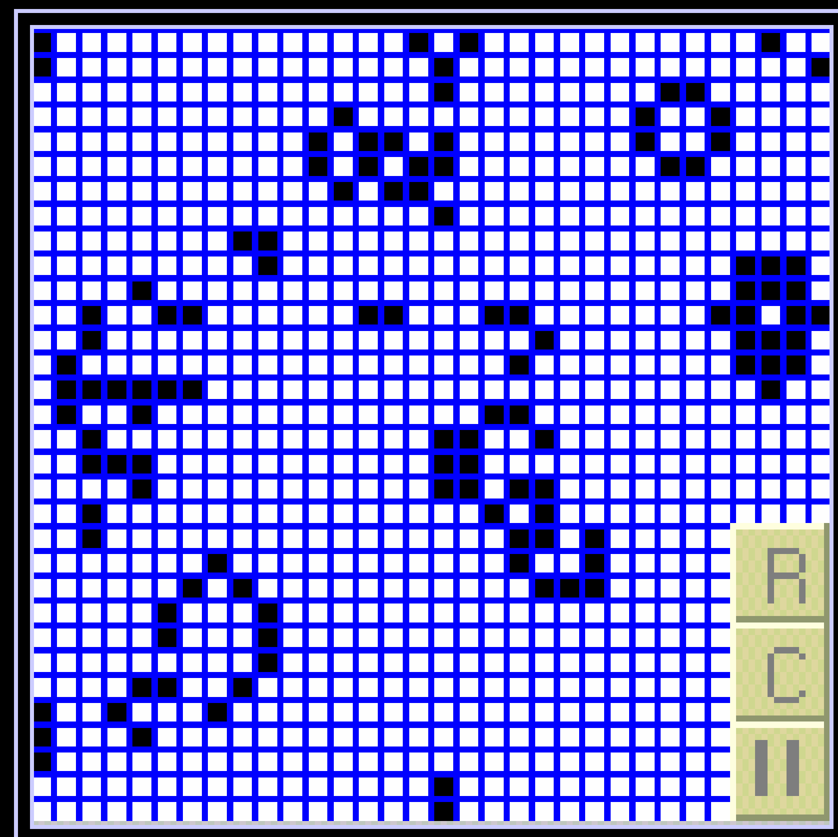

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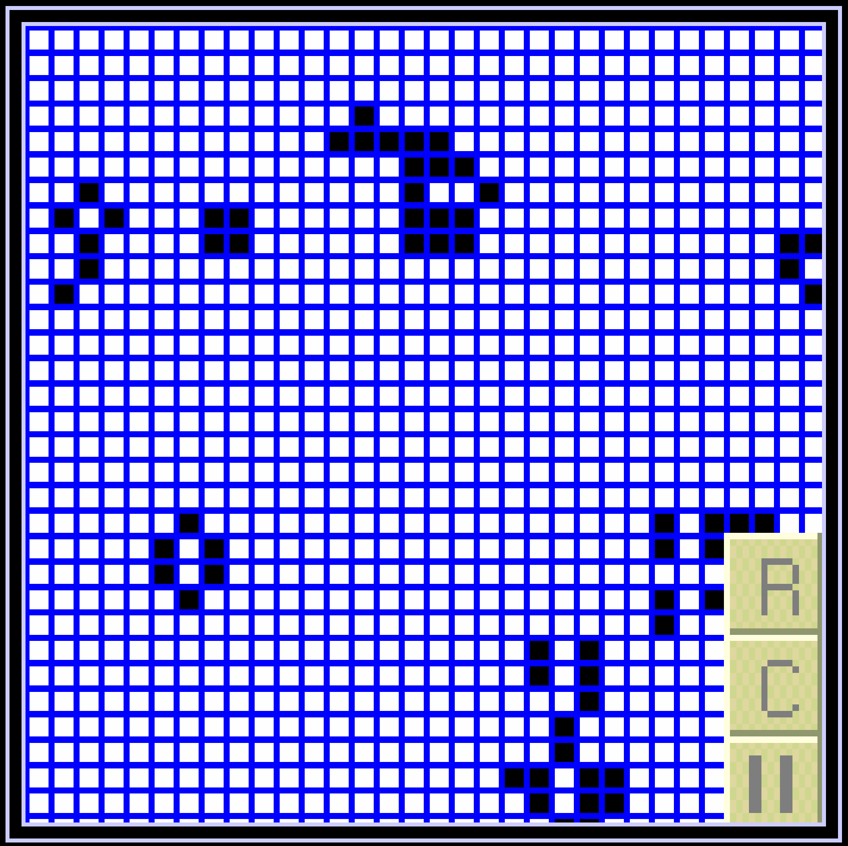

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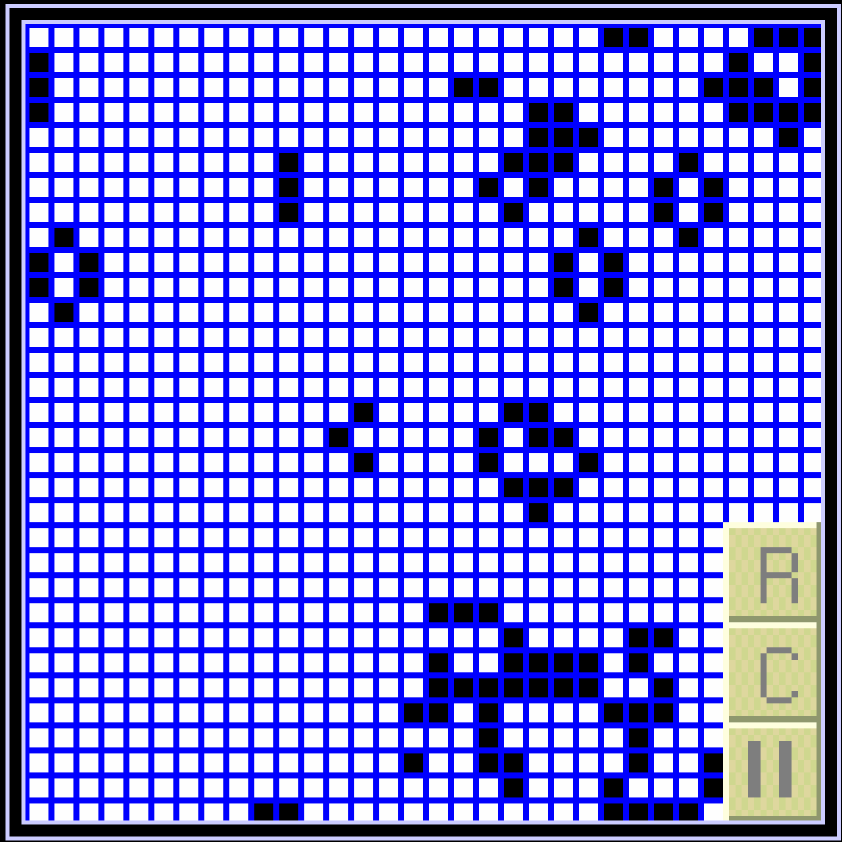

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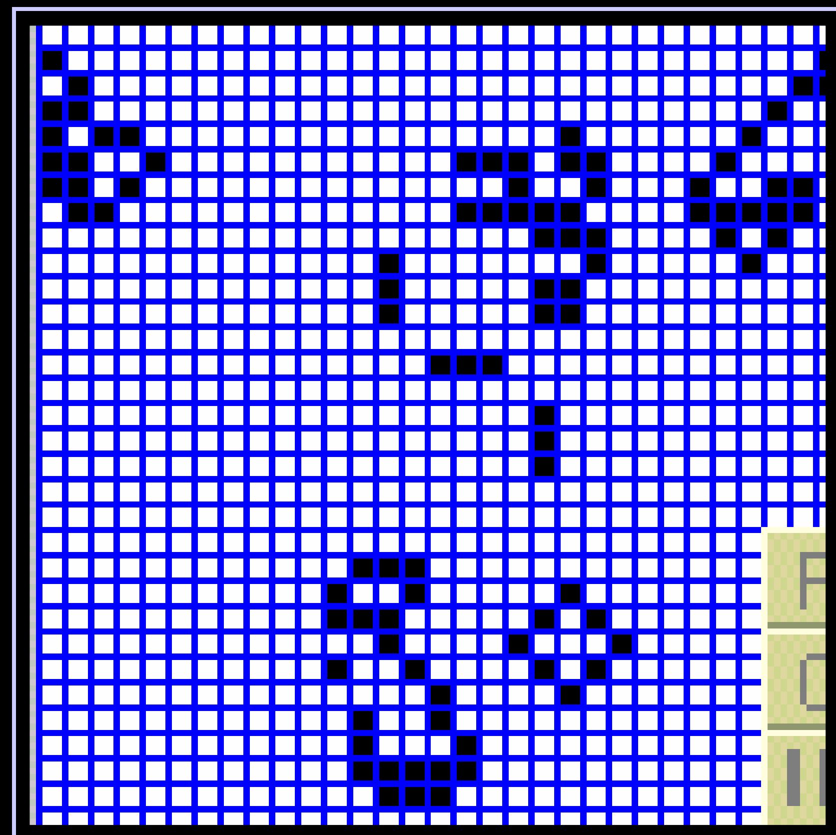

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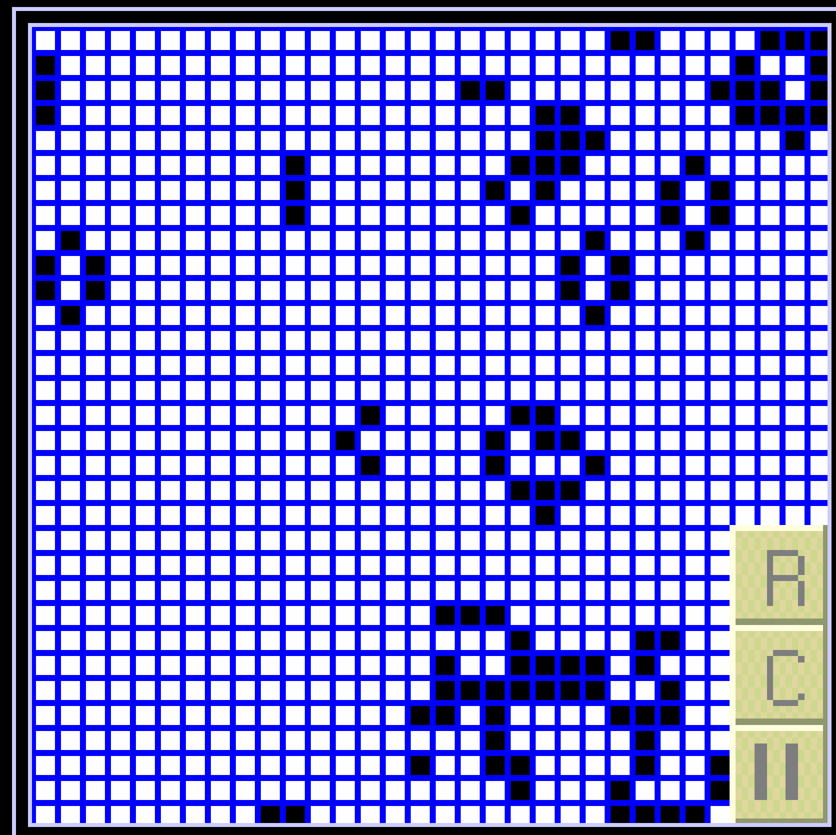

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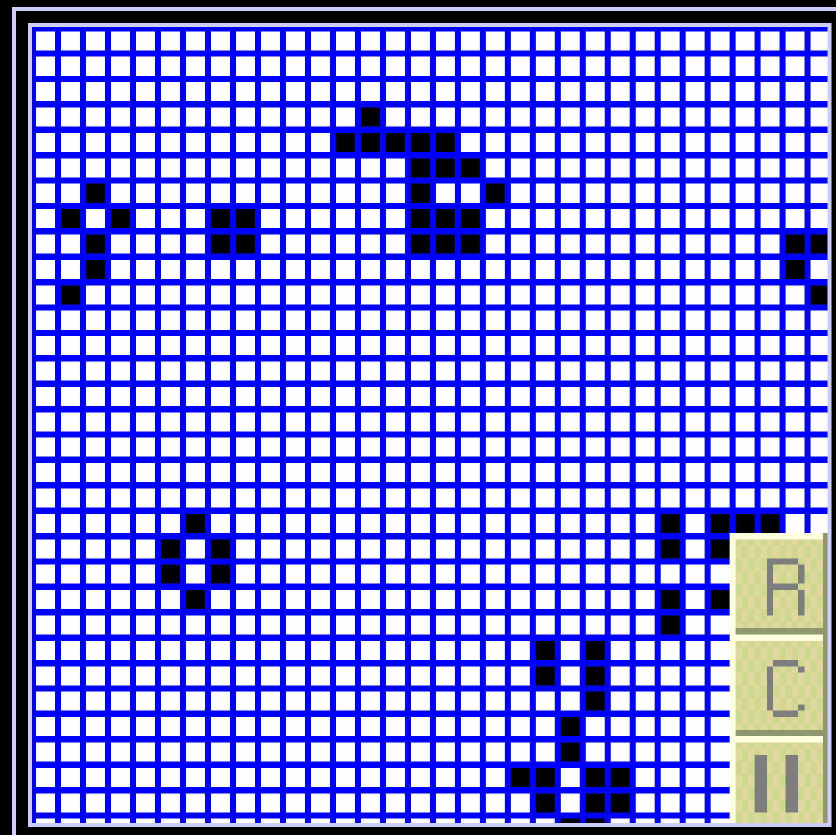

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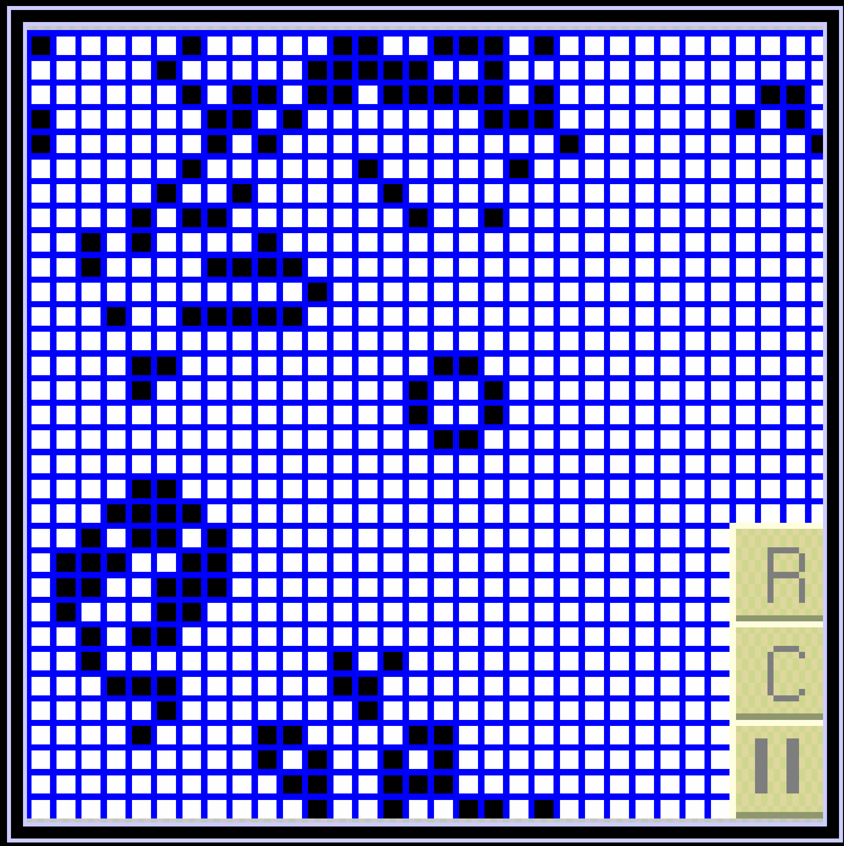

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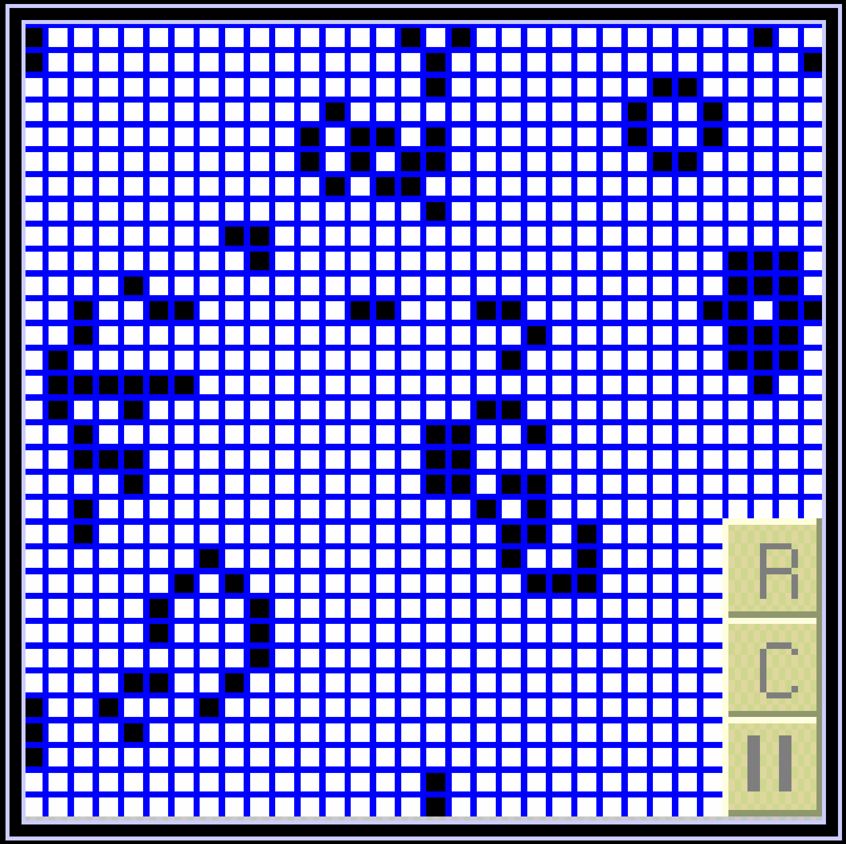

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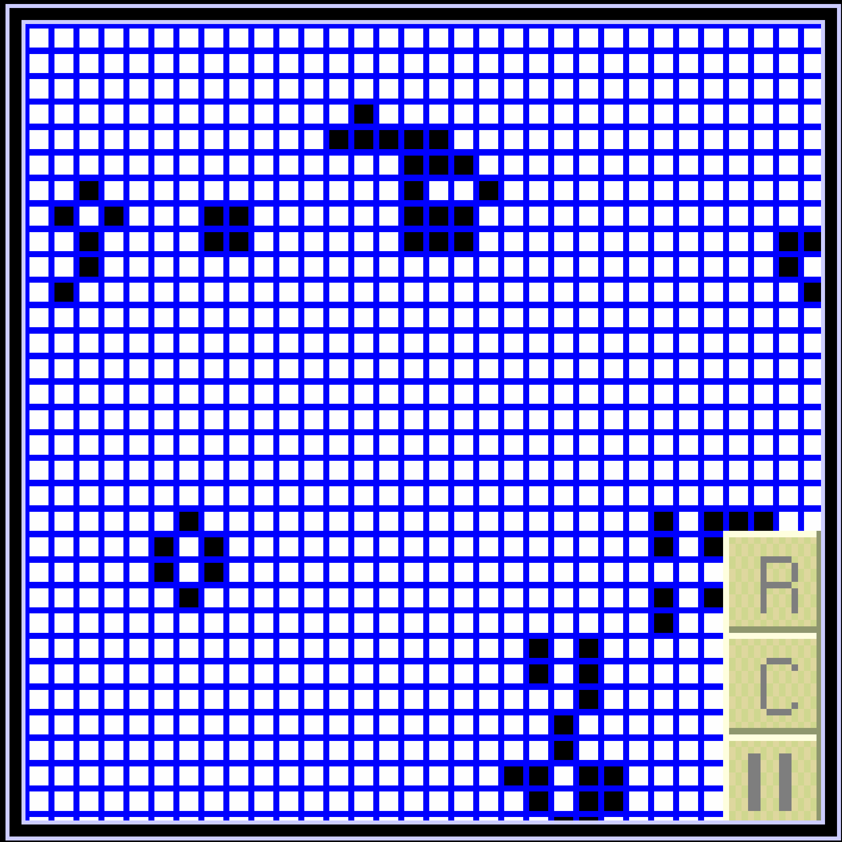

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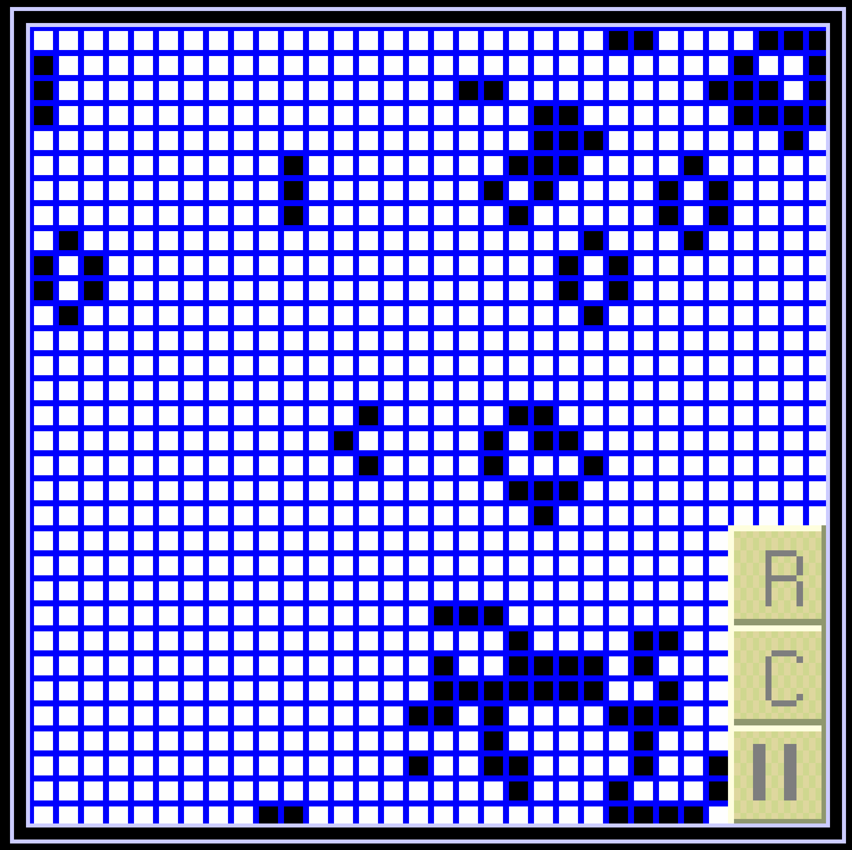

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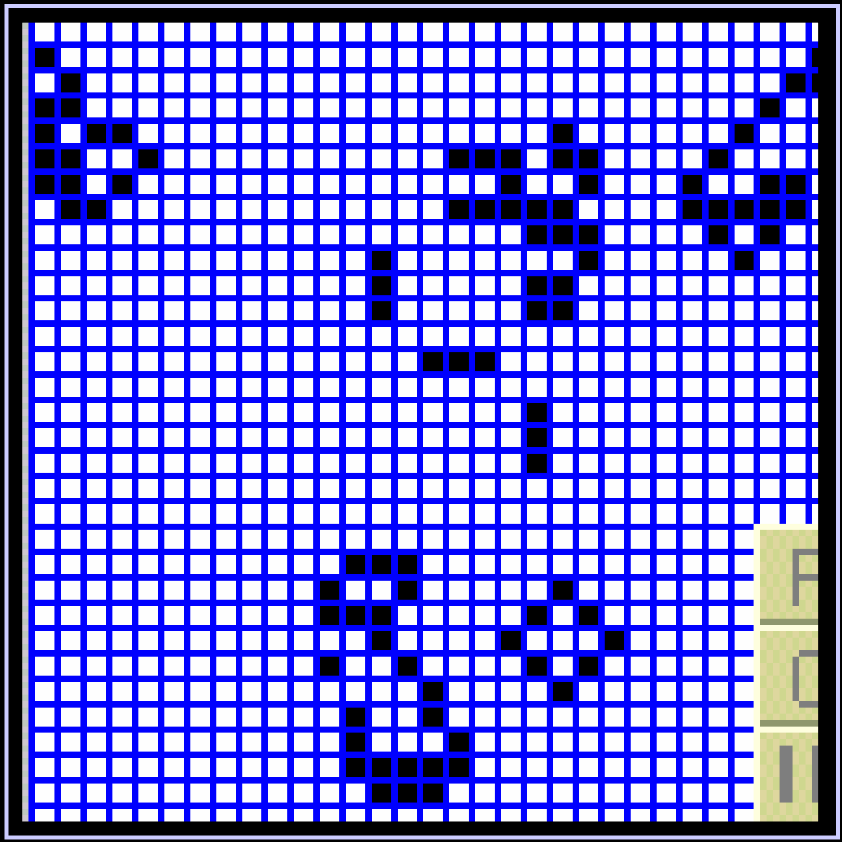

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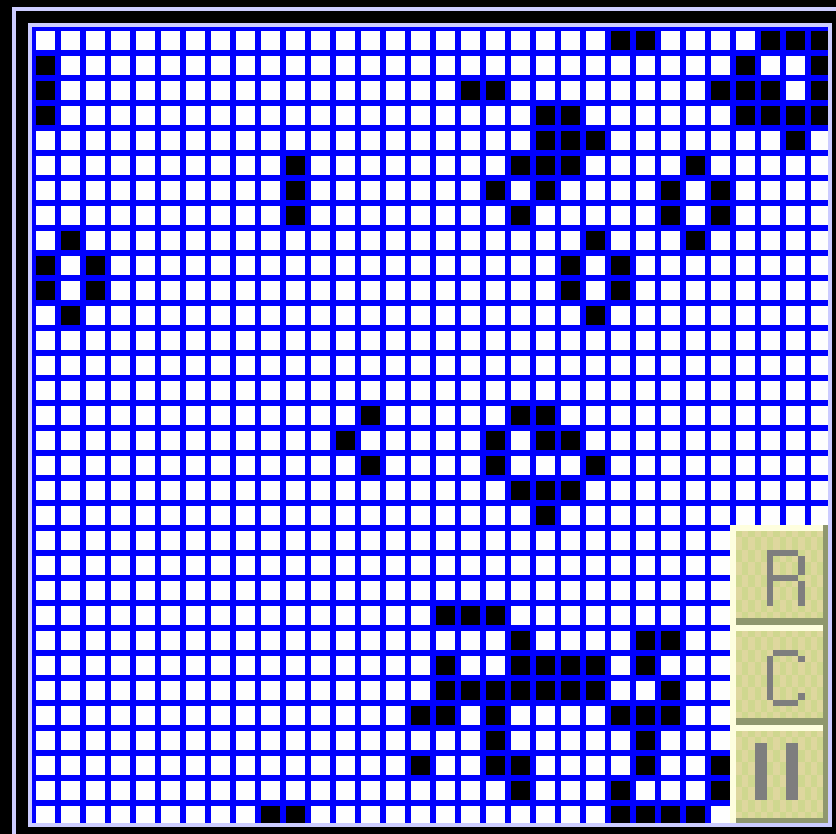

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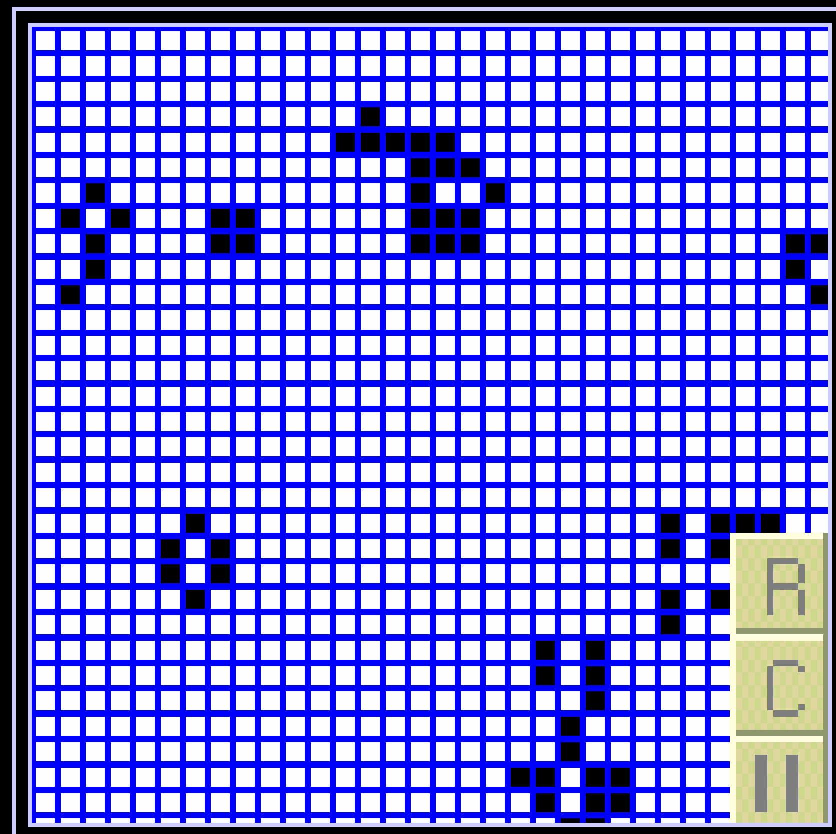

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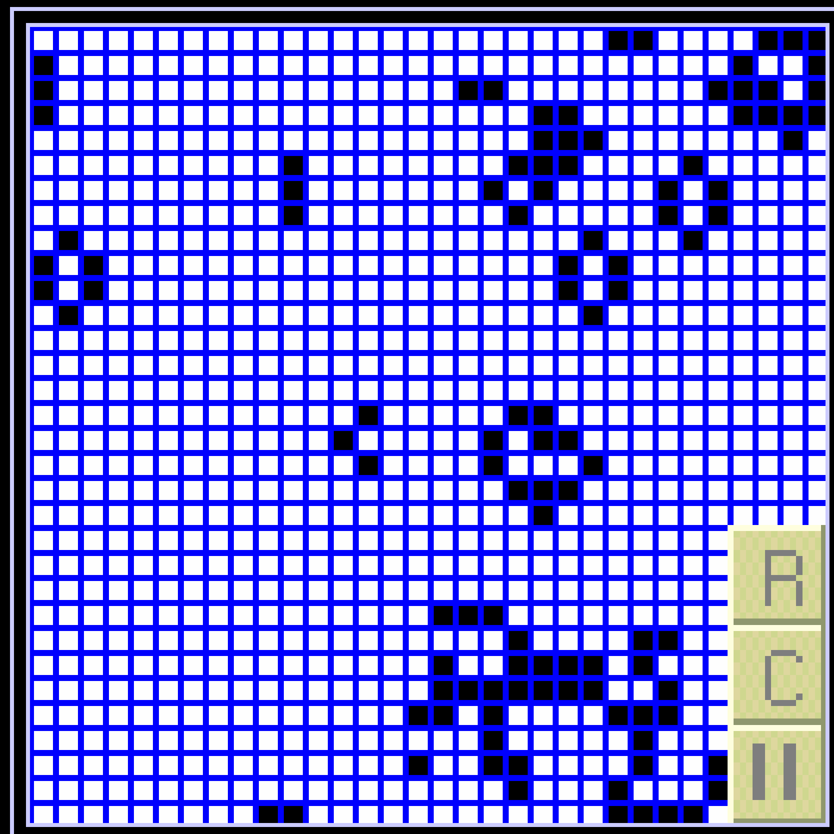

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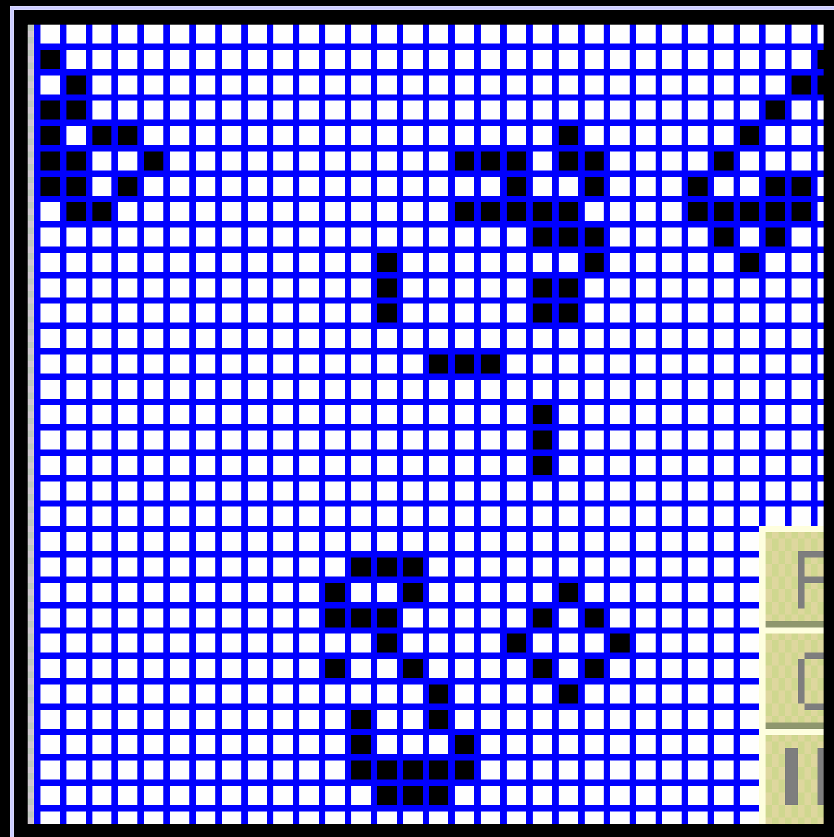

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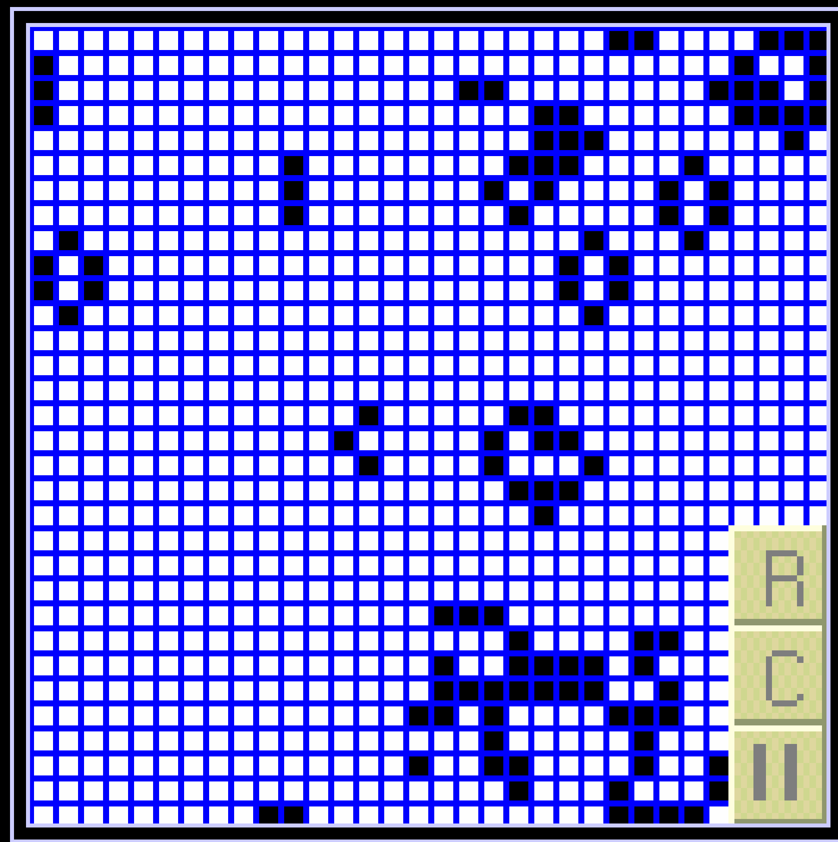

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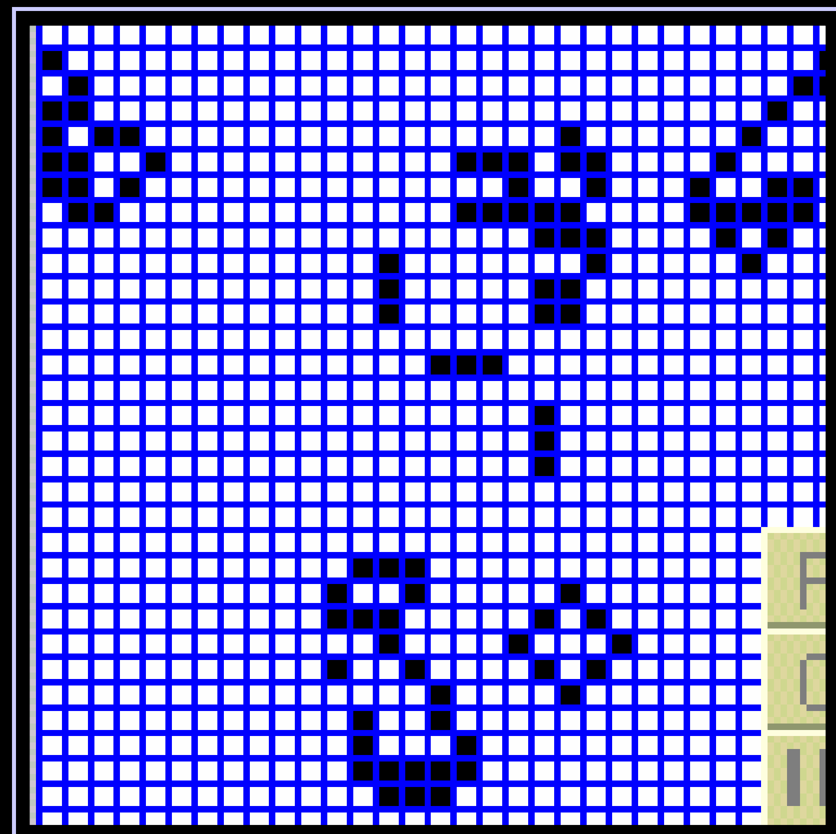

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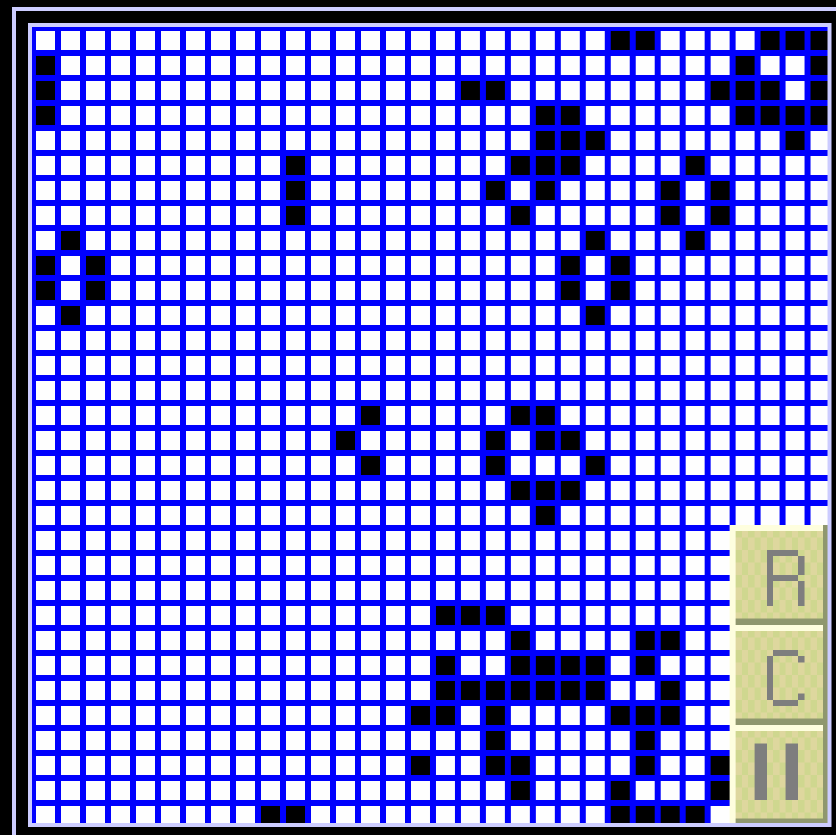

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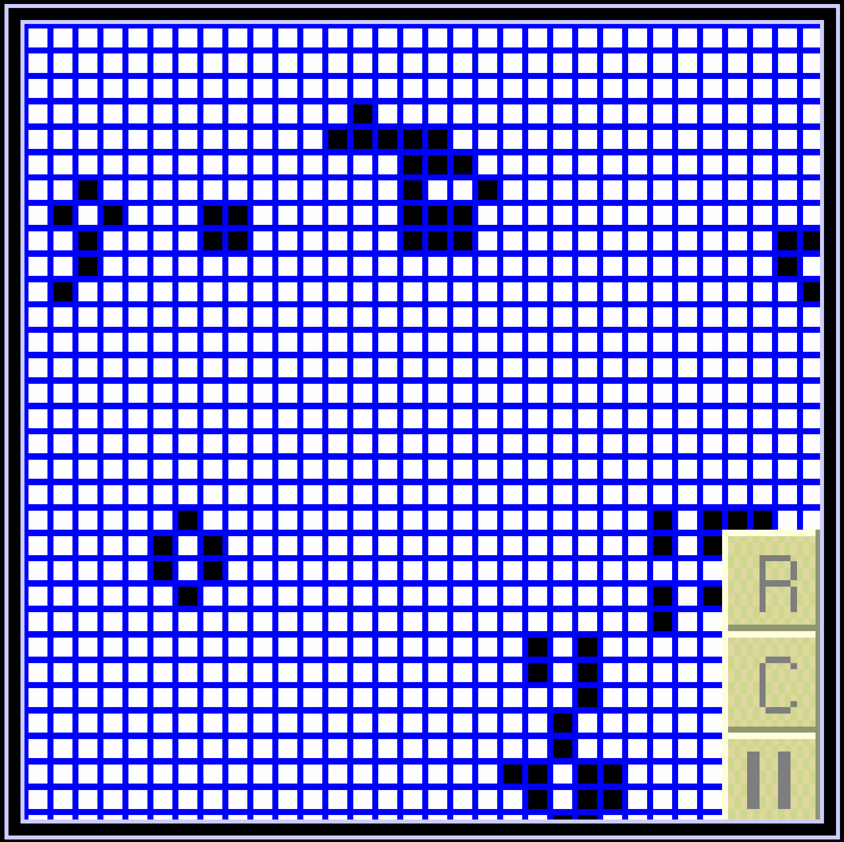

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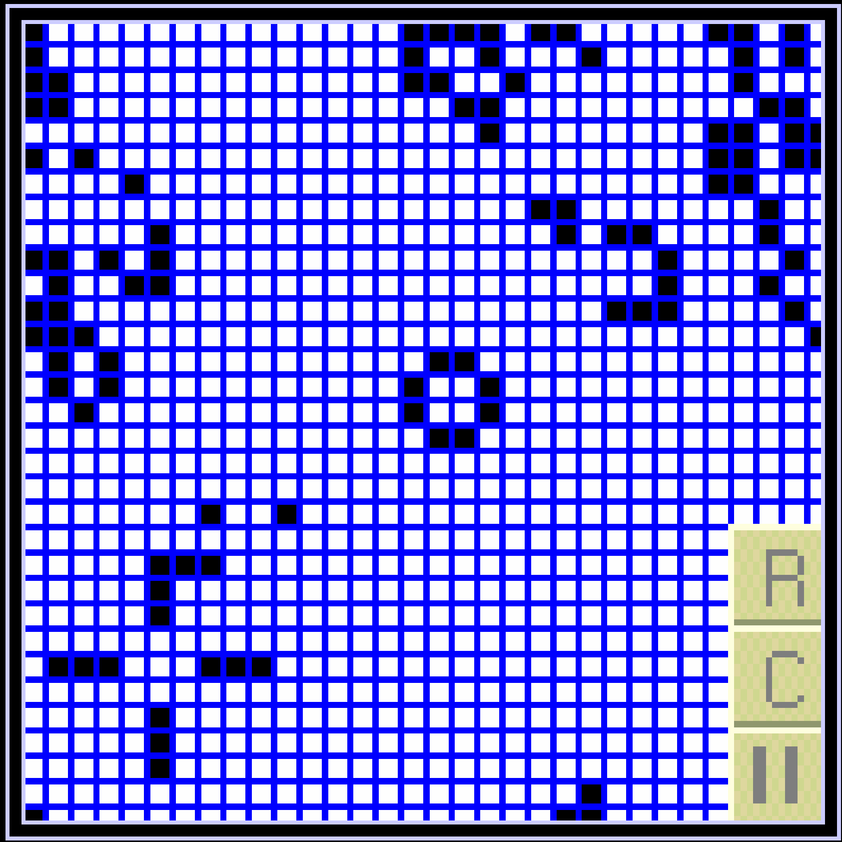

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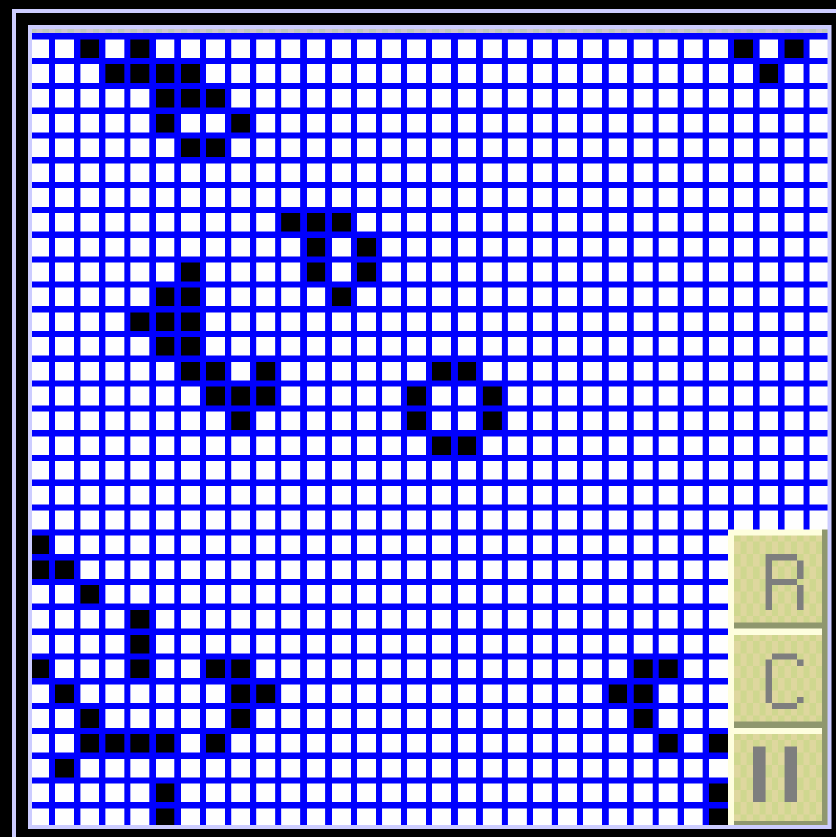

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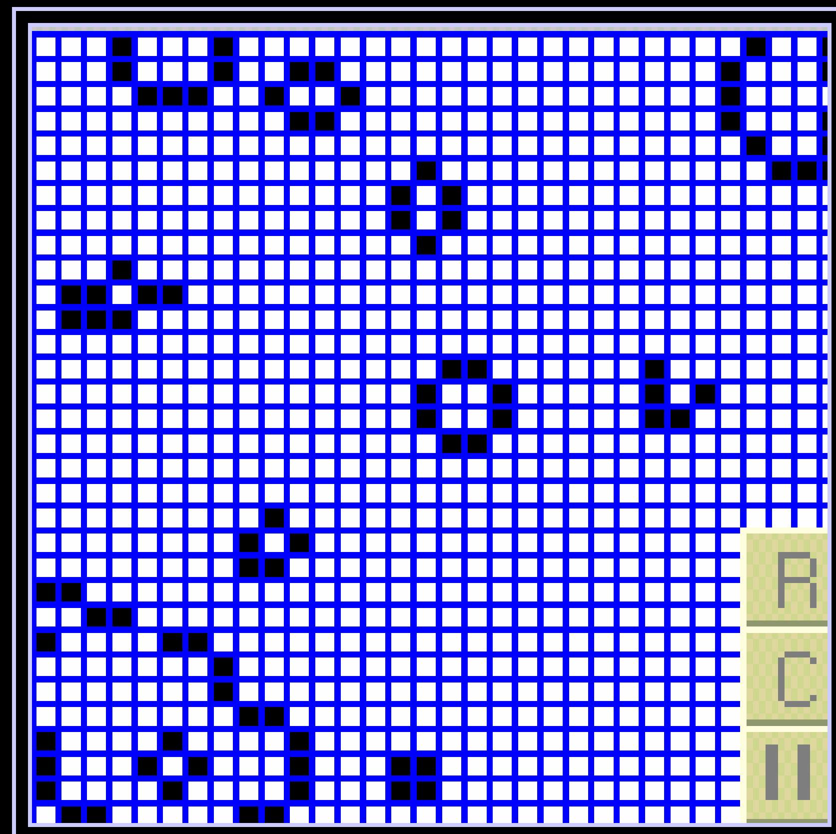

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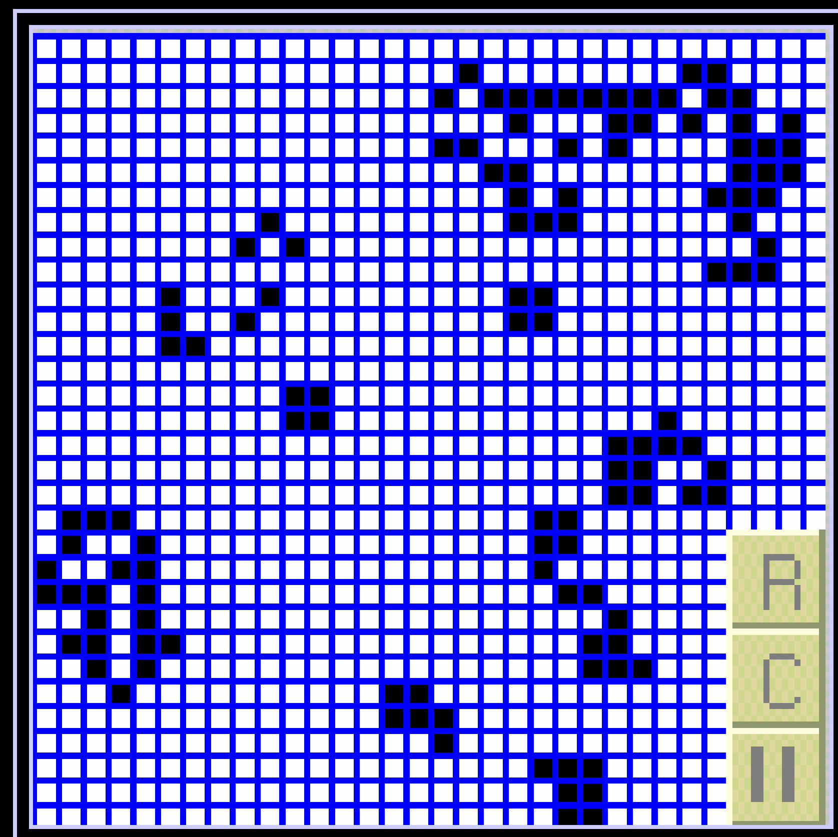

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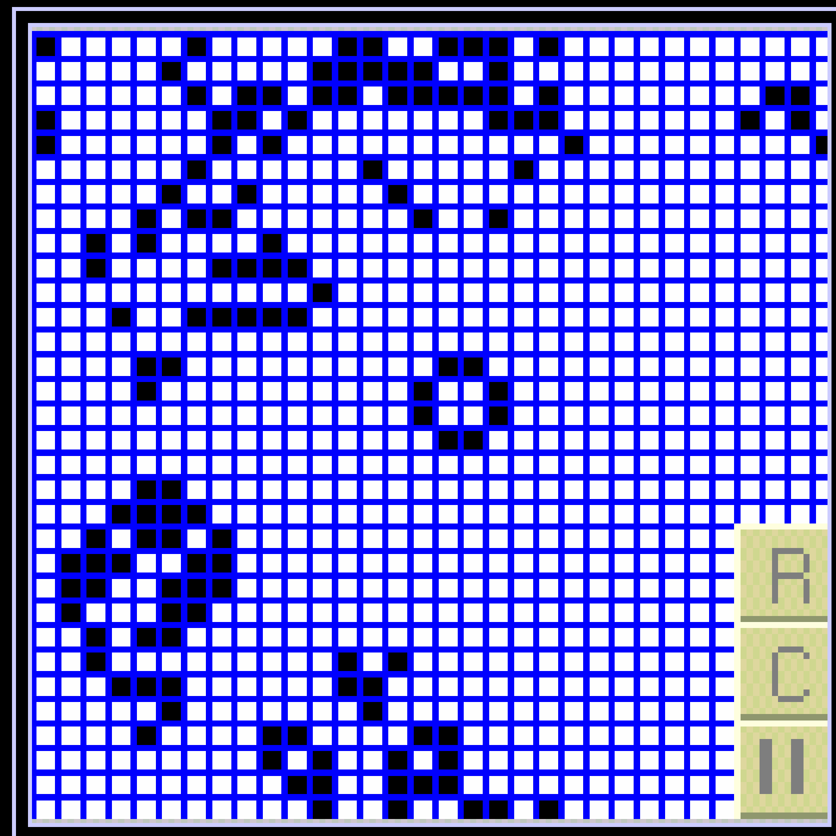

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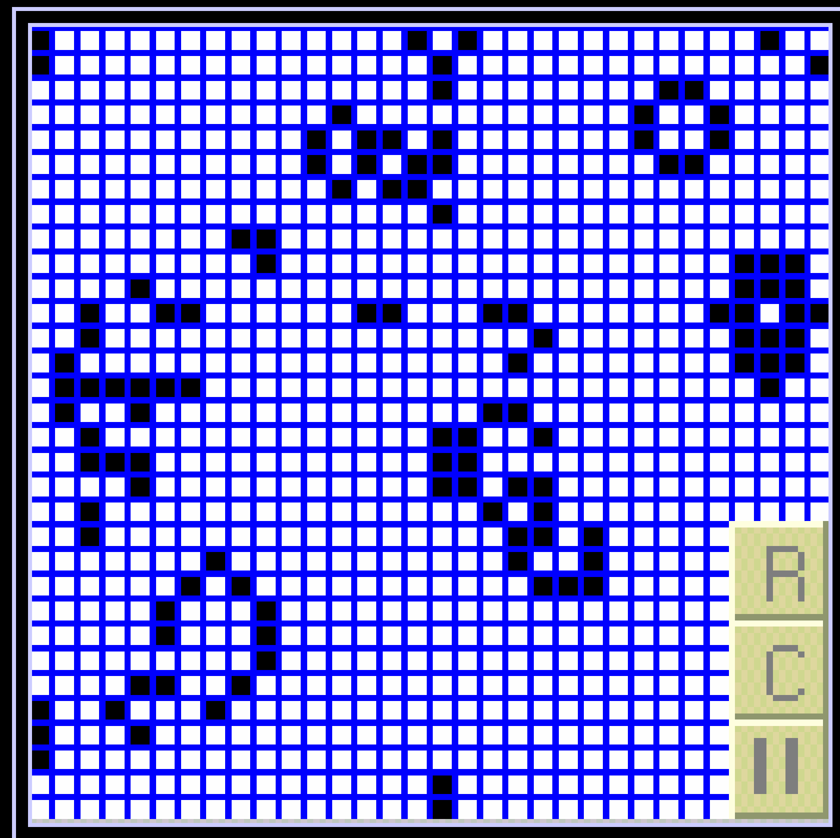

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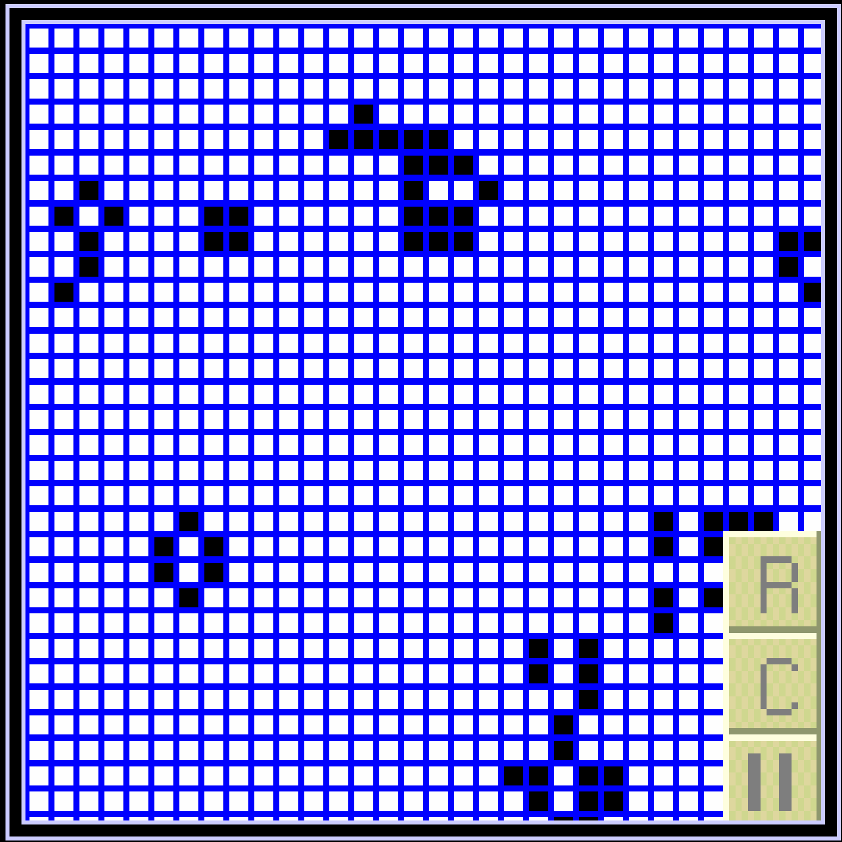

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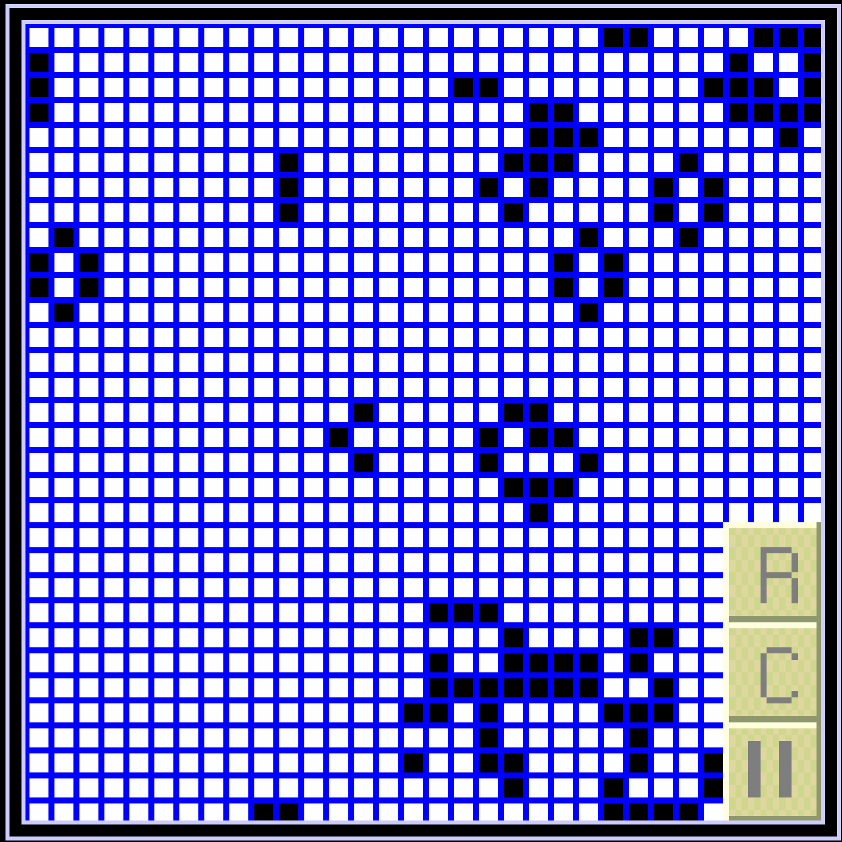

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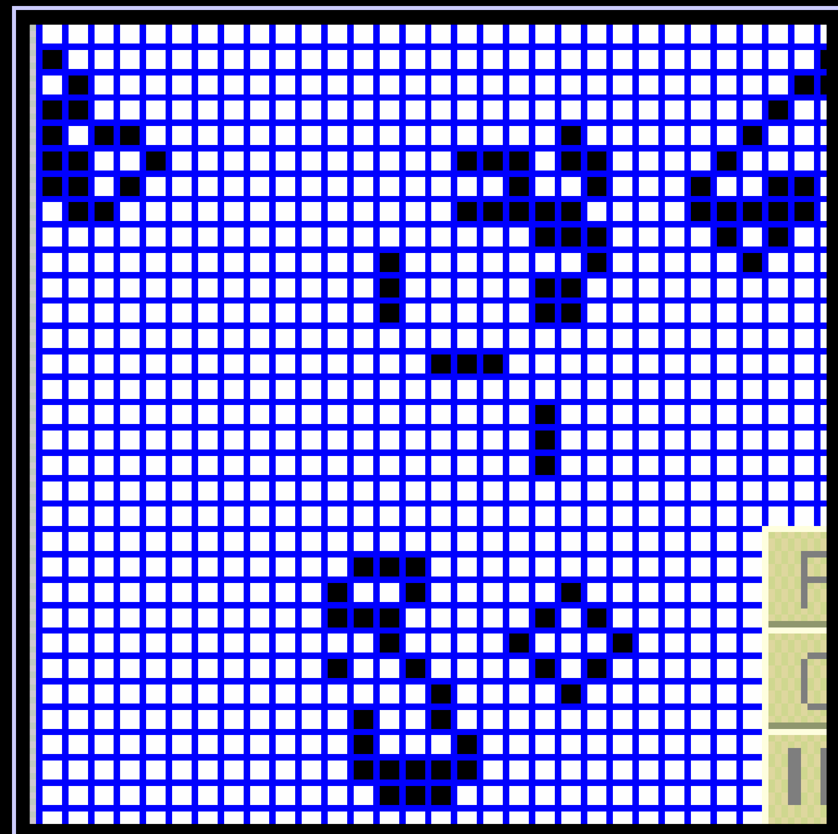

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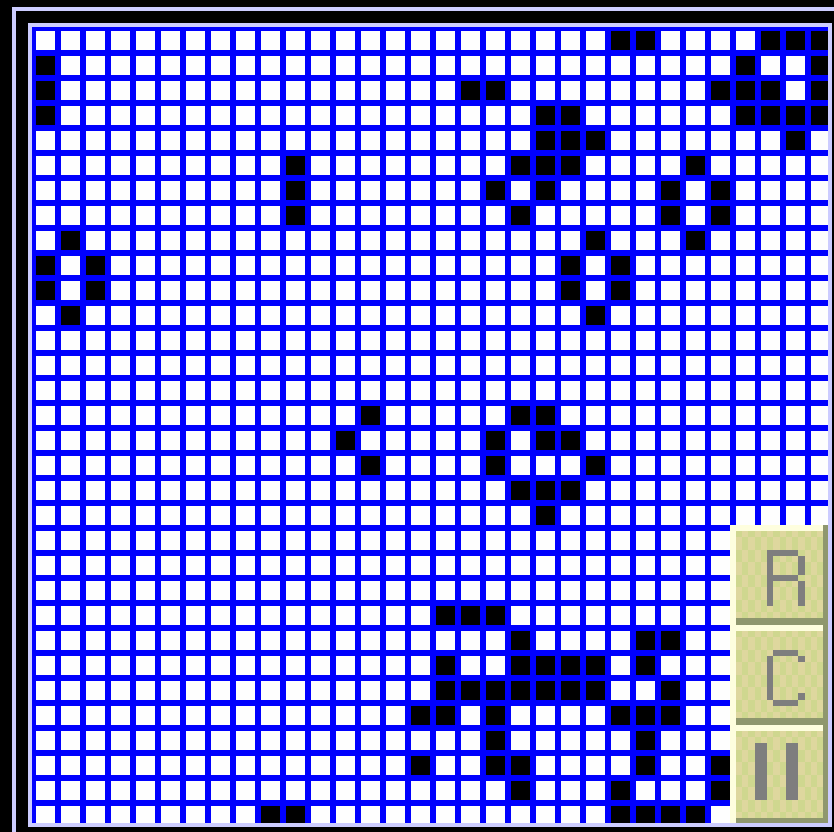

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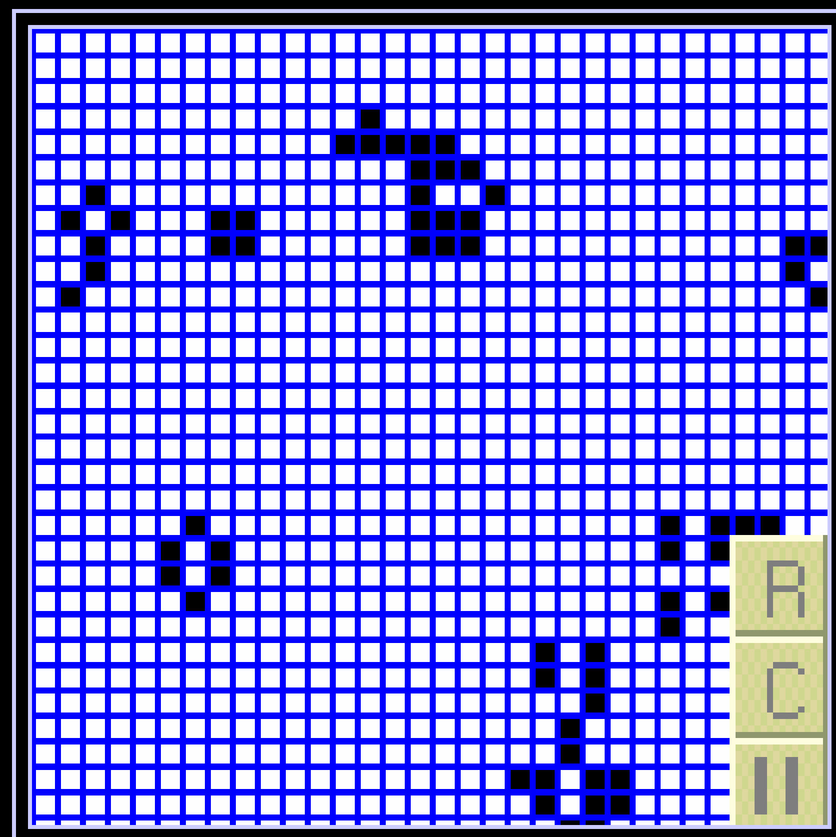

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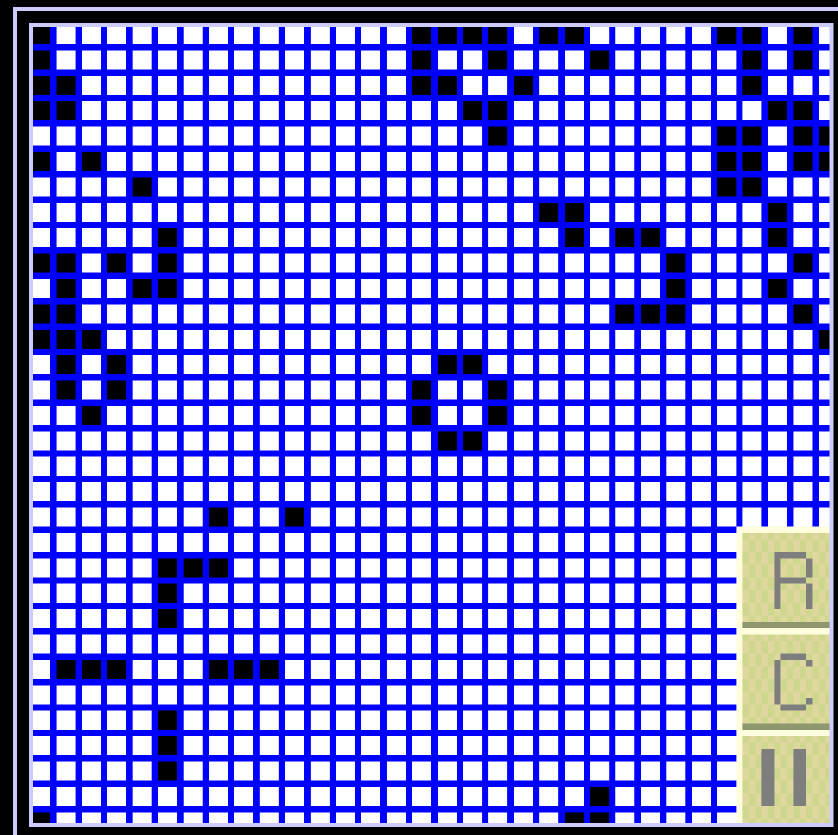

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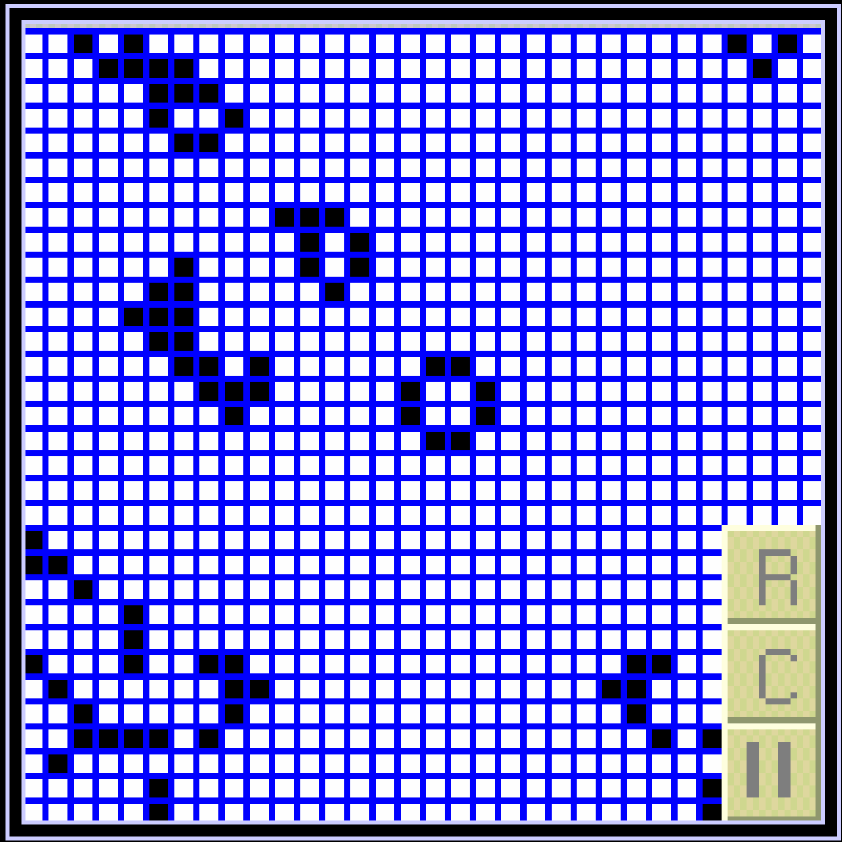

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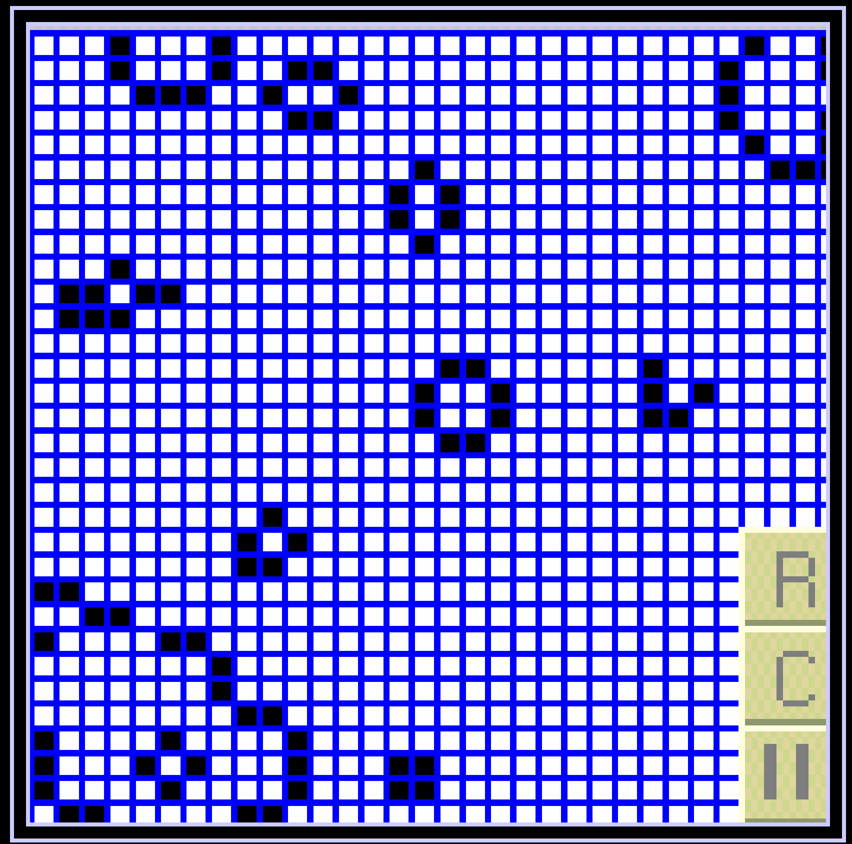

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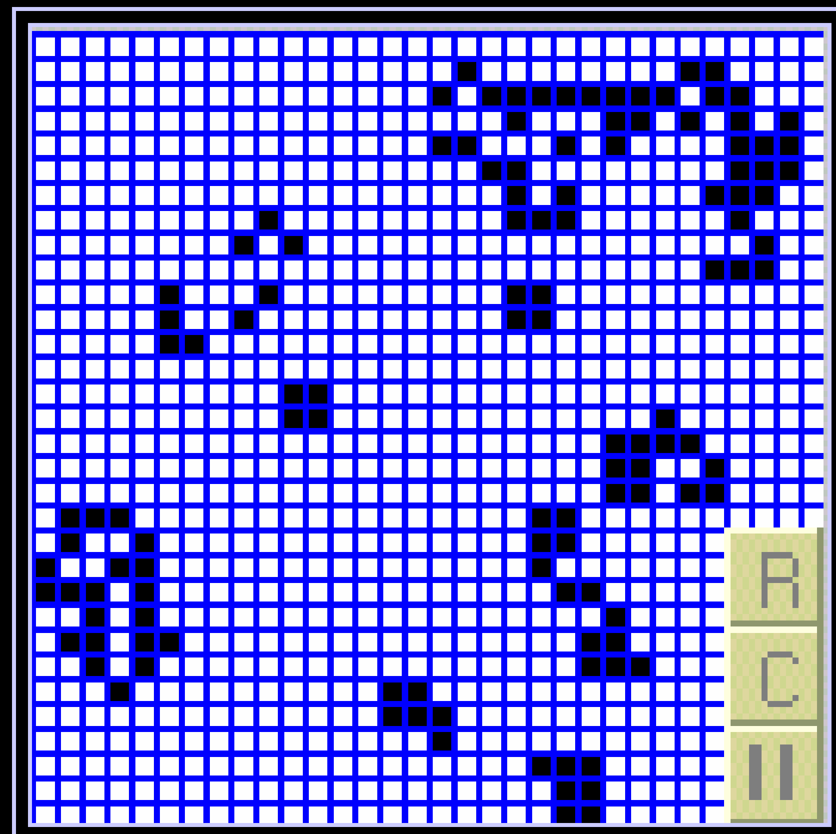

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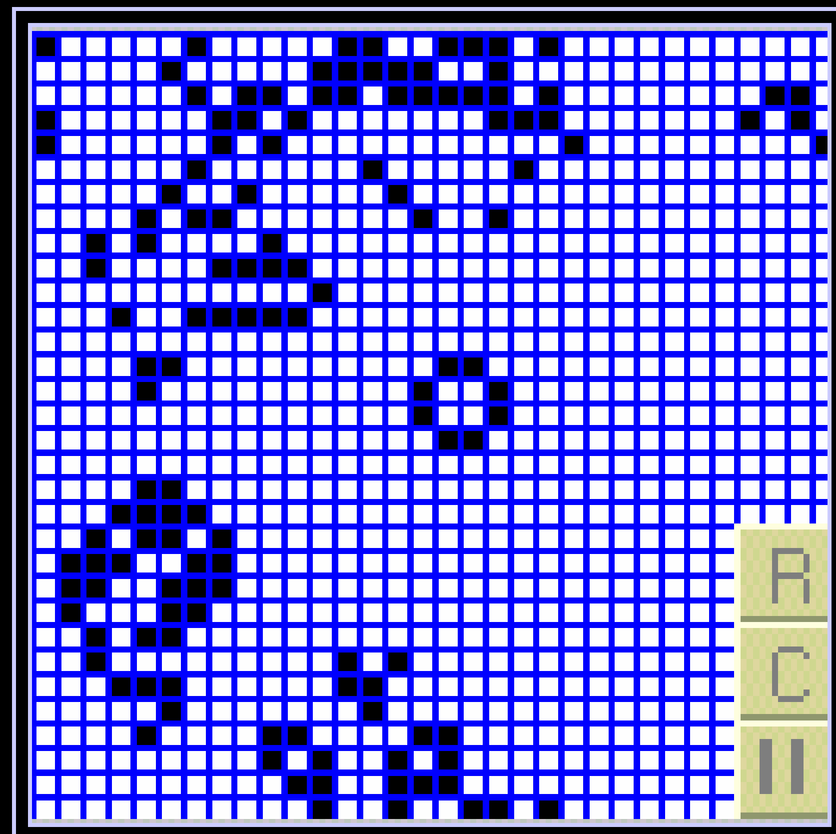

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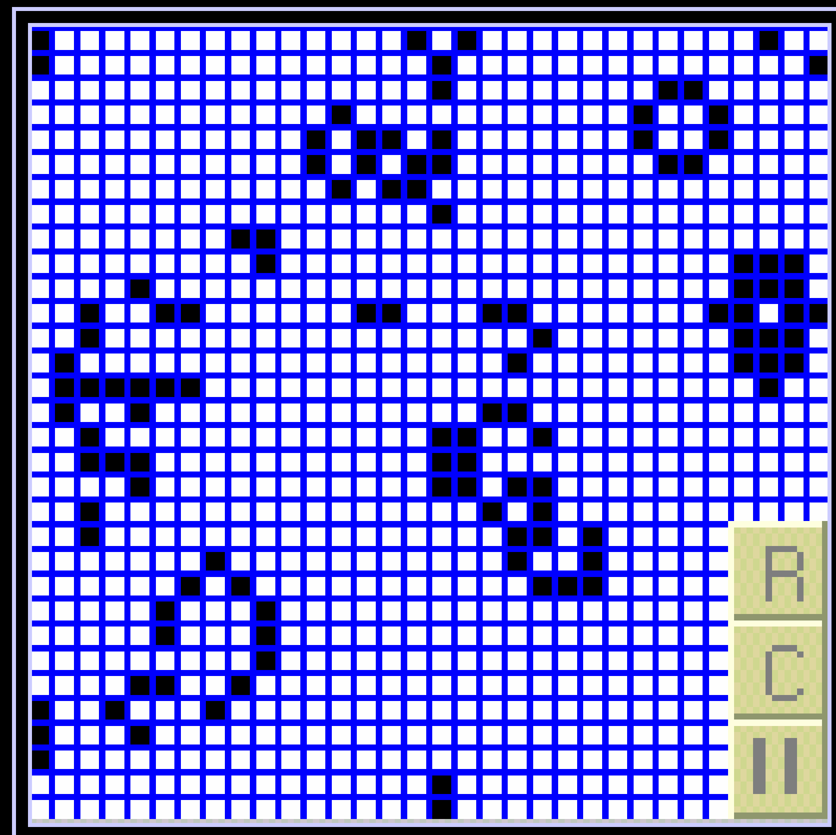

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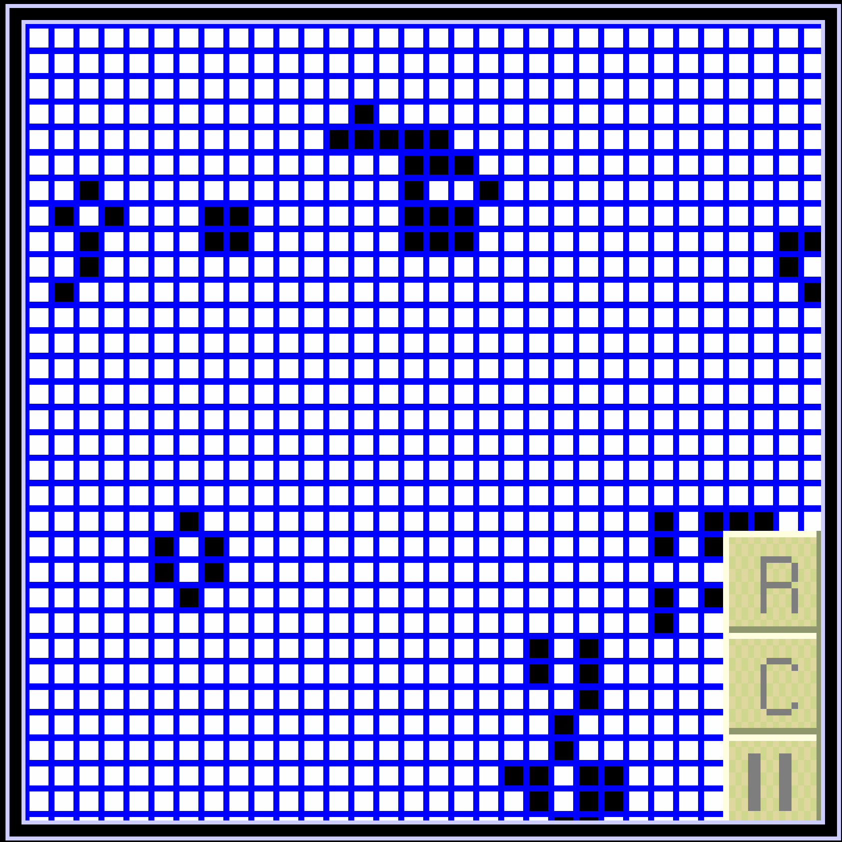

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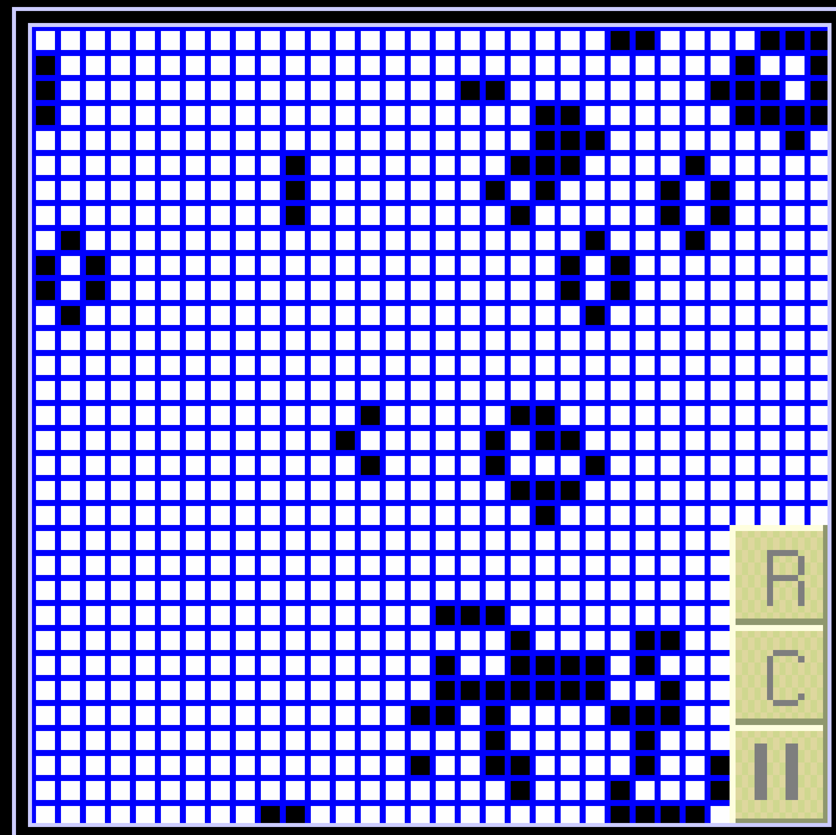

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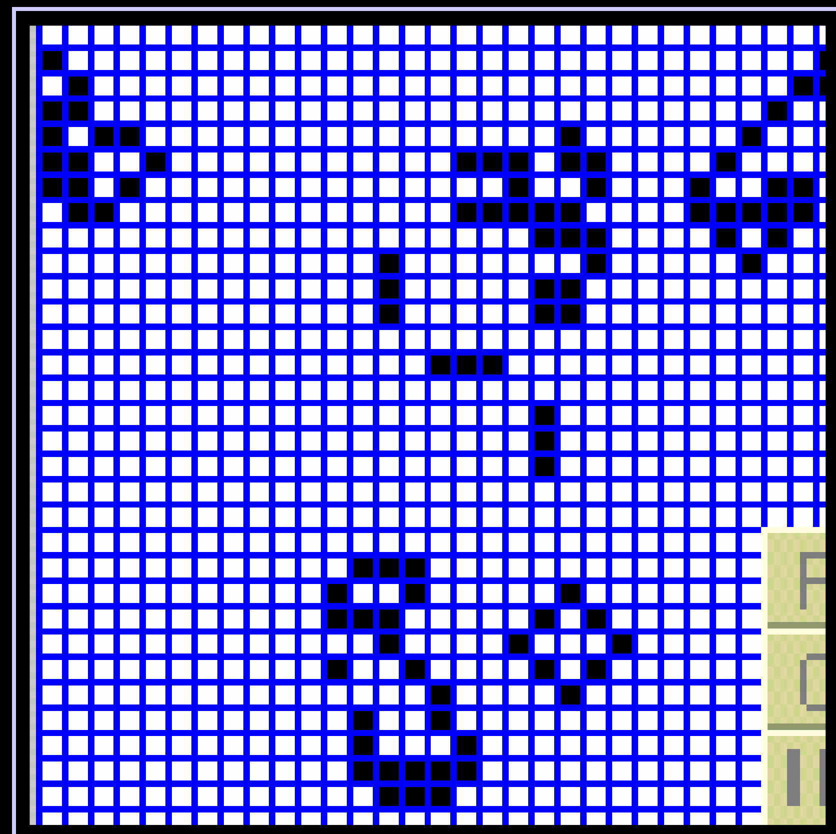

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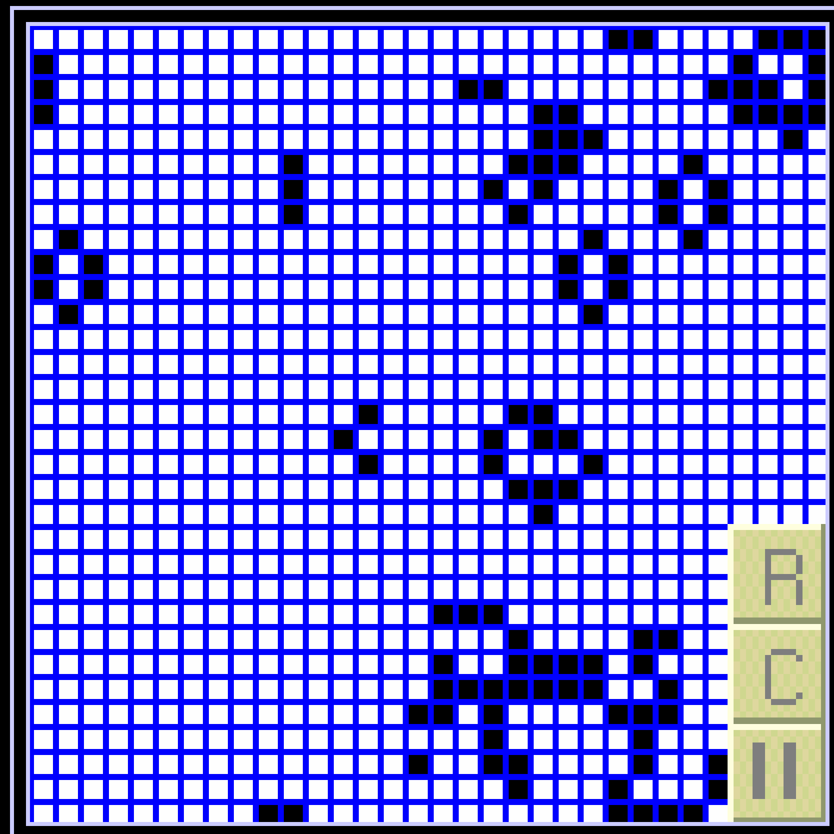

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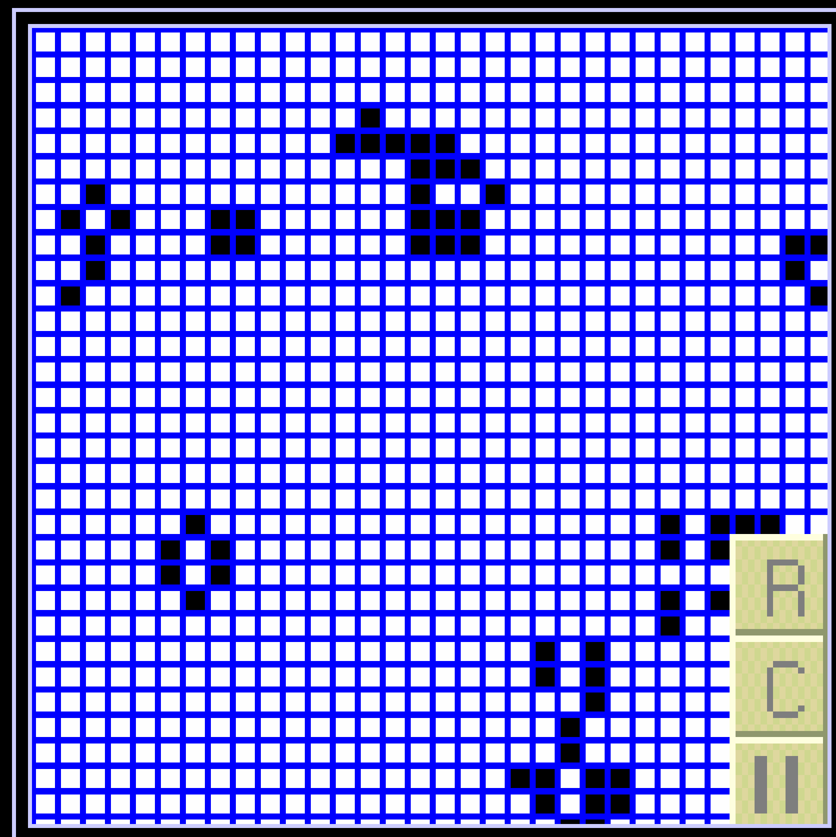

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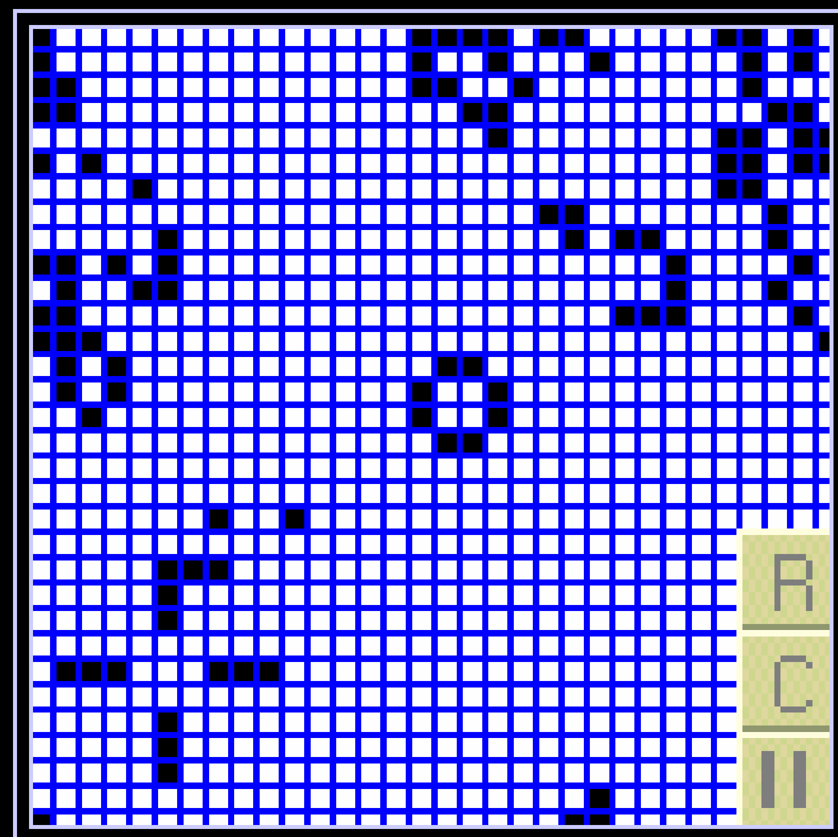

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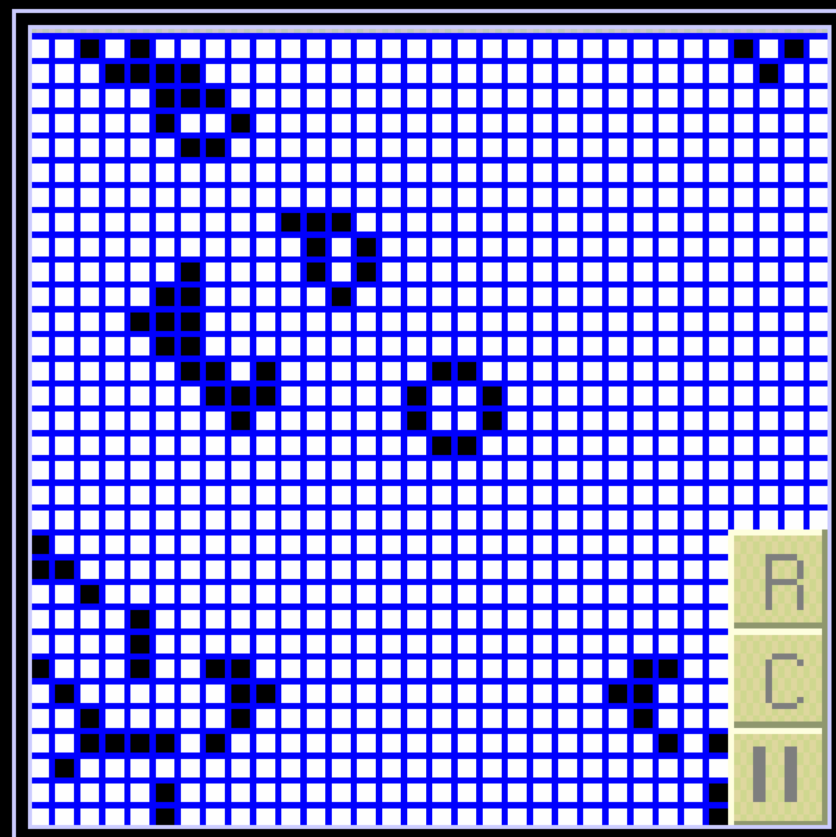

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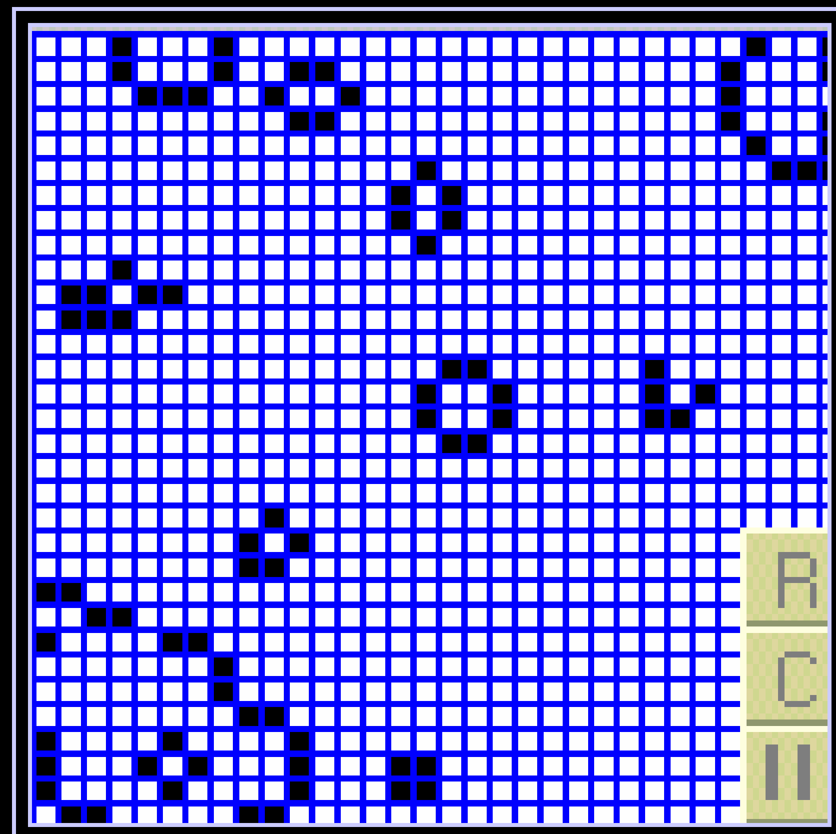

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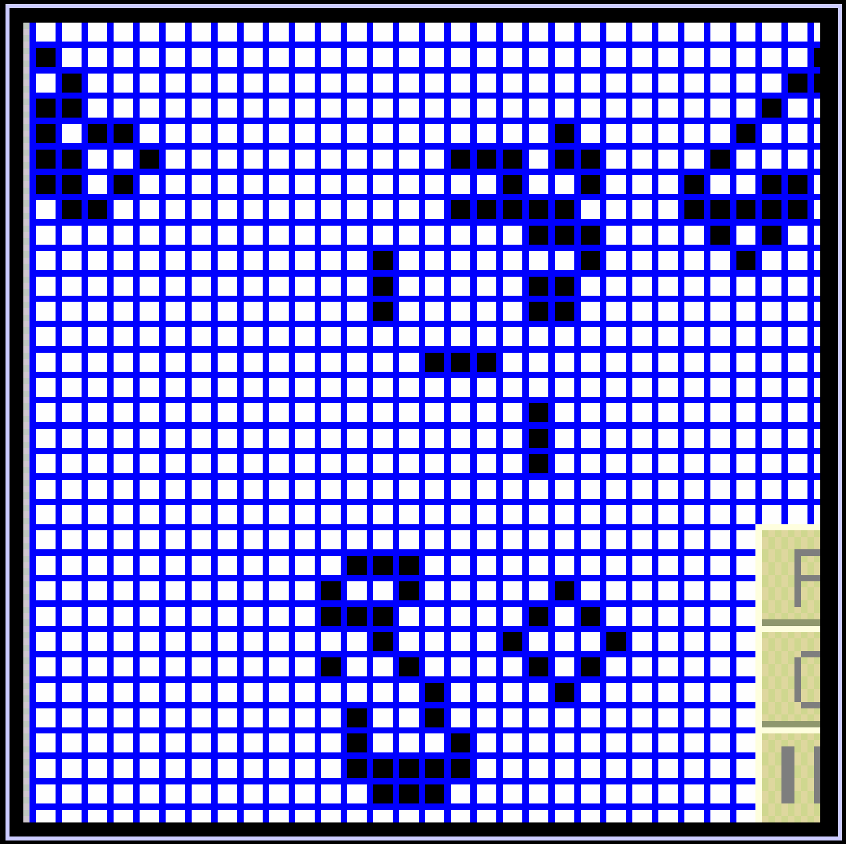

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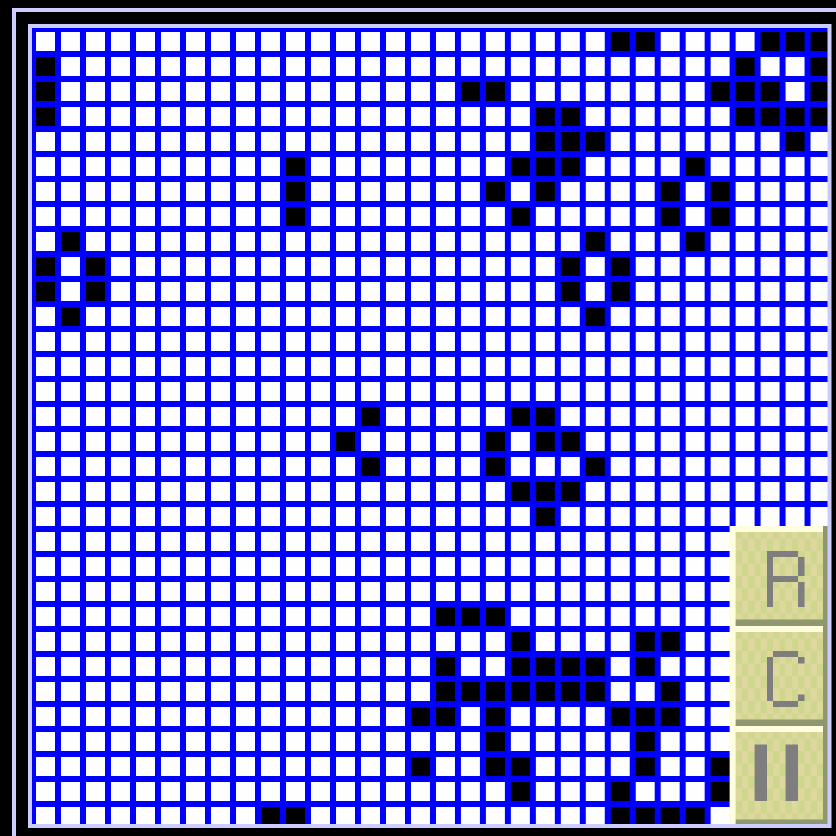

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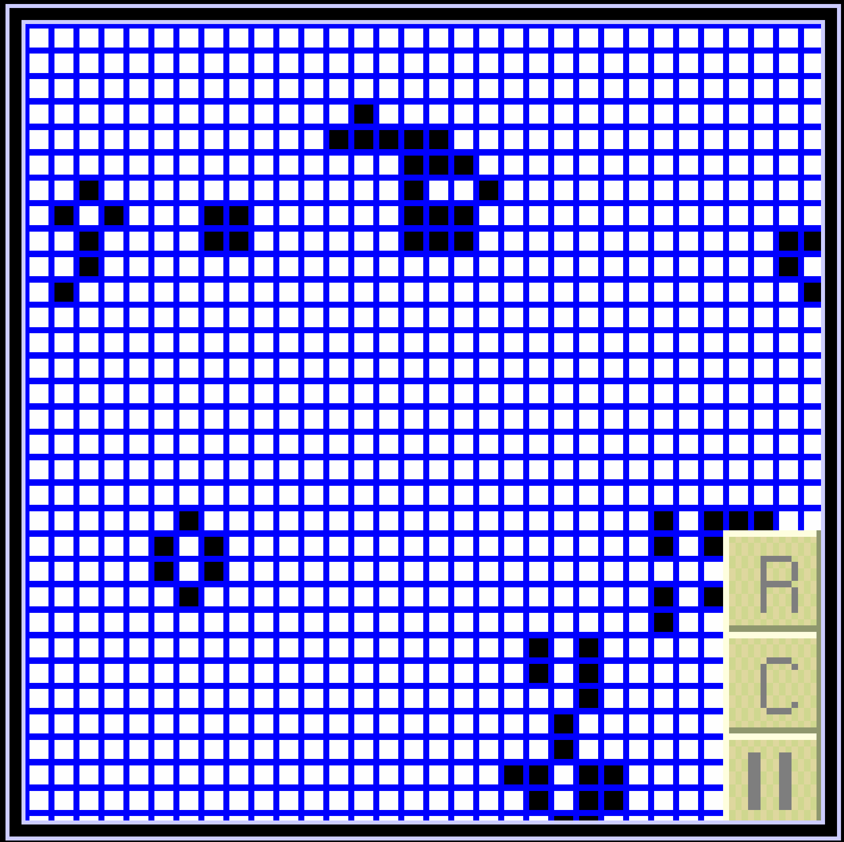

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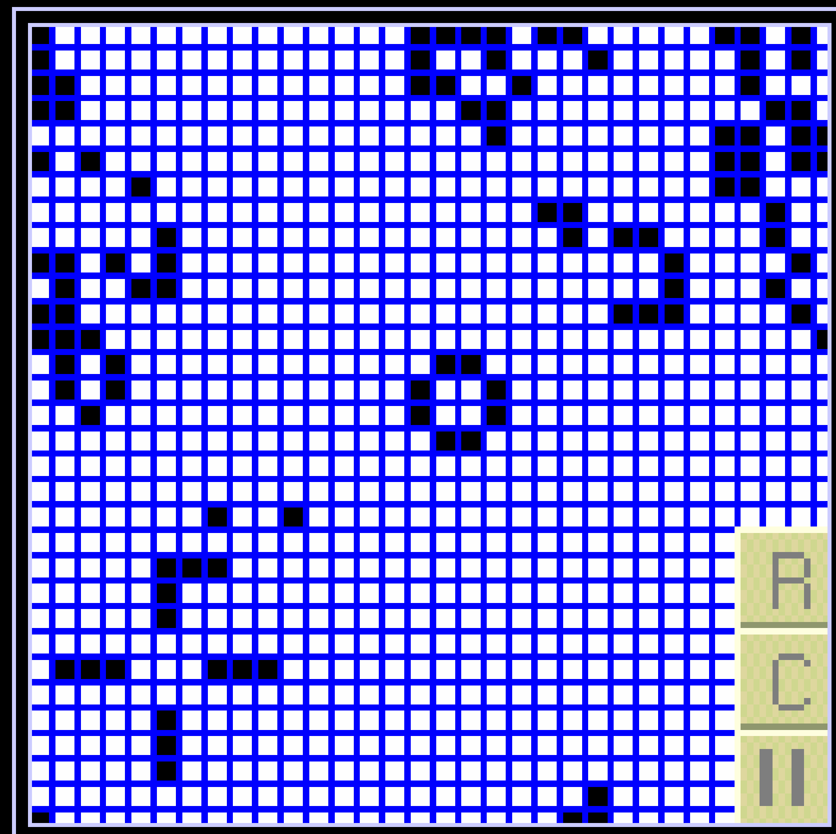

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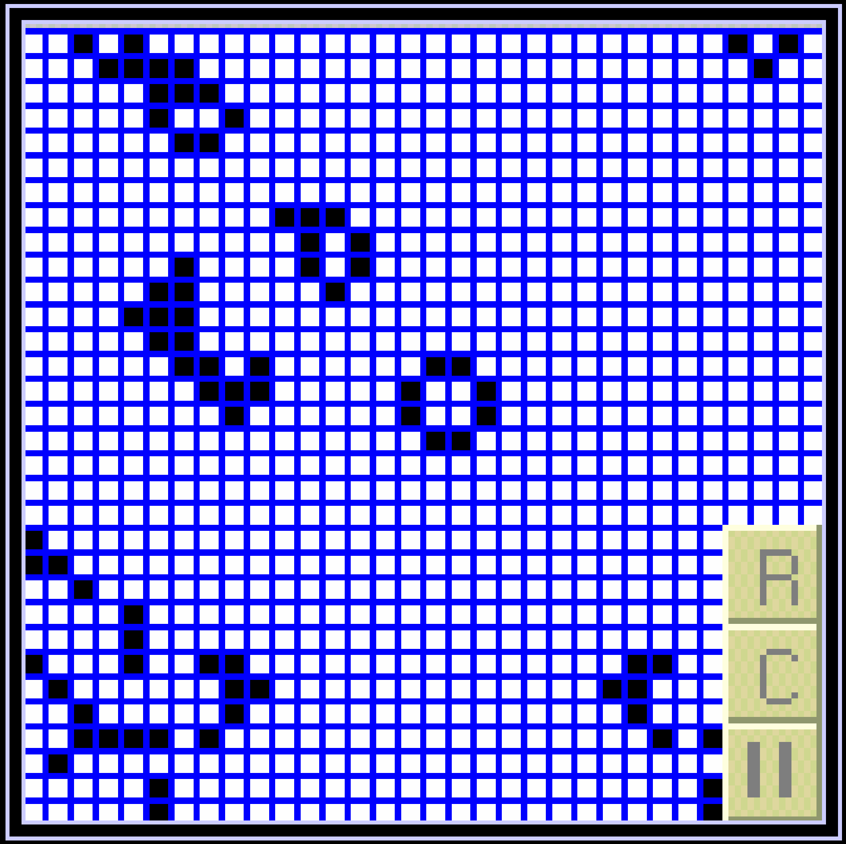

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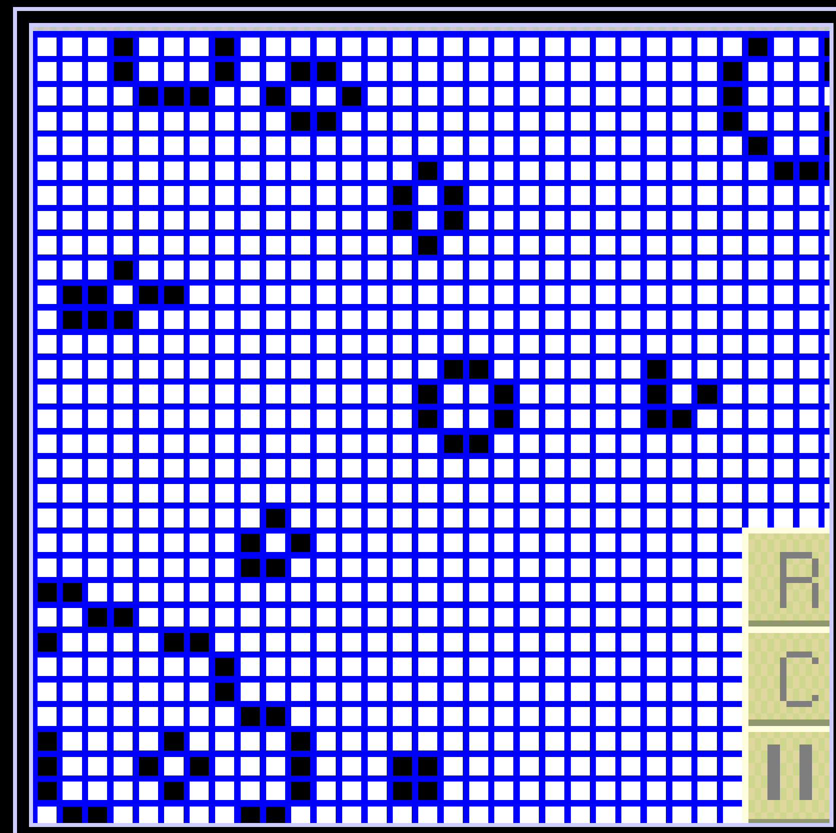

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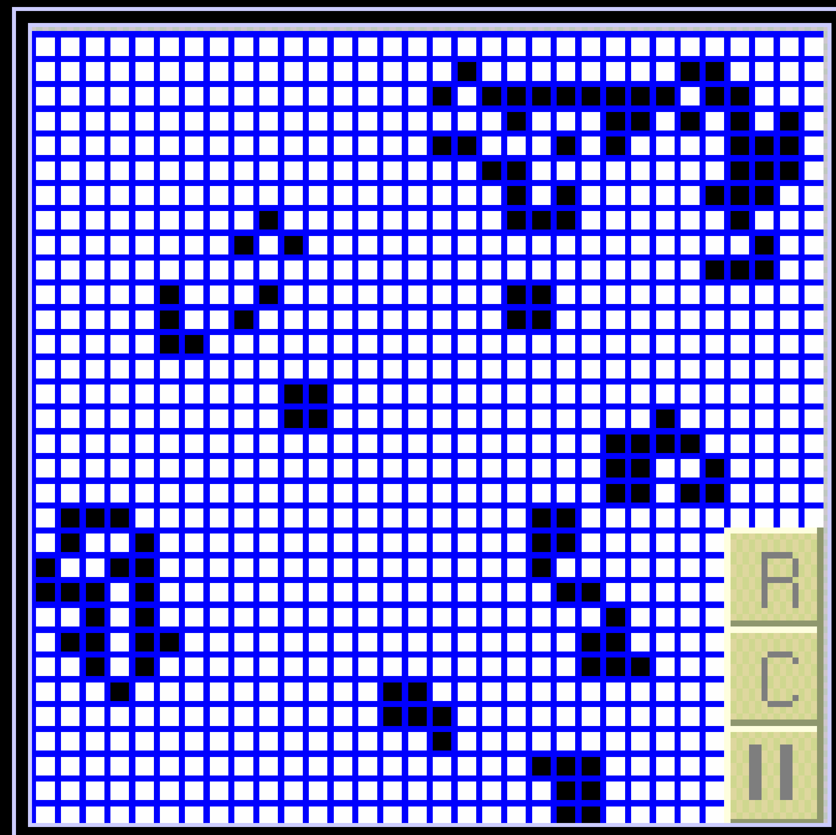

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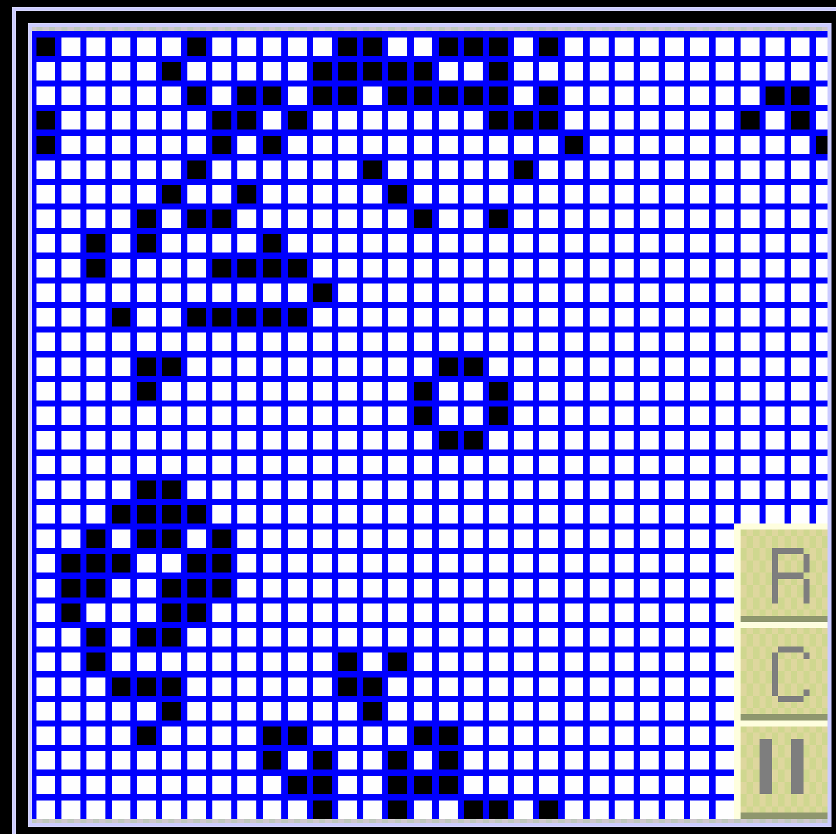

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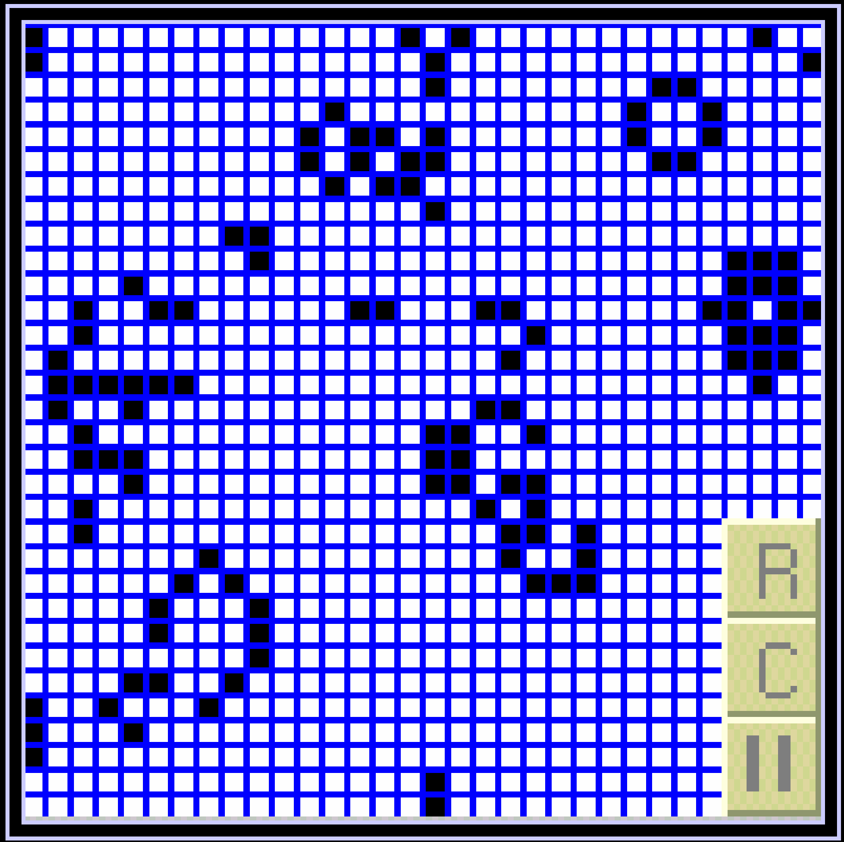

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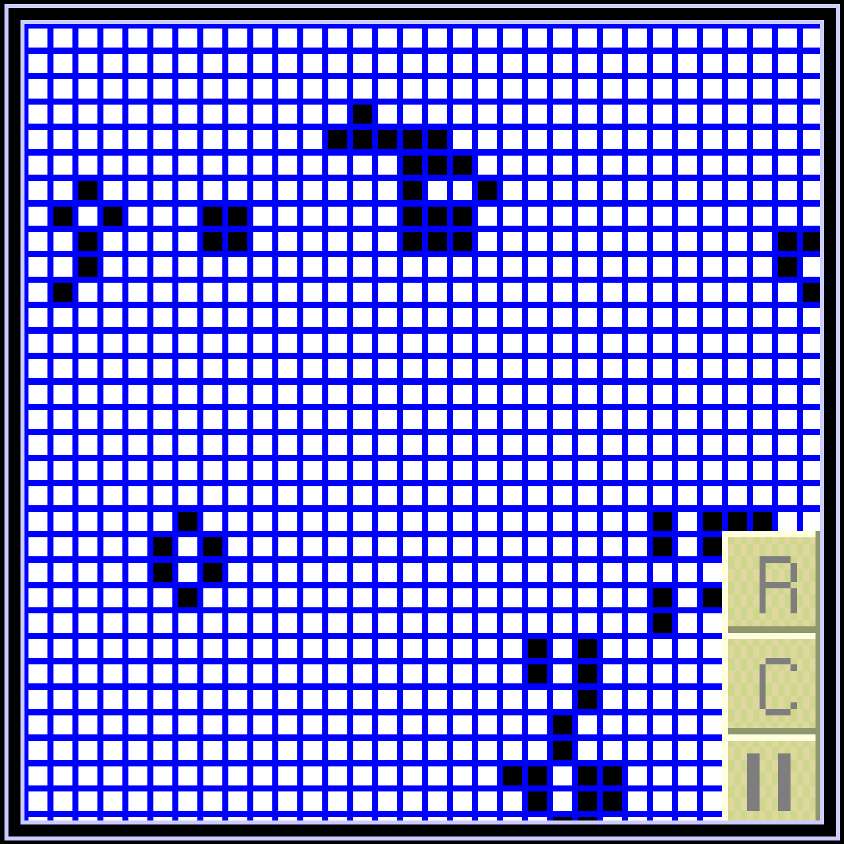

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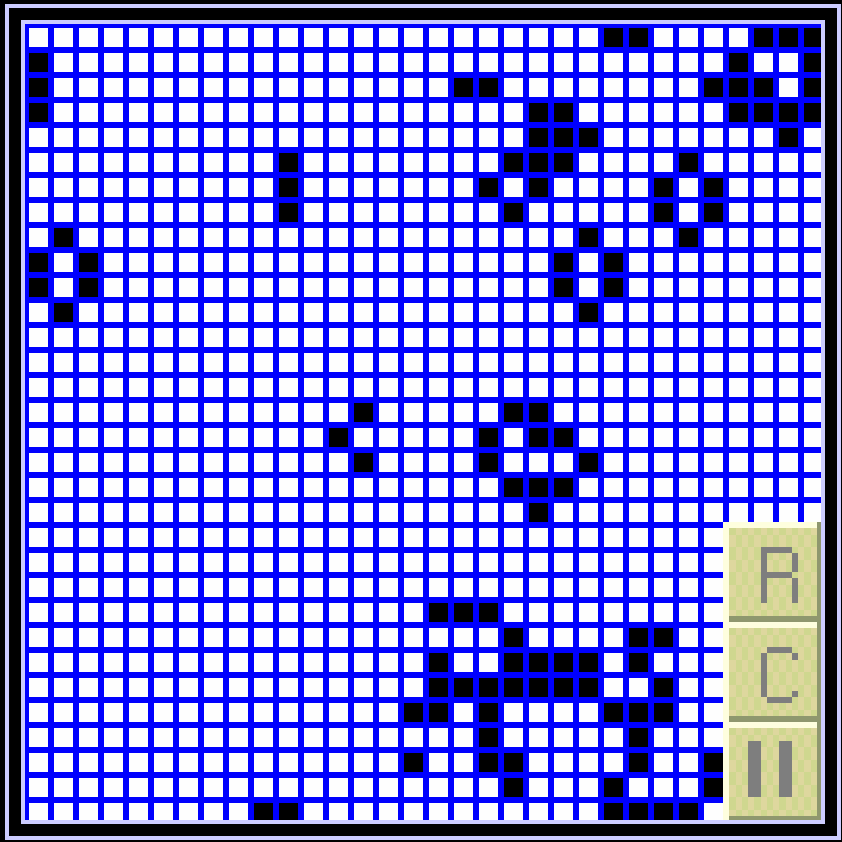

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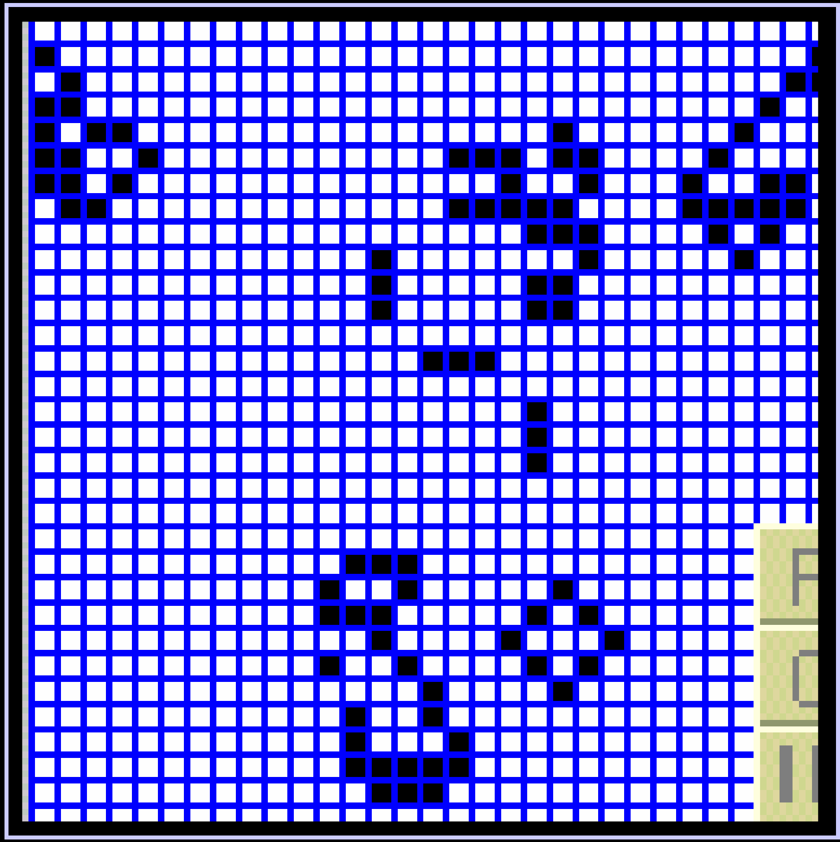

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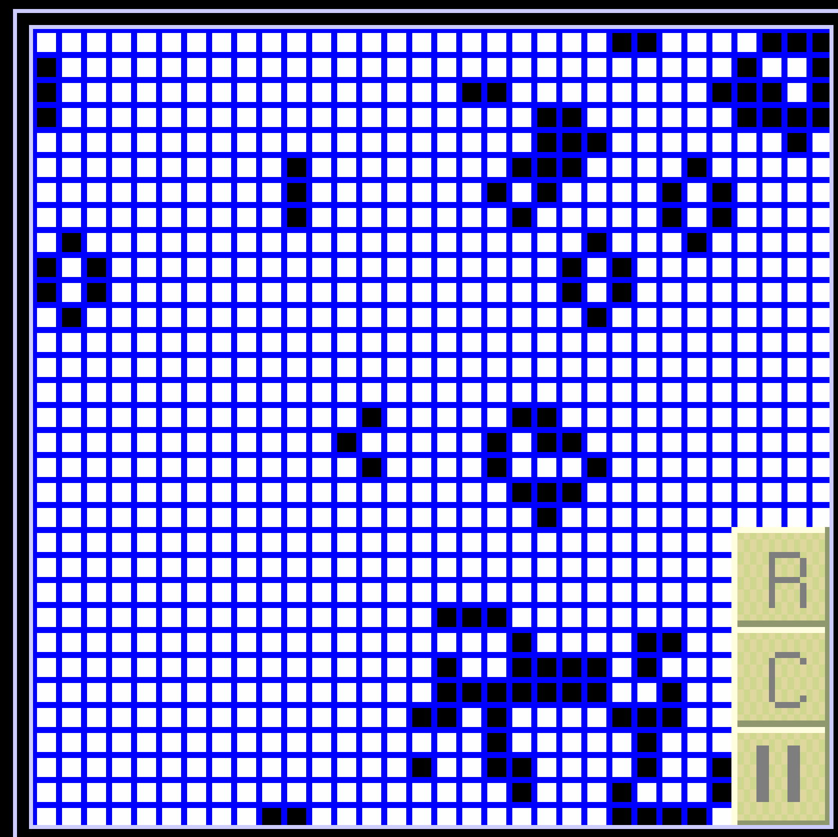

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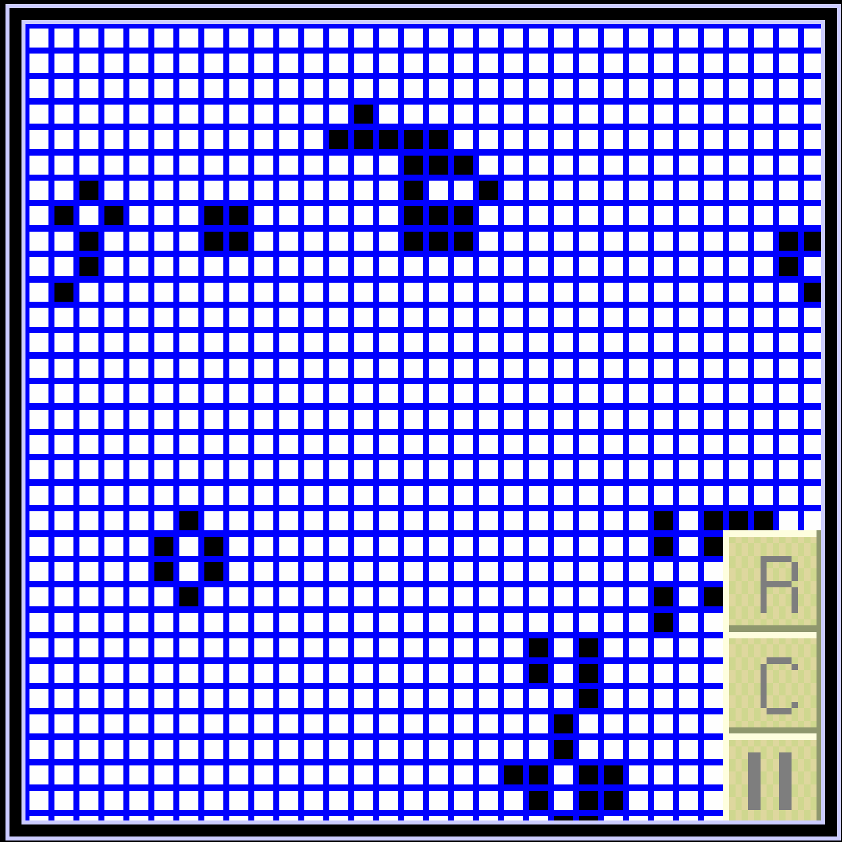

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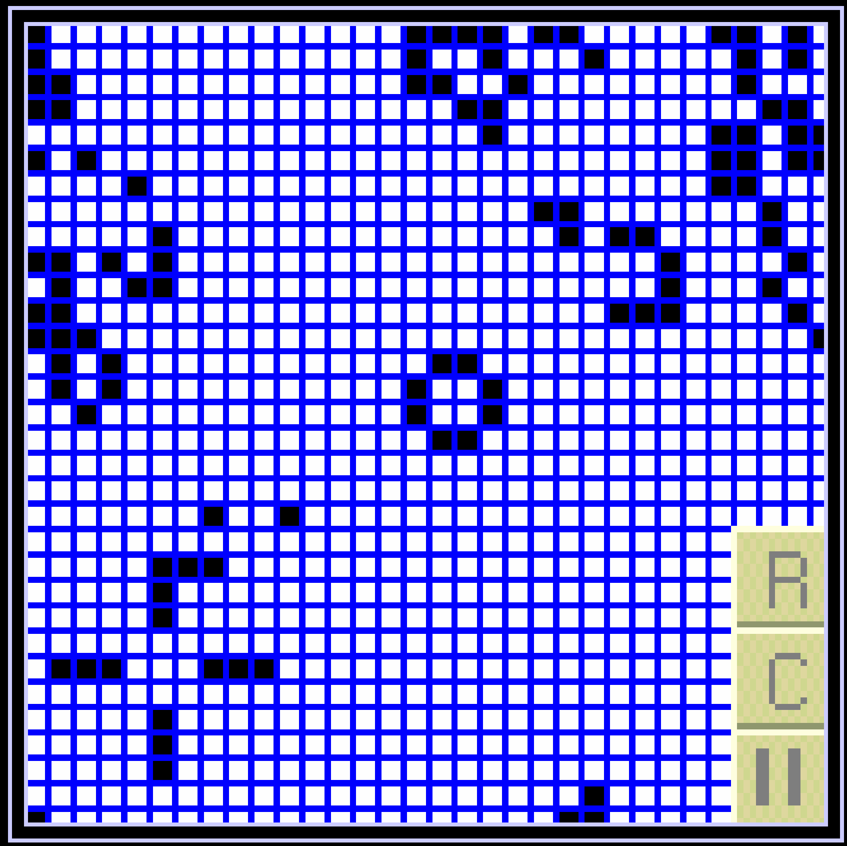

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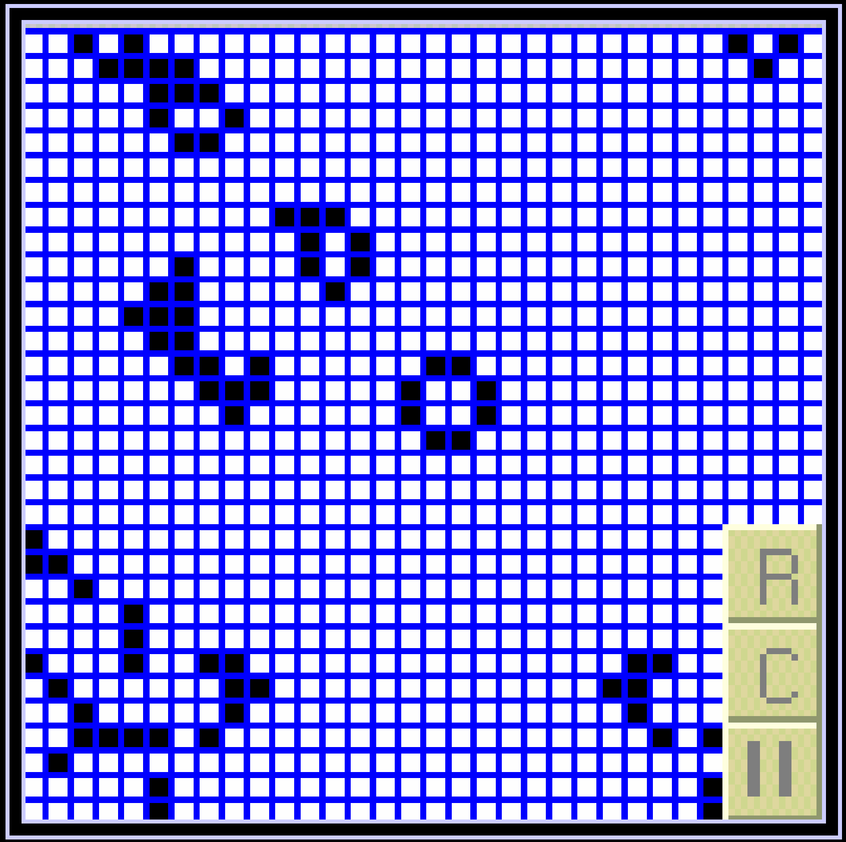

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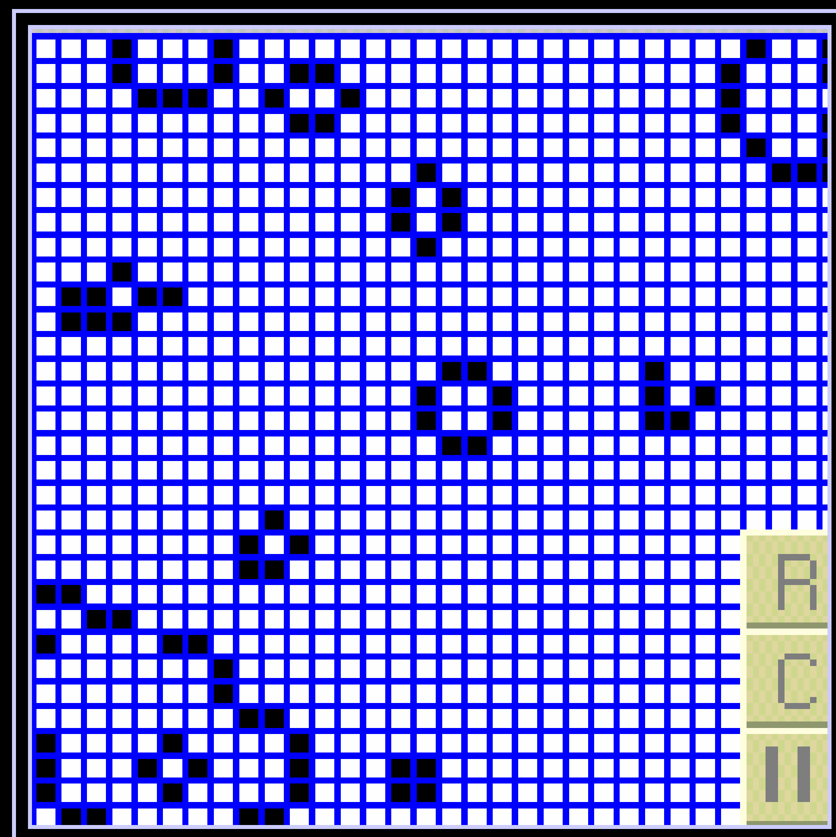

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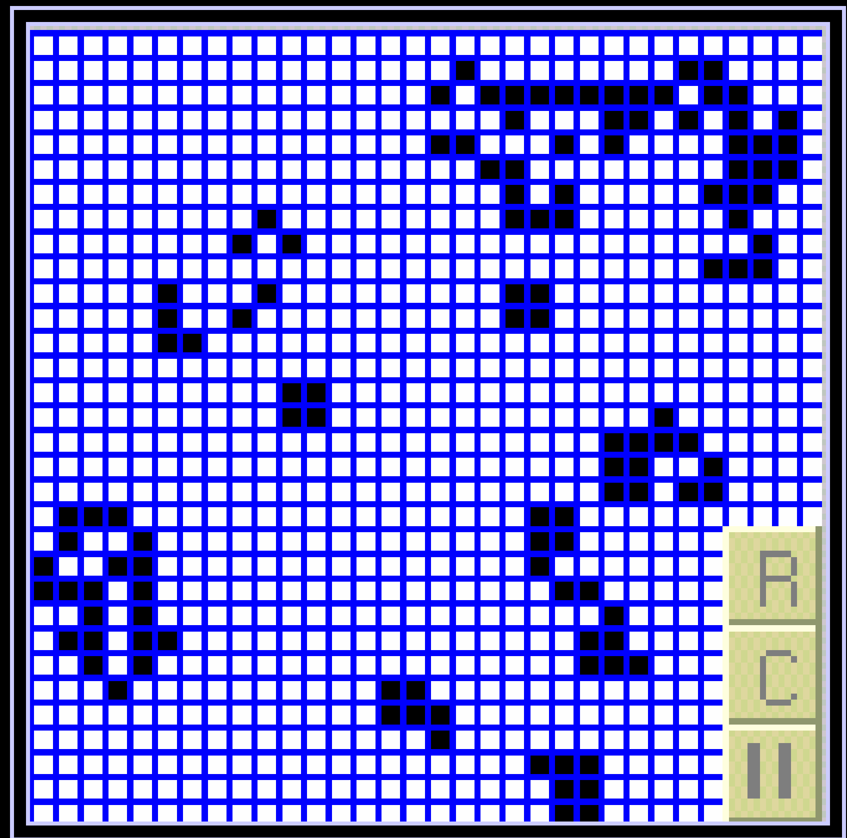

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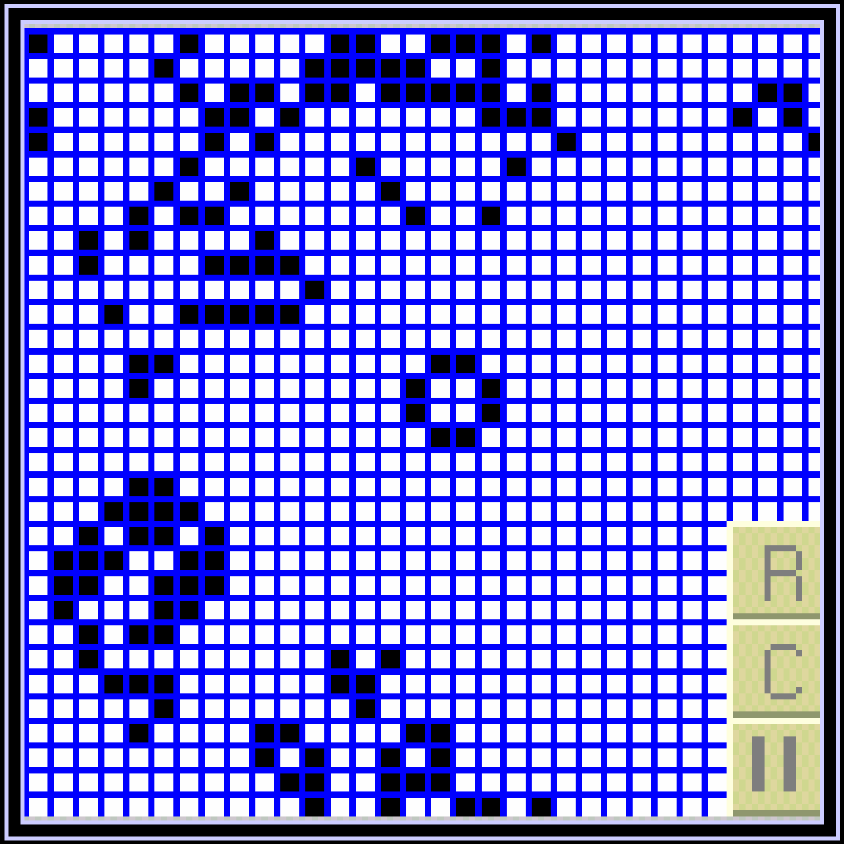

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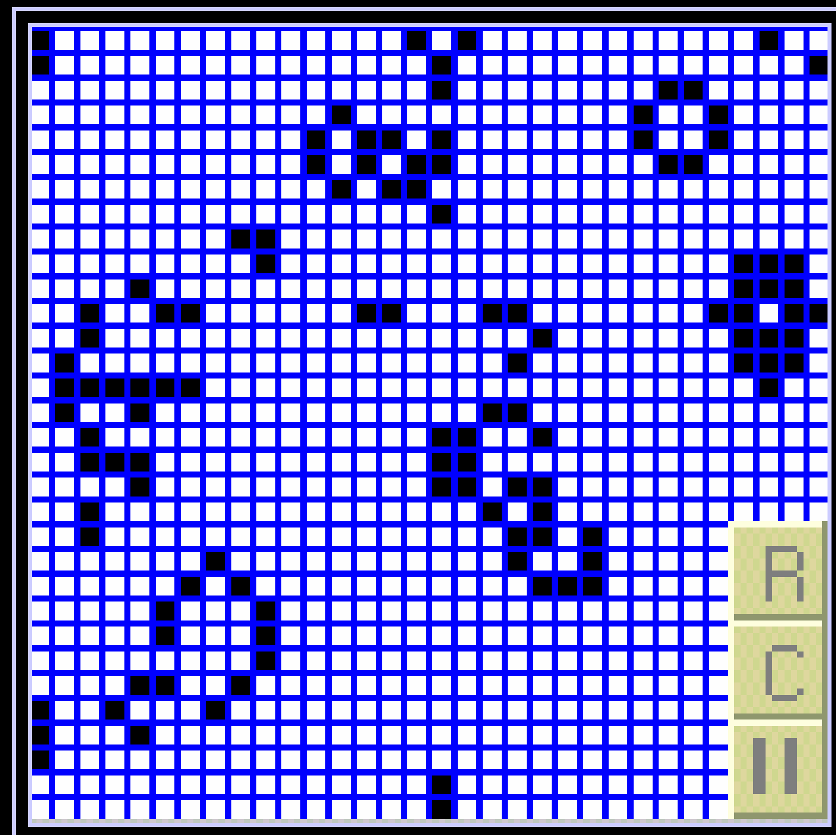

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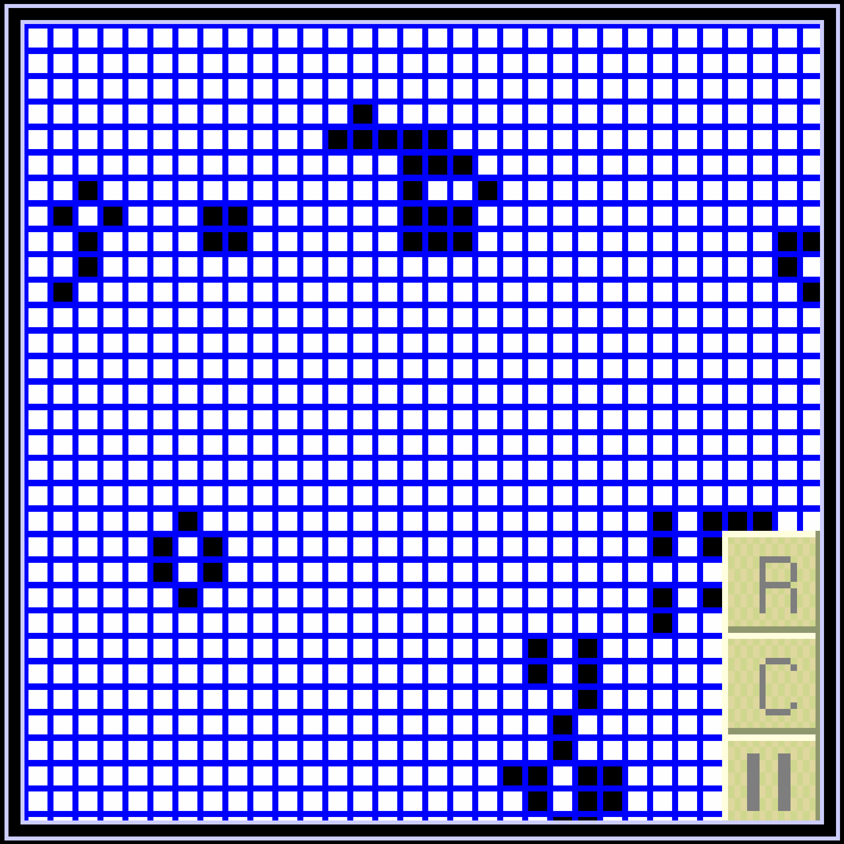

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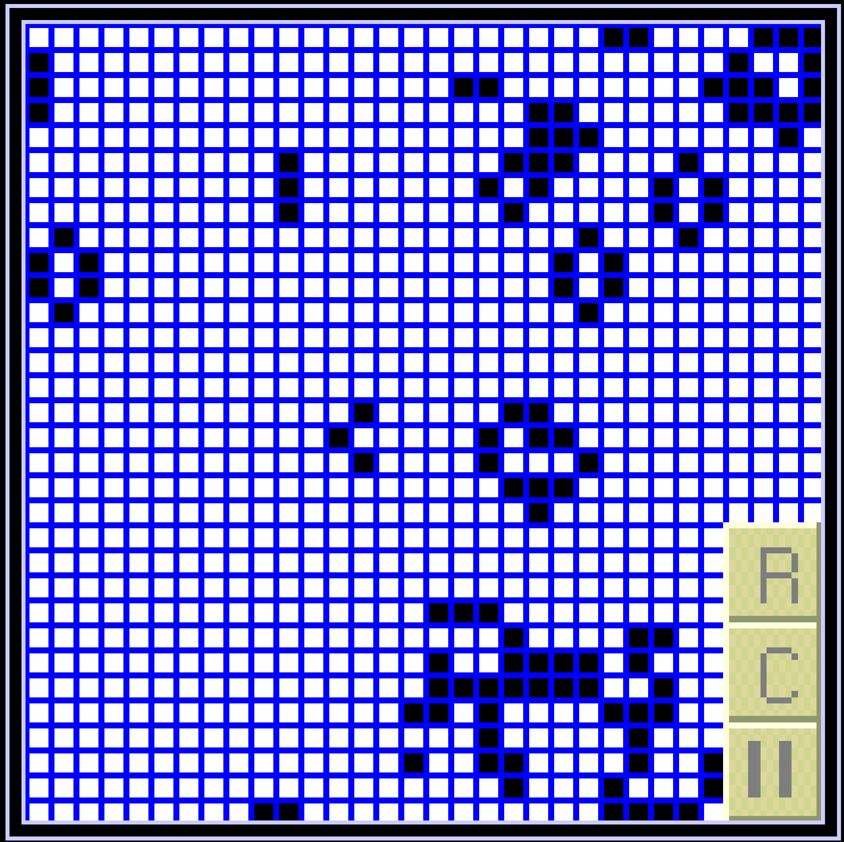

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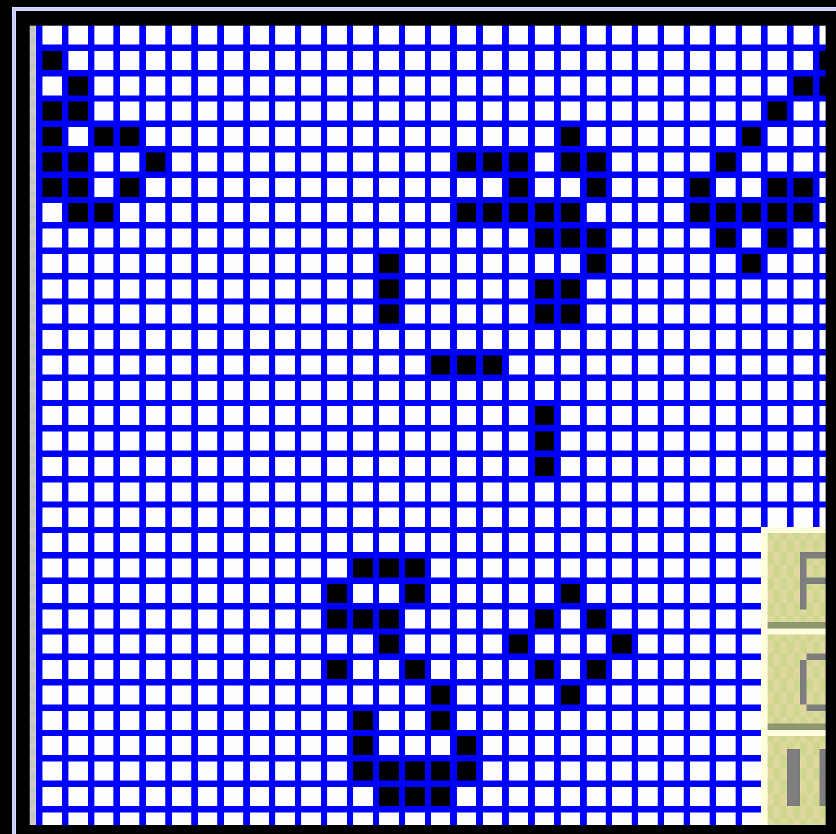

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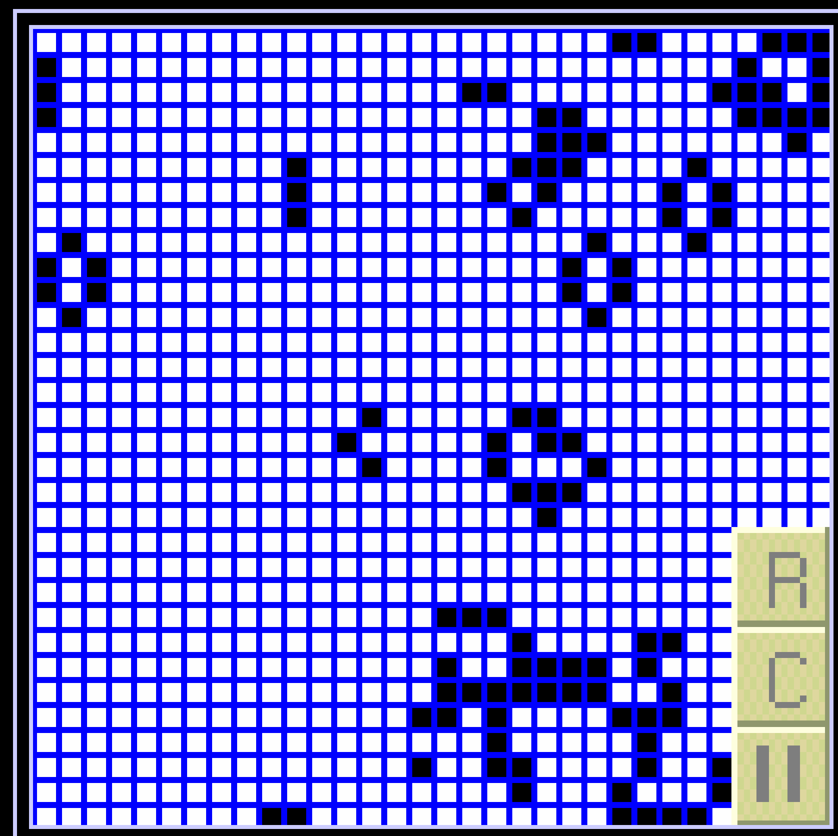

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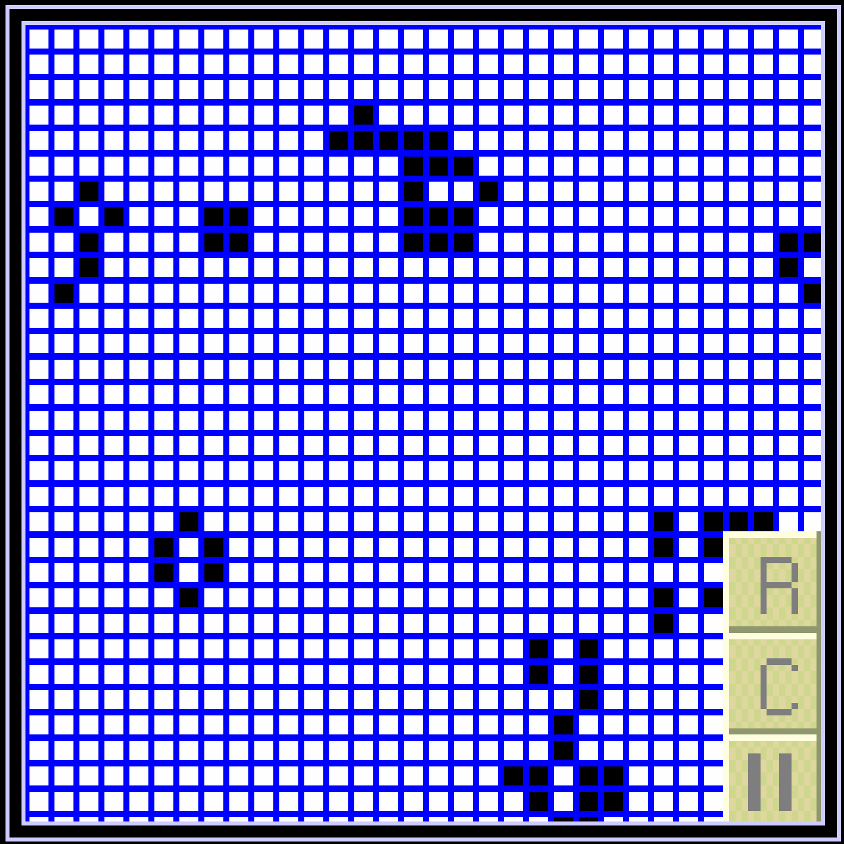

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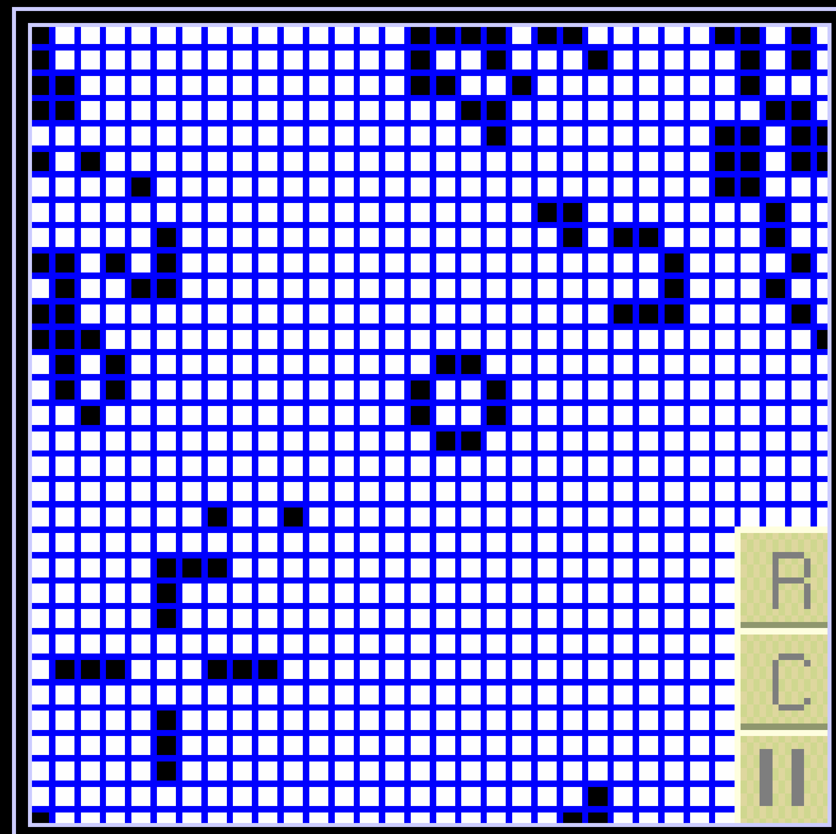

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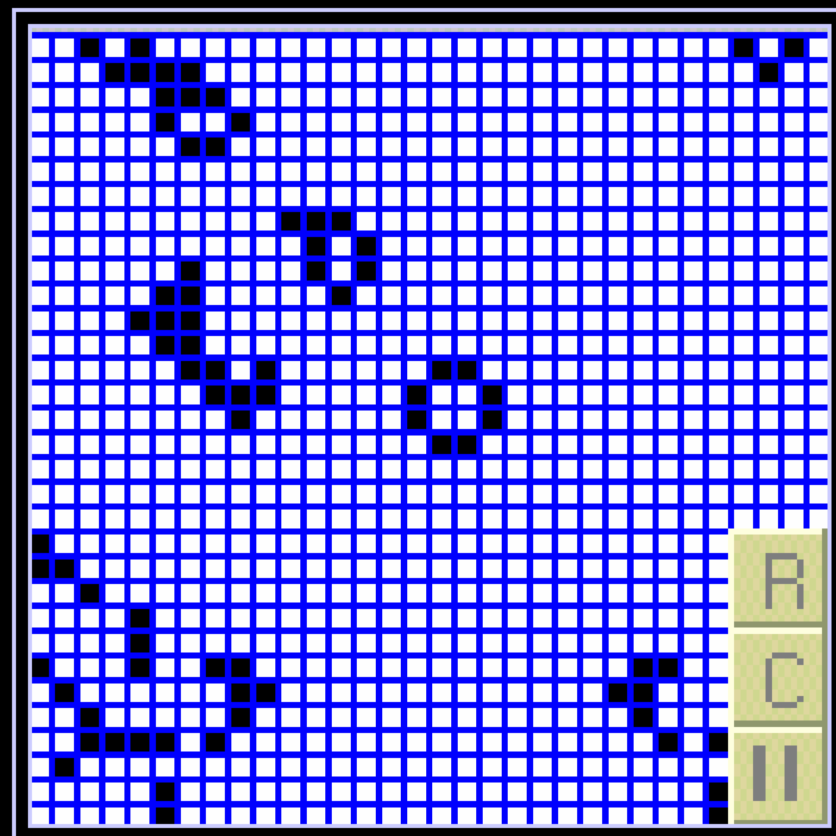

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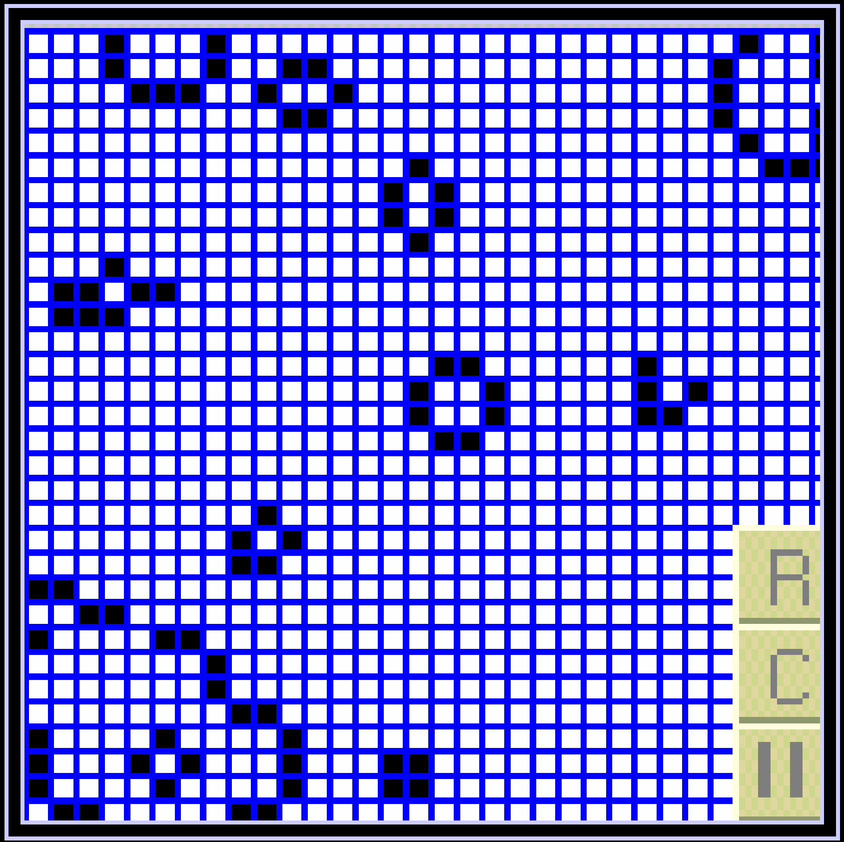

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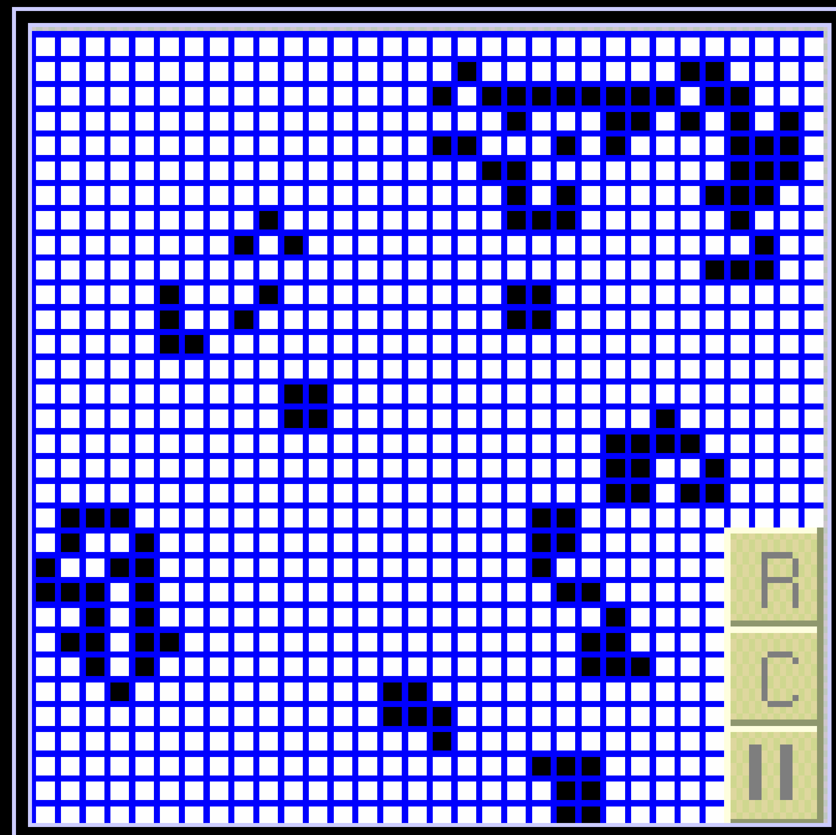

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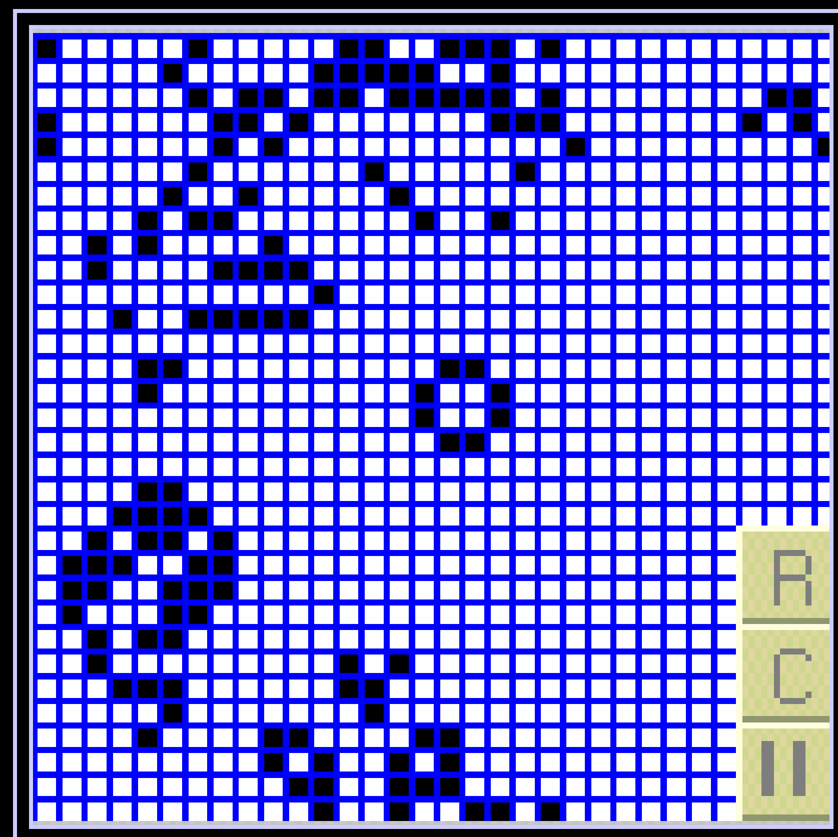

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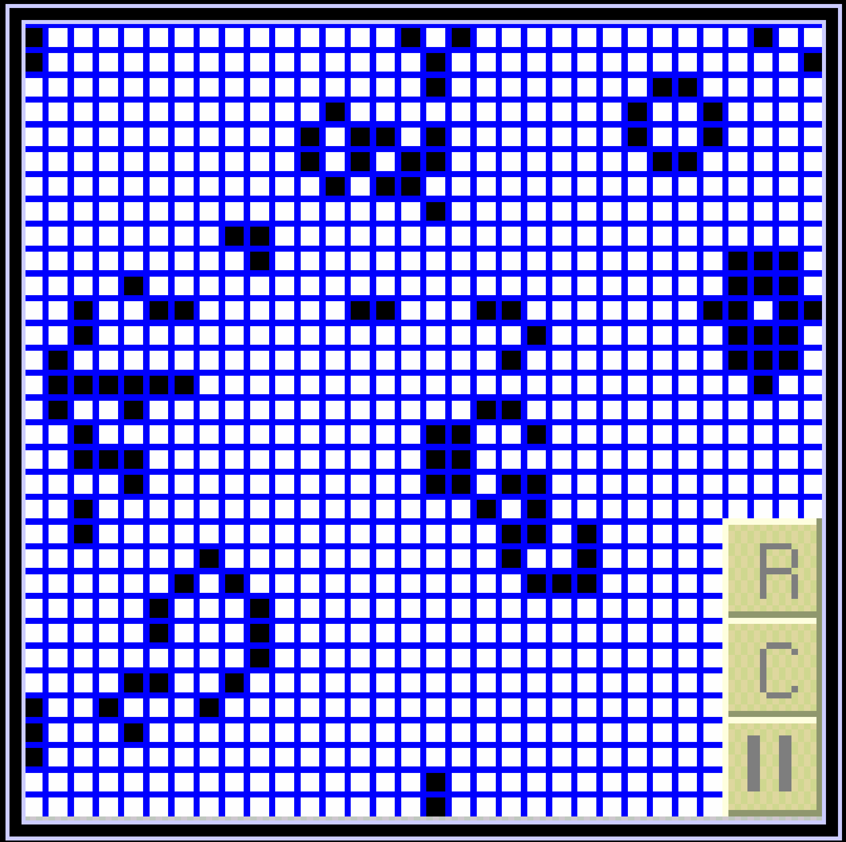

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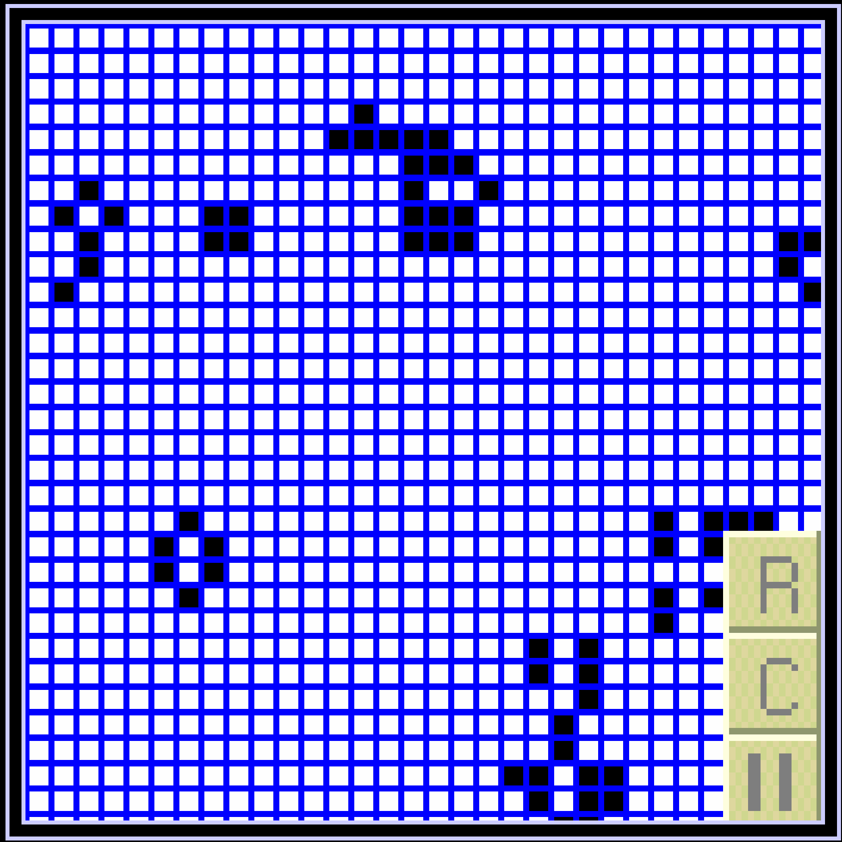

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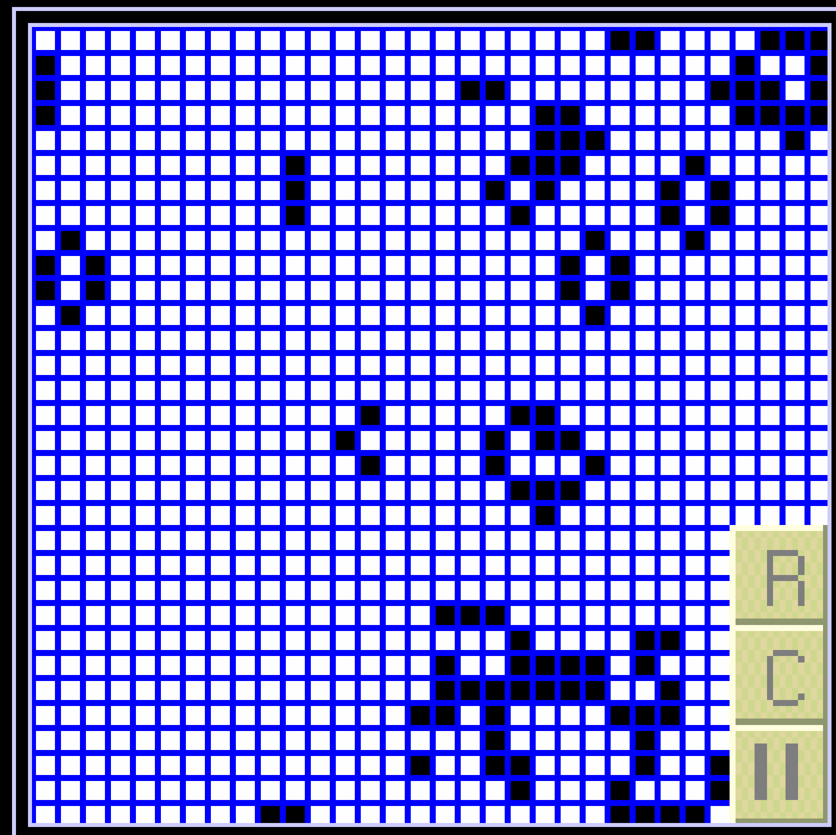

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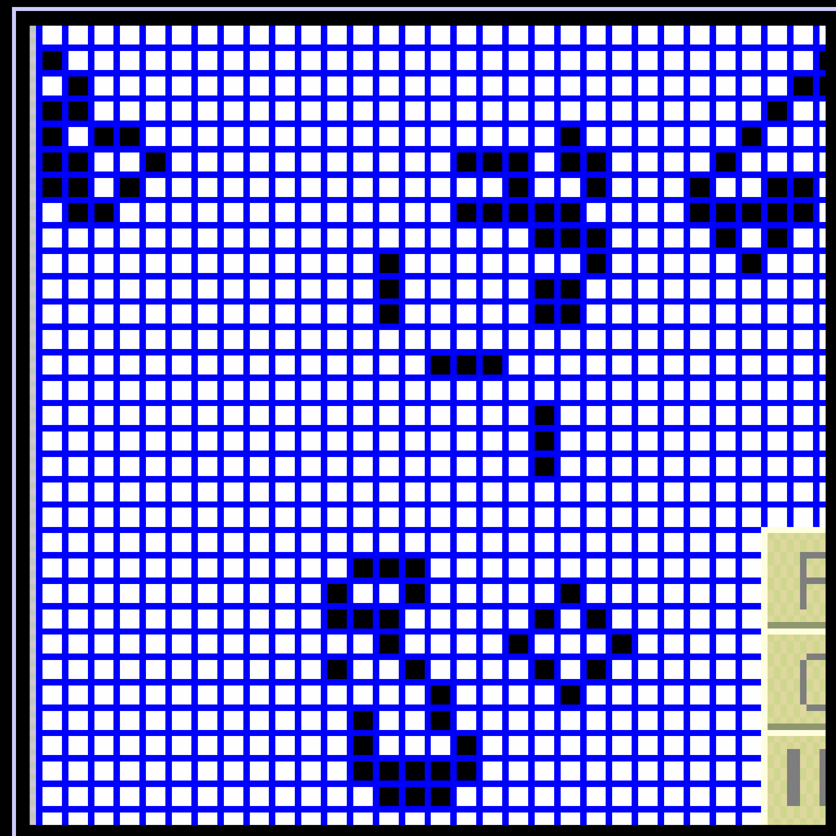

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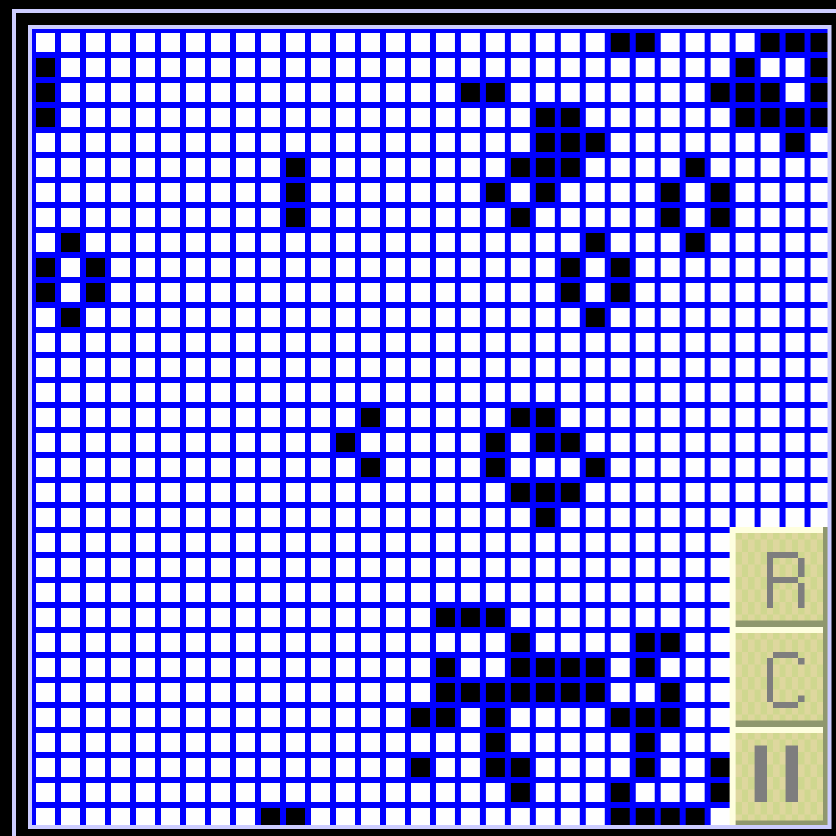

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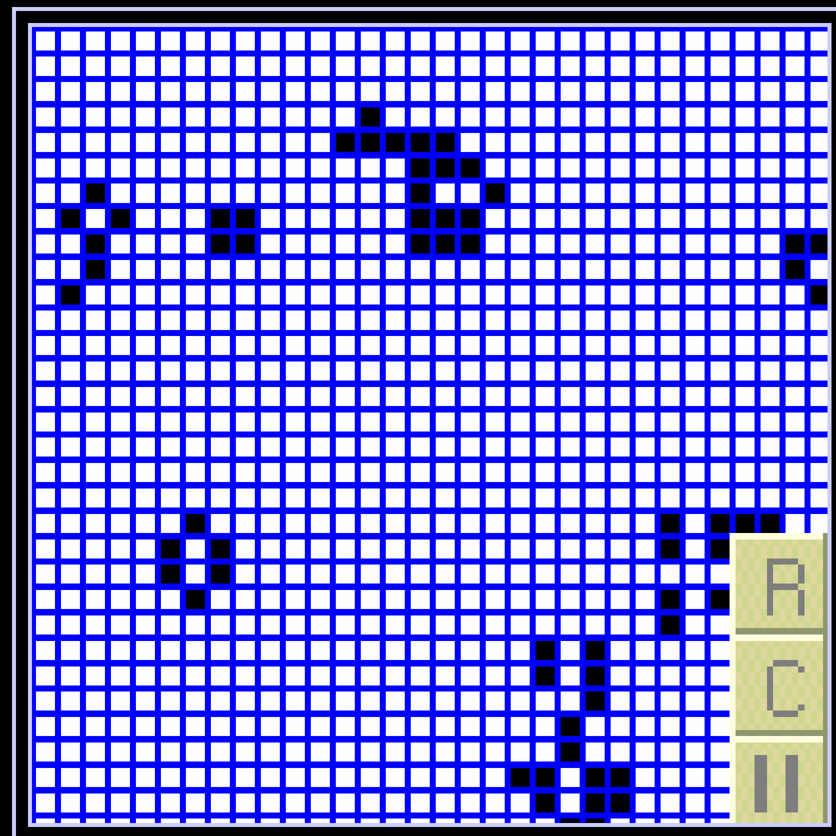

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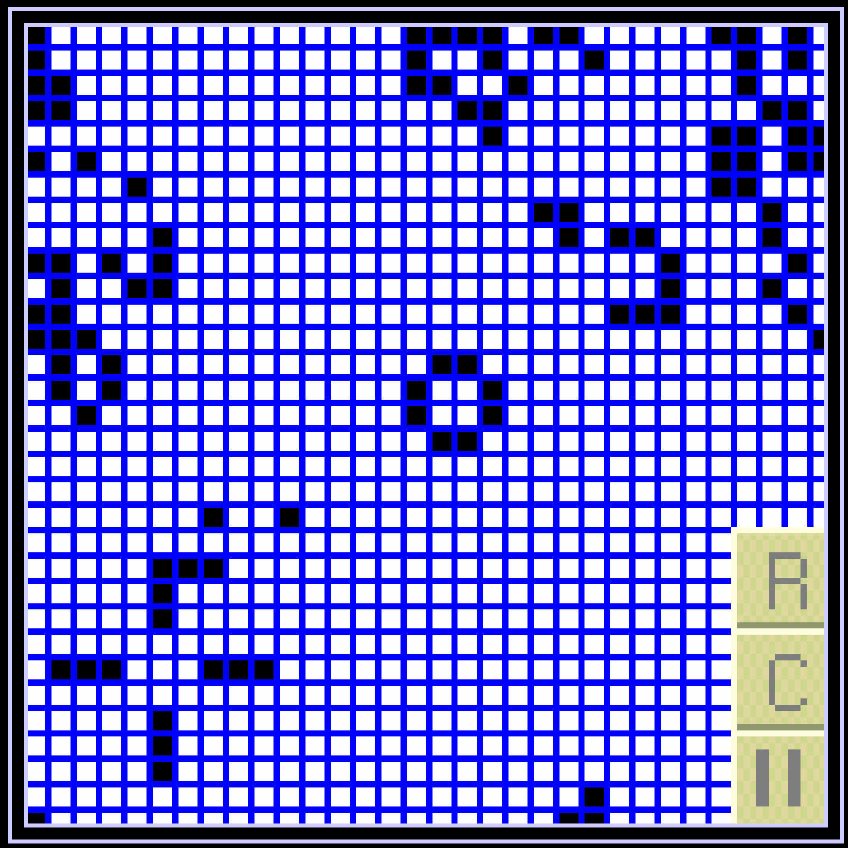

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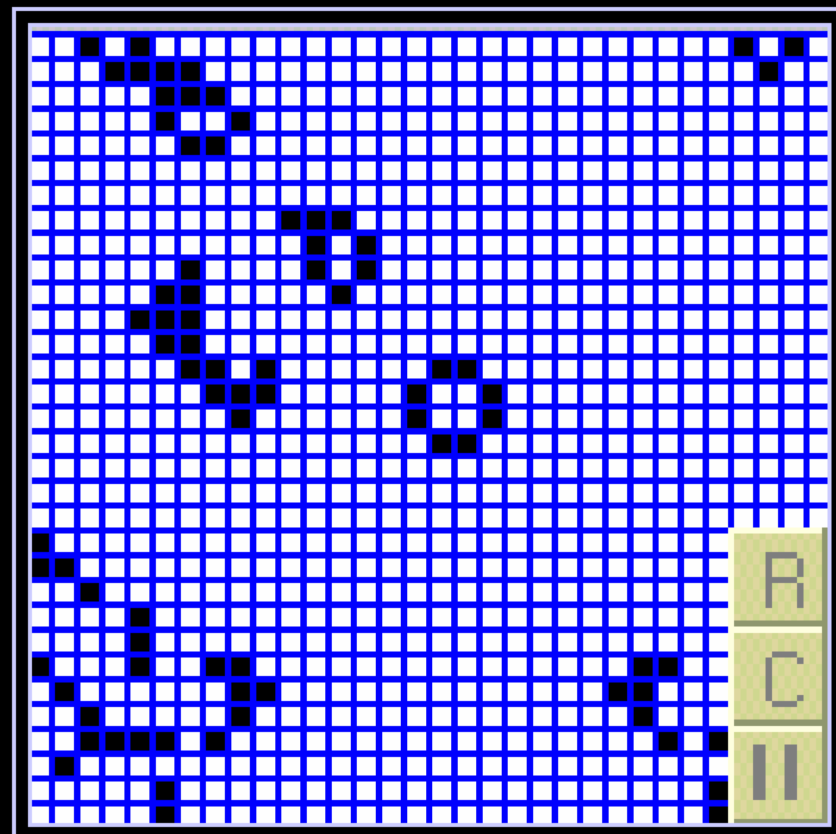

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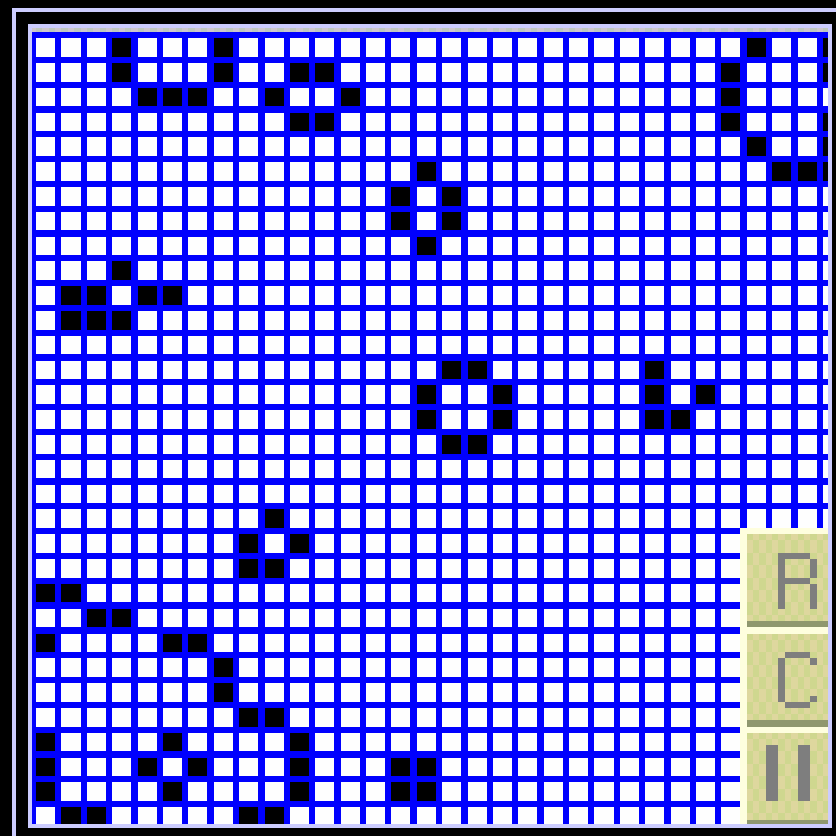

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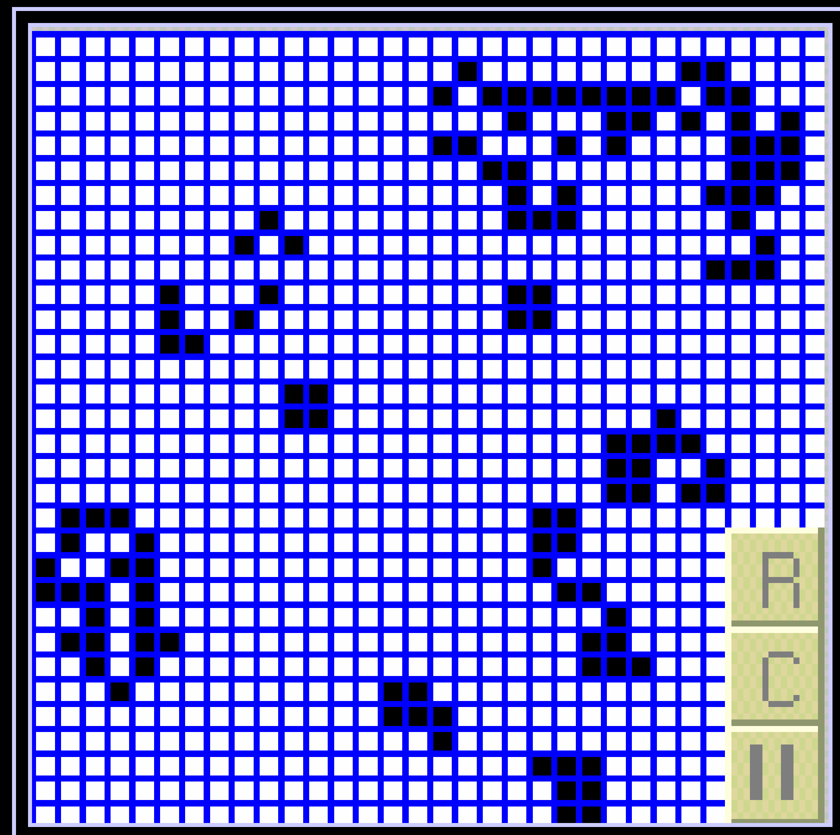

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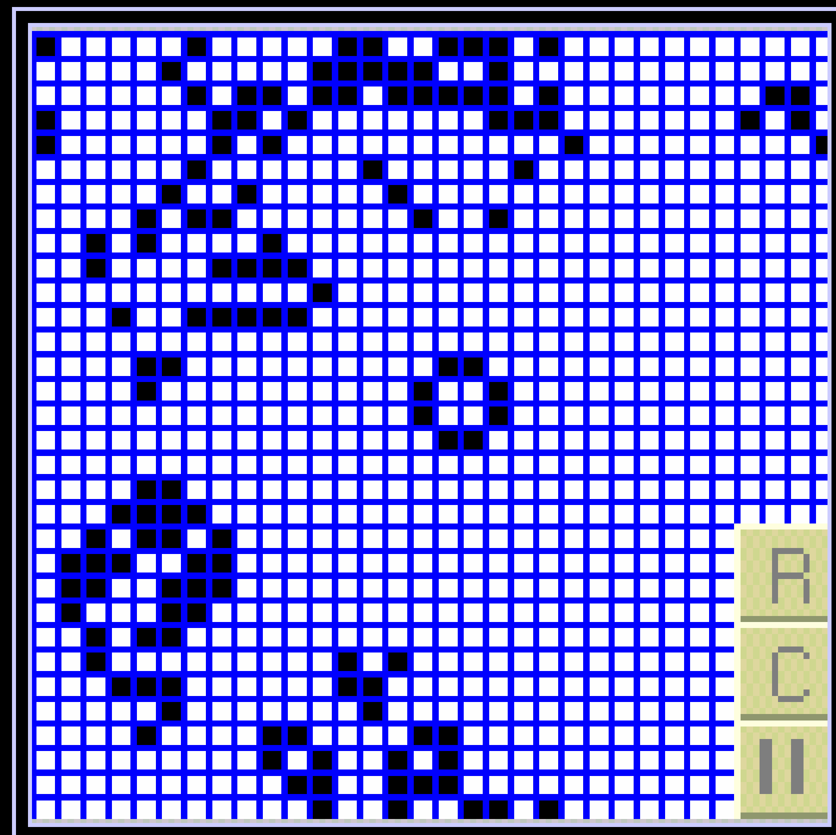

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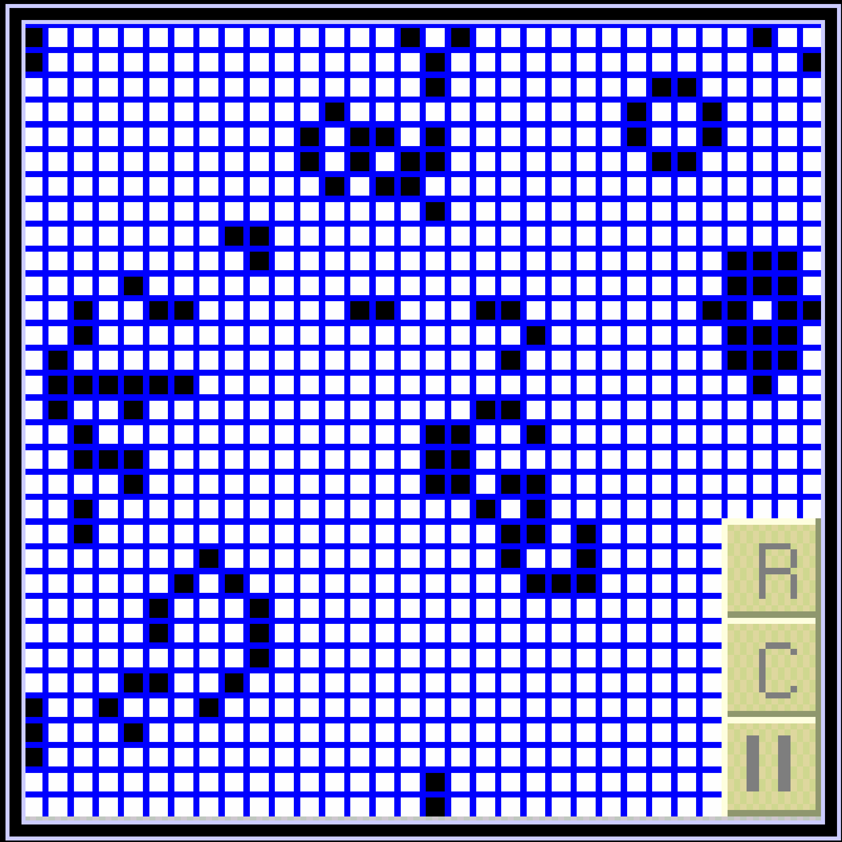

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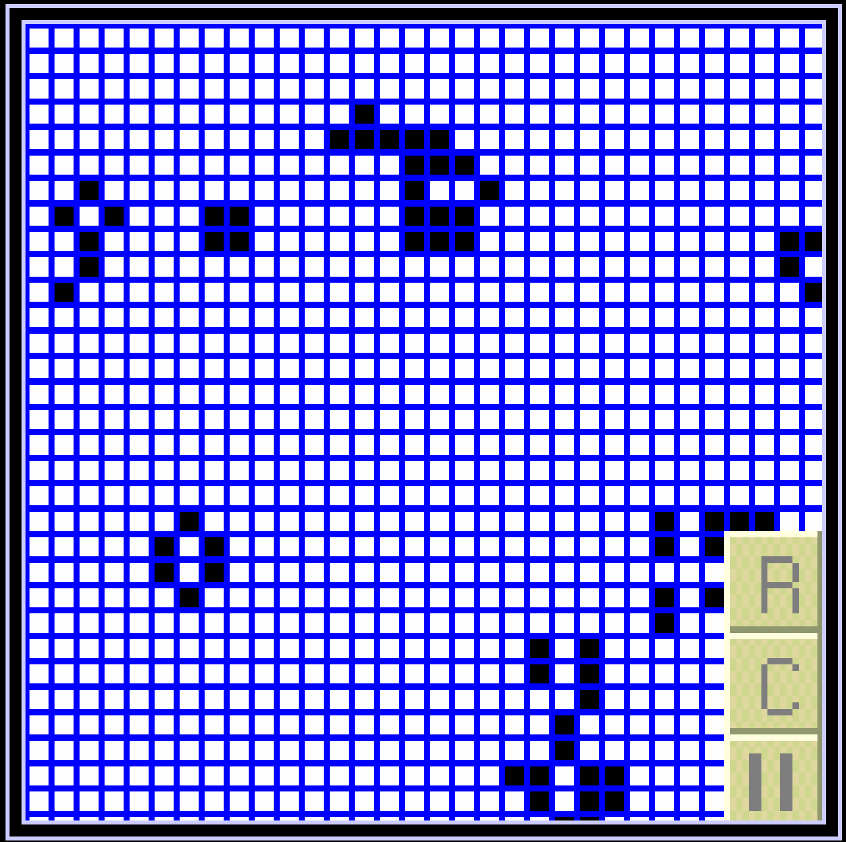

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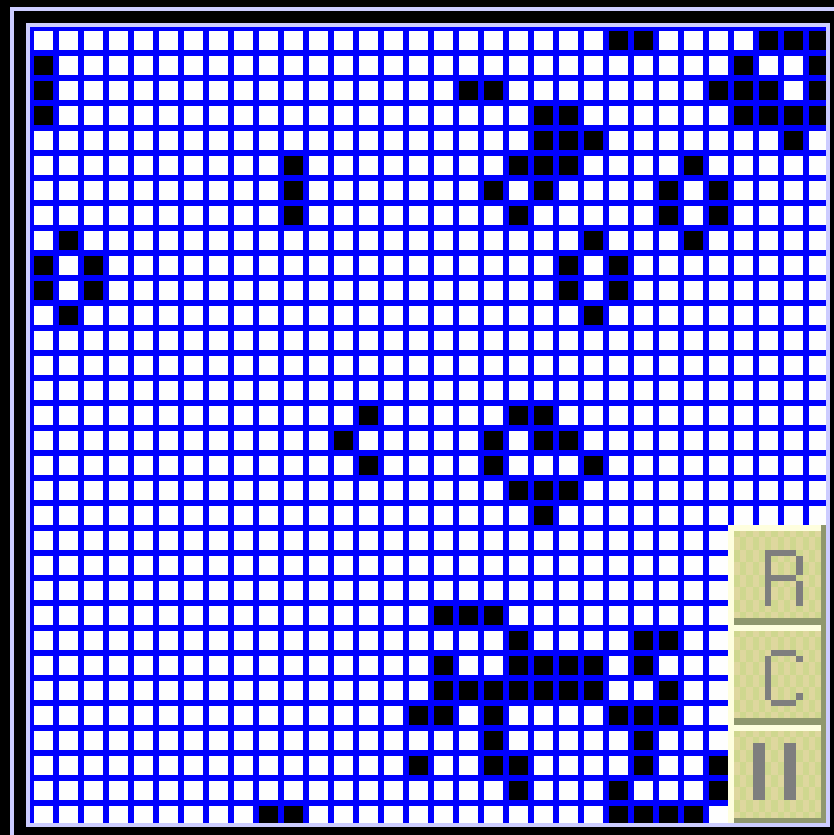

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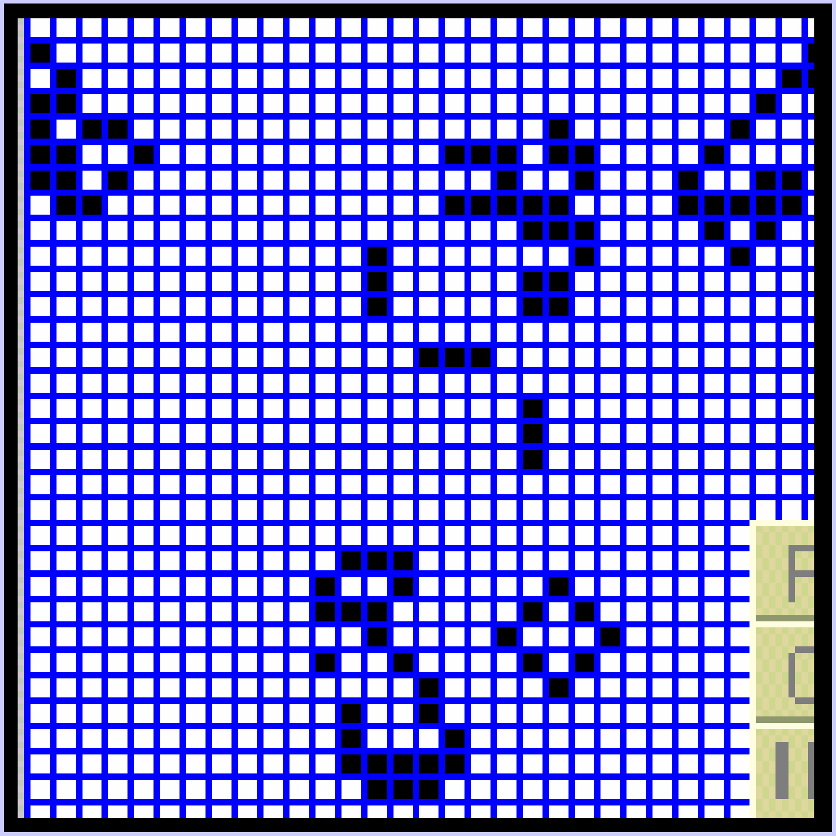
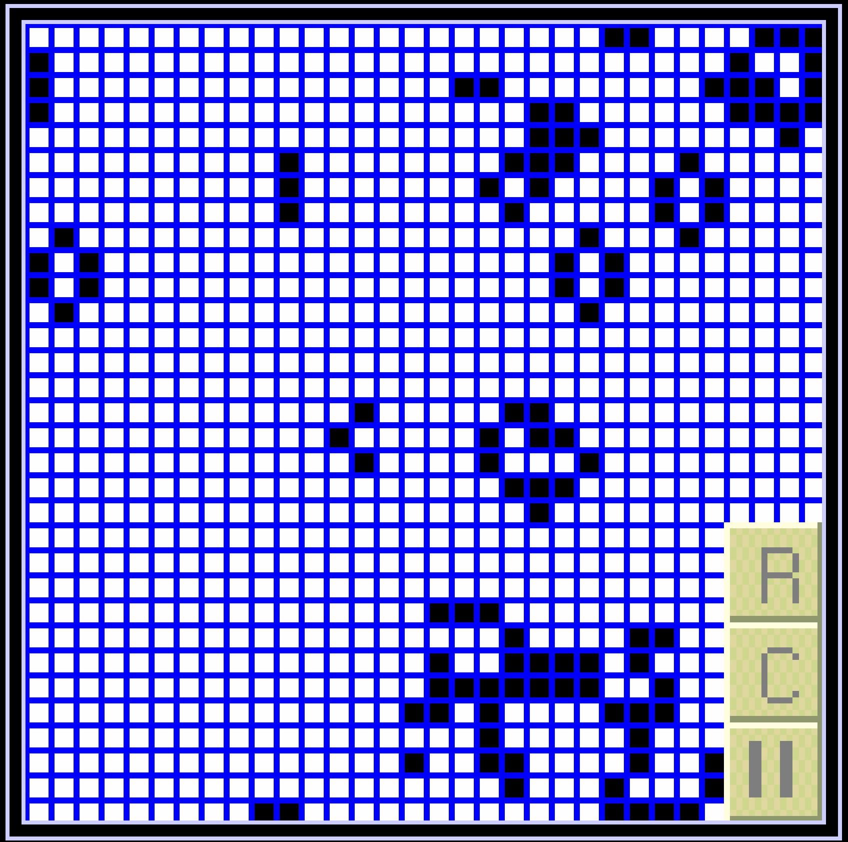
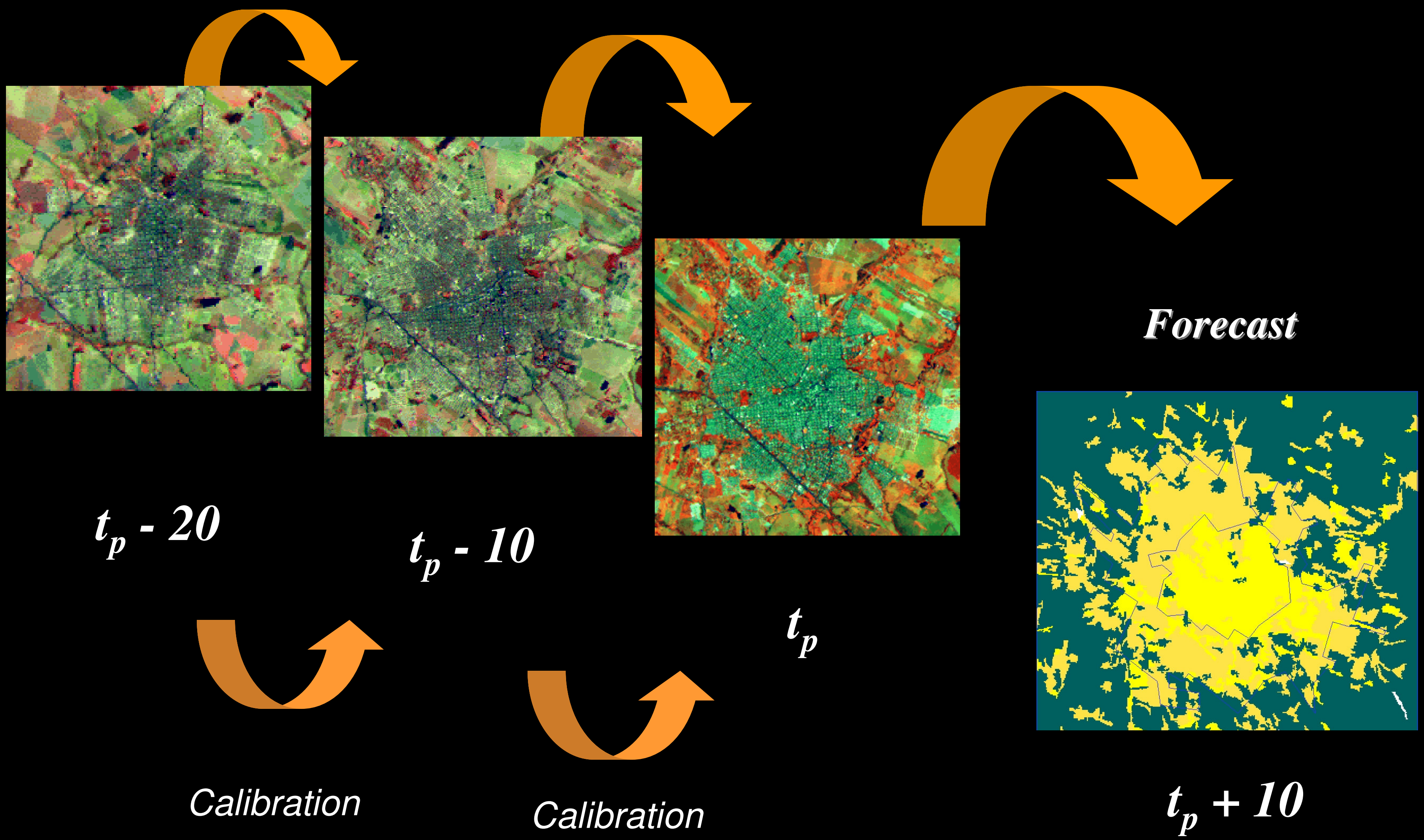


CELLULAR AUTOMATA - CA

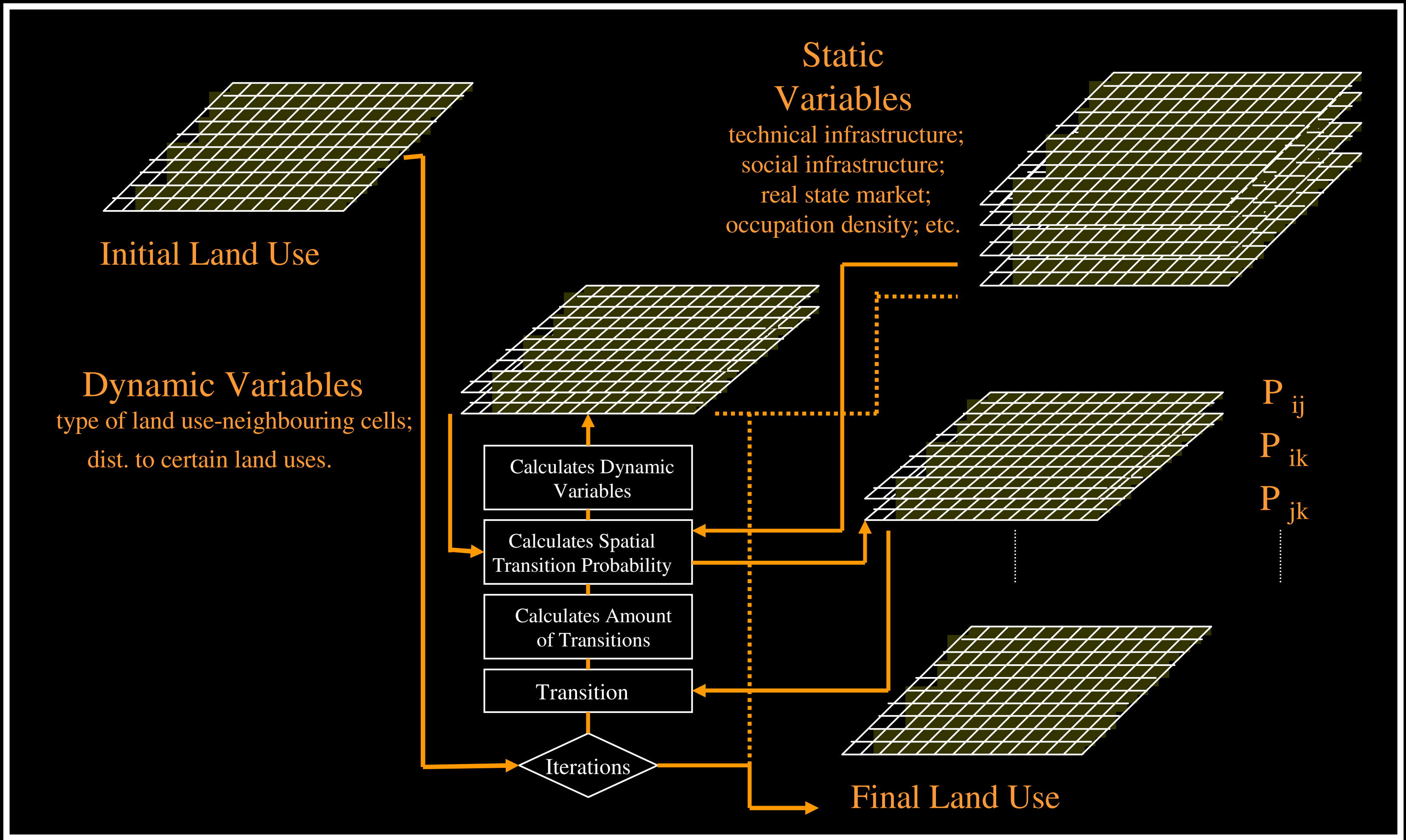
- CA converted into urban space:
- **Cells** ➡ urban tissue (100m x 100m)
- **State** ➡ urban land uses
- **Neighborhood** ➡ according to the study purposes
- **Transition rules** ➡ simple (logics, Boolean operators) or sophisticated (probabilistic models)



LAND USE CHANGE MODELLING - TIME SERIES



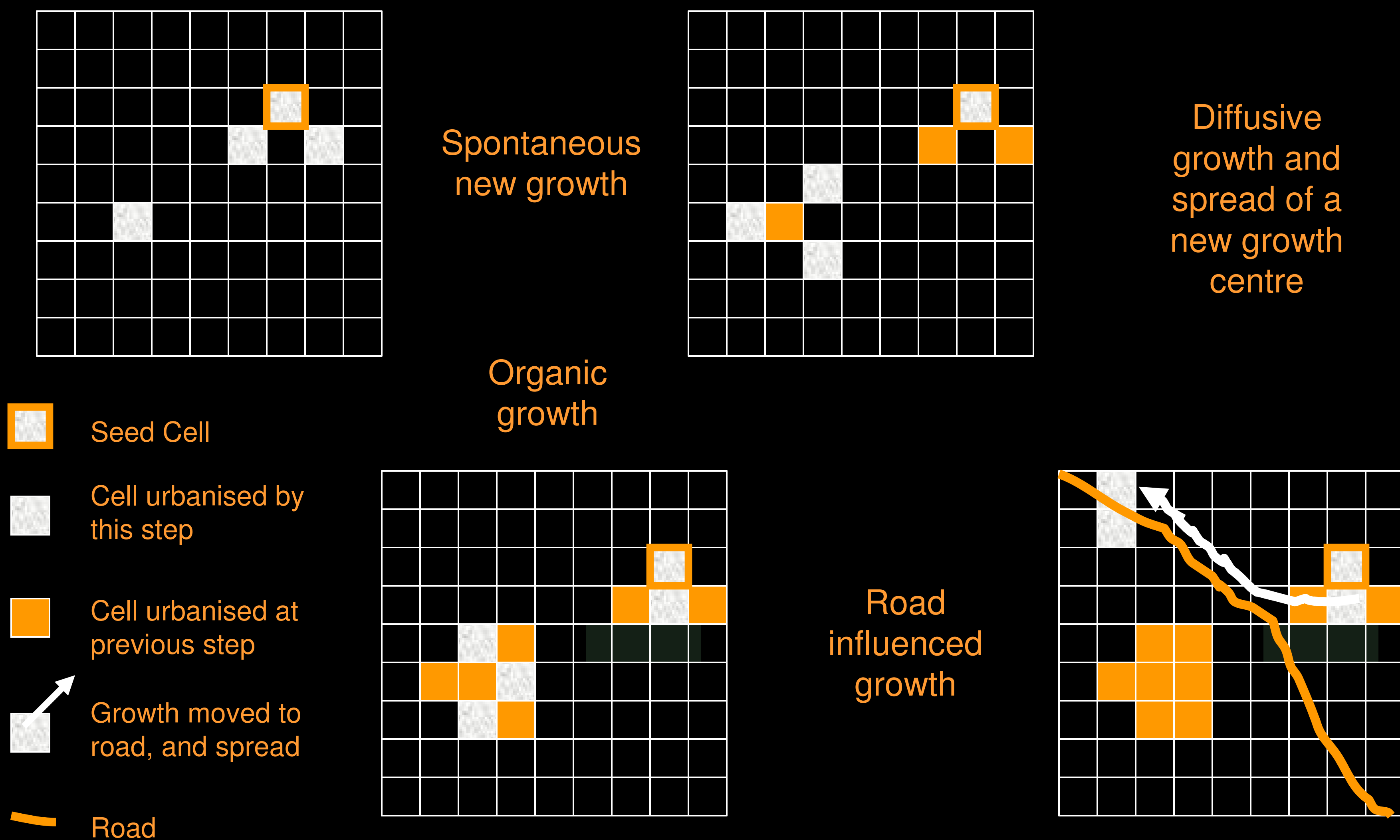
DINAMICA DATA MODEL



Source: Adapted from SOARES (1998).

PREDOMINANTLY DETERMINISTIC MODELS

(Clarke et al., 1997)



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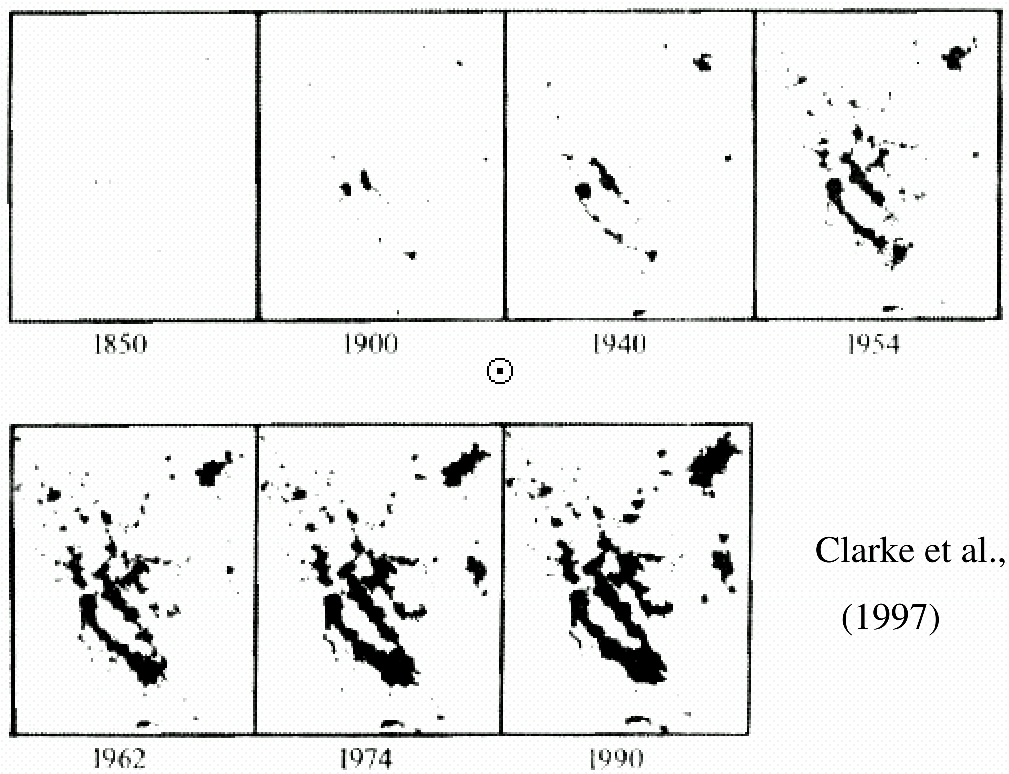
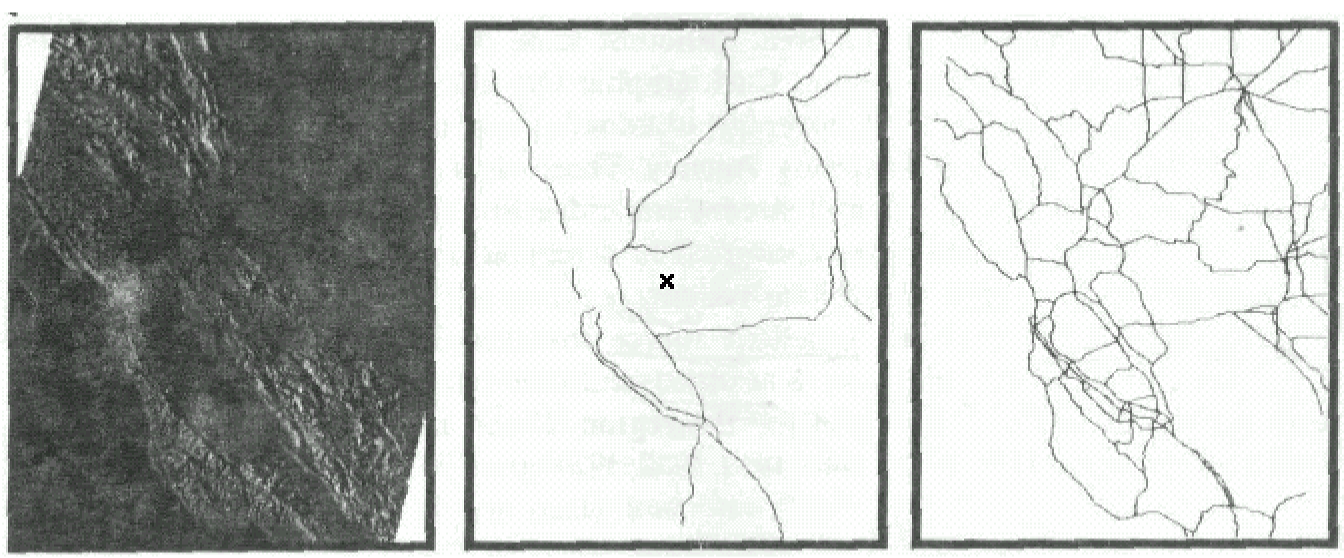


Clarke et al., (1997)

Evolution of Urban Growth - San Francisco Bay Area (USA)

PREDOMINANTLY DETERMINISTIC MODELS

(Clarke et al., 1997)



Decisive factors for urban growth: topography,

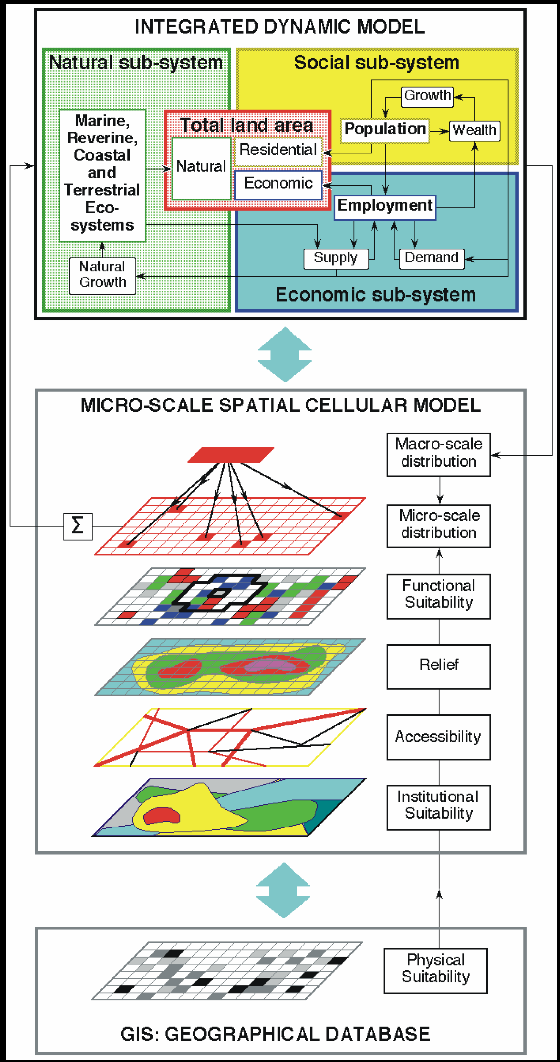
roads in 1920, roads in 1978.

STOCHASTIC MODELS WITH BOTH DETERMINISTIC AREA ESTIMATION AND TRANSITION ALGORITHMS

RIKS - Research Institute for Knowlege Systems, University of Maastricht, Holland (1999)

- SIMLUCIA - Model with categories of urban land use,   which incorporates regionalised variables.

http://www.riks.nl/projects/SimLucia



STOCHASTIC MODELS WITH BOTH DETERMINISTIC AREA ESTIMATION AND TRANSITION ALGORITHMS

- Global Transition Probabilities or Transition Rates (impacts on the system as a whole):

  Regionalized Economic/Demographic Models, Markov Chain, Multivariate Regressions, Vensin/Stella, etc.

- Local Transition Probabilities or Cells Probabilities (responses to the demands considering variables of local reach):

  Weights of Evidence, Logistic Regression, Analytical Hierarchical Programming (AHP), Neural Networks, Decision Tree, etc.

STOCHASTIC MODELS WITH BOTH DETERMINISTIC AREA ESTIMATION AND TRANSITION ALGORITHMS

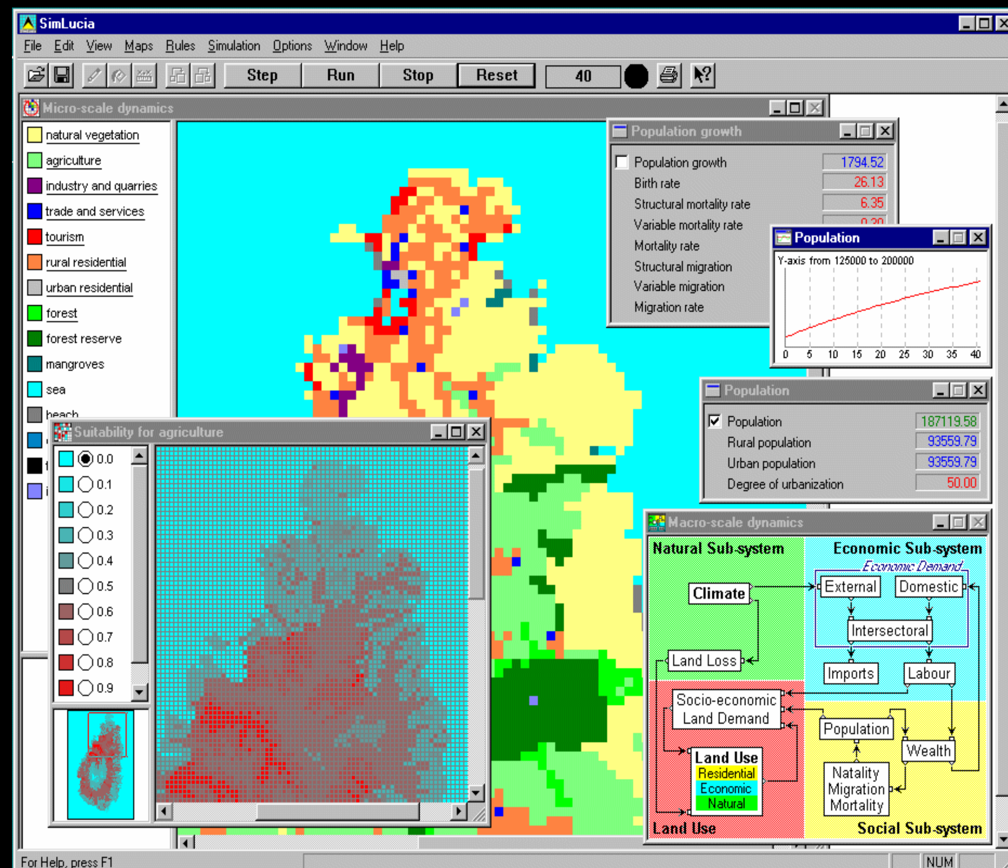
RIKS - Research Institute for Knowledge Systems, University of Maastricht, Holland (1999)

Economic Performance Model

$$Y\Delta_{i,t} = \Delta p_t c_i \exp(n_i(u_t - u_{t=0})) + \Delta E_{i,t}$$

Cells Transition Probability

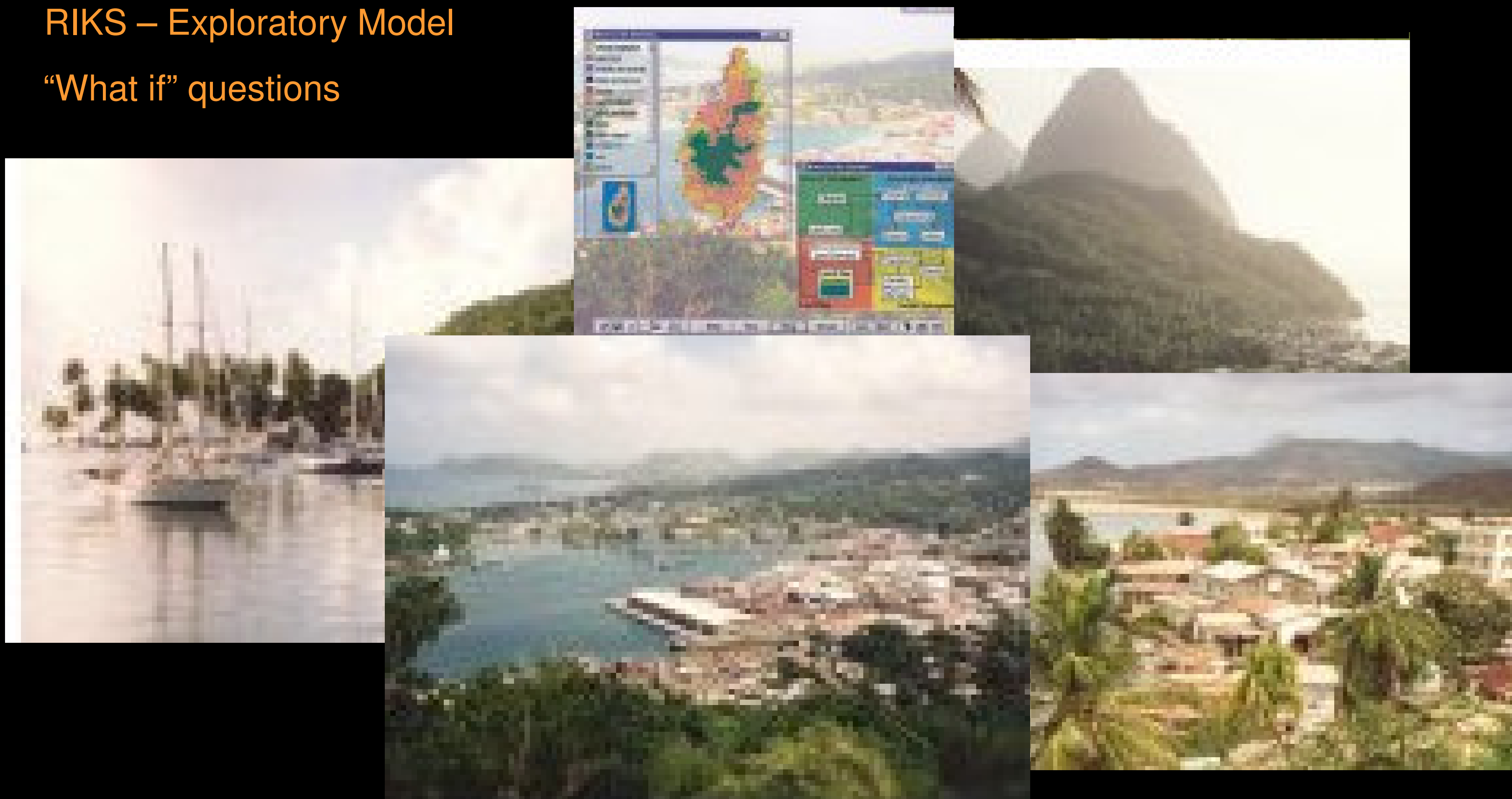
$$P_z = f(S_z).f(A_z).\sum_{d} \sum_{i} (w_{z,y,d} \times I_{d,i}) + \xi_z$$



STOCHASTIC MODELS WITH BOTH DETERMINISTIC AREA ESTIMATION AND TRANSITION ALGORITHMS

RIKS – Exploratory Model

“What if” questions



Transition Algorithm :

- Ranking of Transition Probabilities:

Residential	Commercial	...	Industrial
c_i 0,975	c_t 0,984		c_u 0,901
0,968	0,981		0,897
0,879	0,803		0,796
.	.		.
.	.		.

Cells are ranked by their highest potential, and cells transition begin with the highest ranked cell and move downwards until the number of cells demanded by the Economic and Demographic Models are reached.

URBAN LAND USE DYNAMICS

- *What are the phenomena under analysis ?*

- *What are driving forces of such phenomena ?*

WEIGHTS OF EVIDENCE

- *events* ➡ *land use transitions*
- *evidences* ➡ *infrastructure and socio-economic aspects*

LOGISTIC REGRESSION

- *dependent variable* ➡ *land use transitions*
- *independent variable* ➡ *infrastructure and socio-economic aspects*

Transition Algorithm – Dinamica (http://www.csr.ufmg.br)

- Allocation of possible cells for transition f(i,j);

- Selection of a random number (from 0 to 255), and comparison of it with the transition probability of the considered cell;

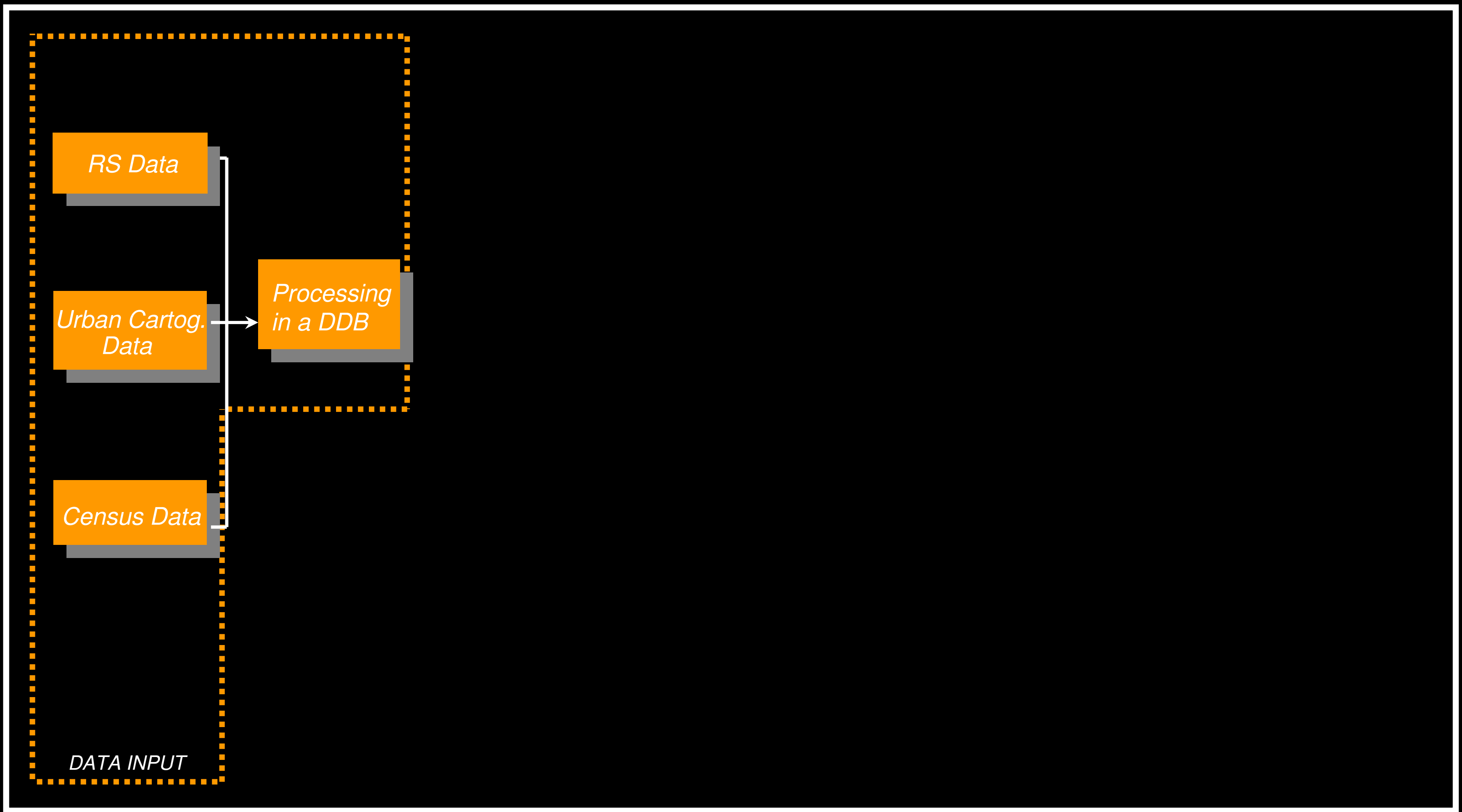
- Random Number > Probability ➡ Do not change;

  Random Number < Probability ➡ Change.

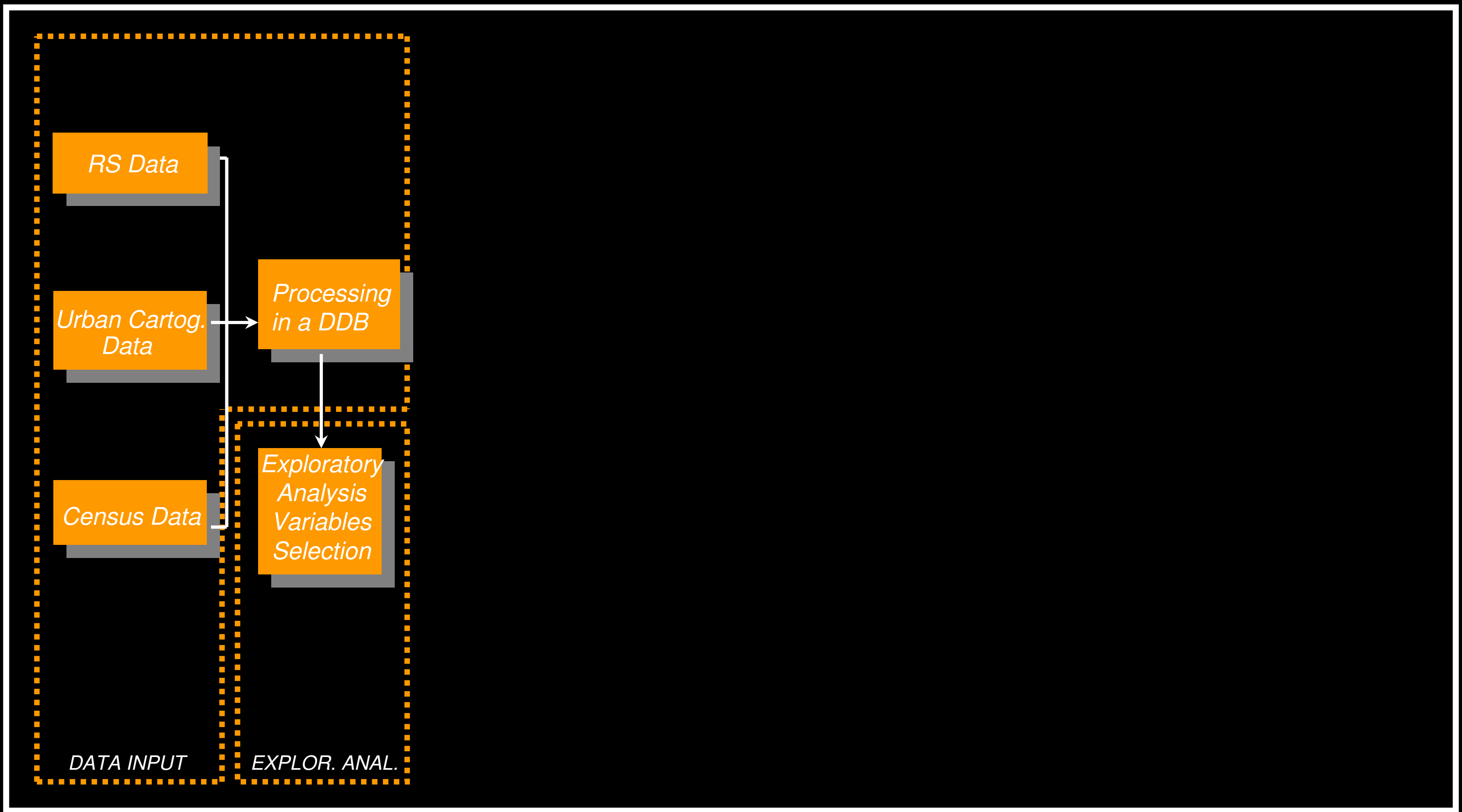
CHALLENGES TO MODELLING

- *the variables available for modelling not always represent the set of necessary variables able to produce highly satisfactory results;*
- *the urban land use dynamics is in general subject to sudden and unforeseeable forces, unsuitable for modelling,e.g. the landlords' decisions to develop certain areas in disregard of others;*
- *"urbanisation booms" - as it is the case of Bauru - are often regarded as chaotic or highly complex systems, what render the current computational modelling technologies not best appropriate to cope with such phenomena.*

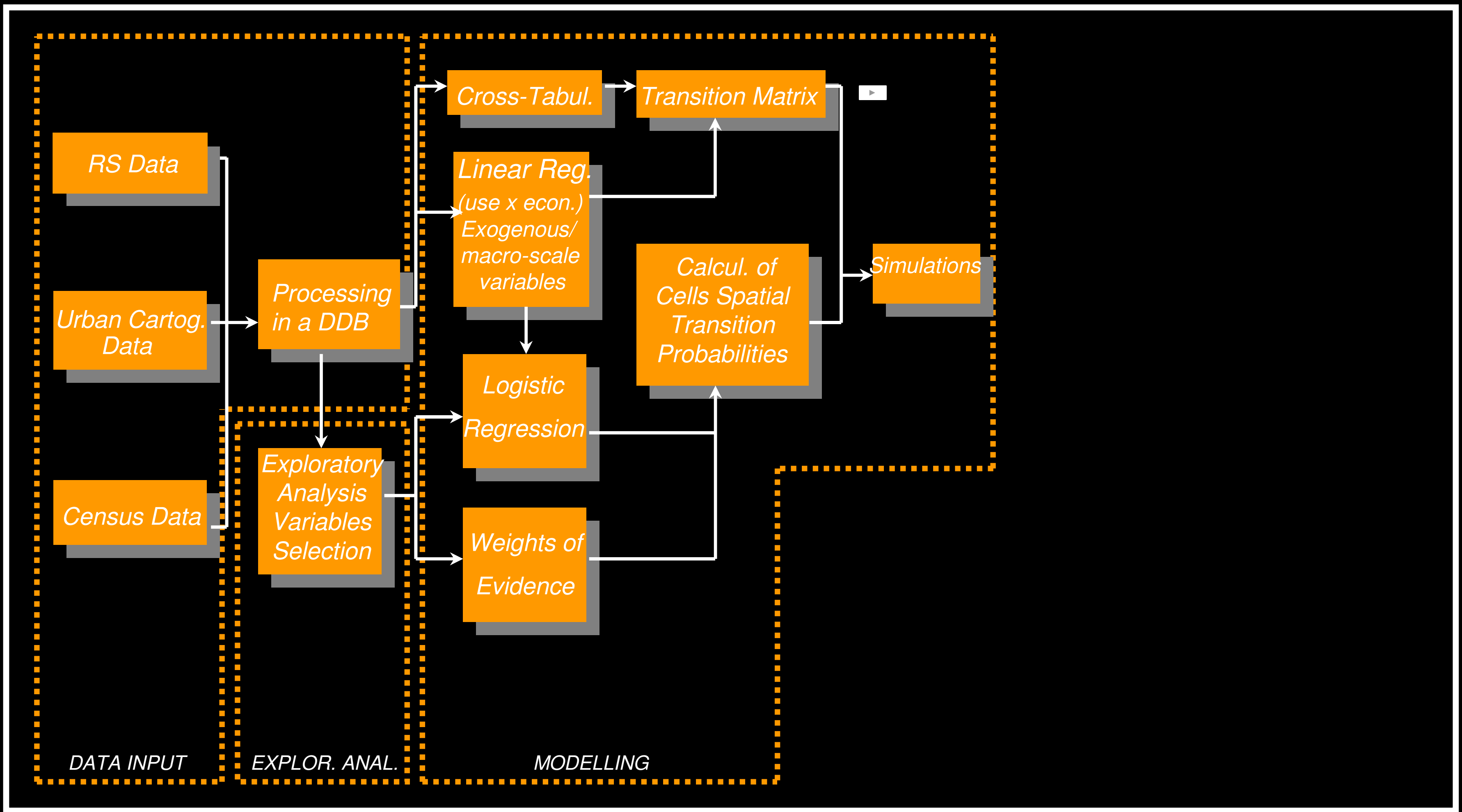
METHODOLOGICAL FLOWCHART



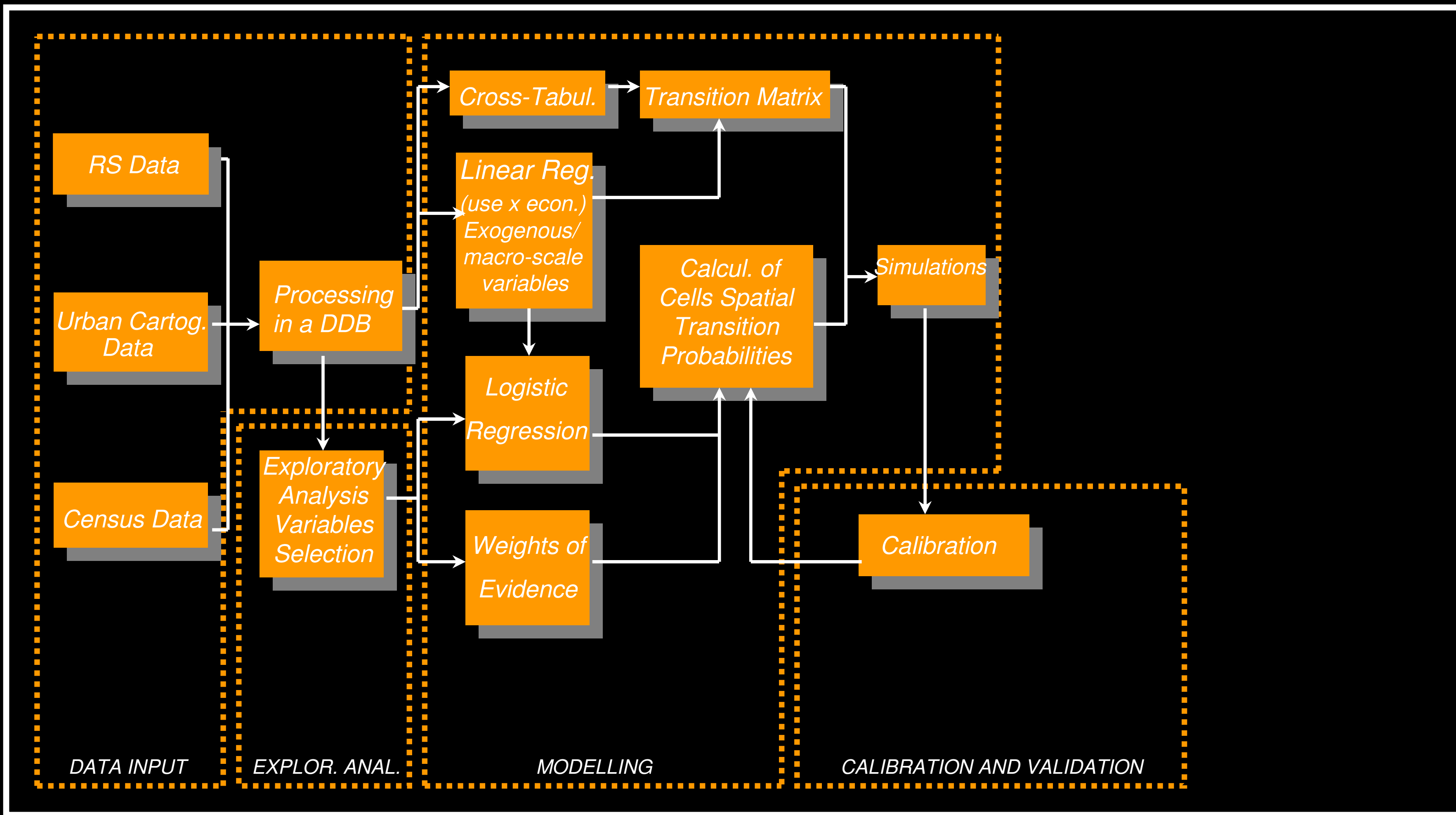
METHODOLOGICAL FLOWCHART



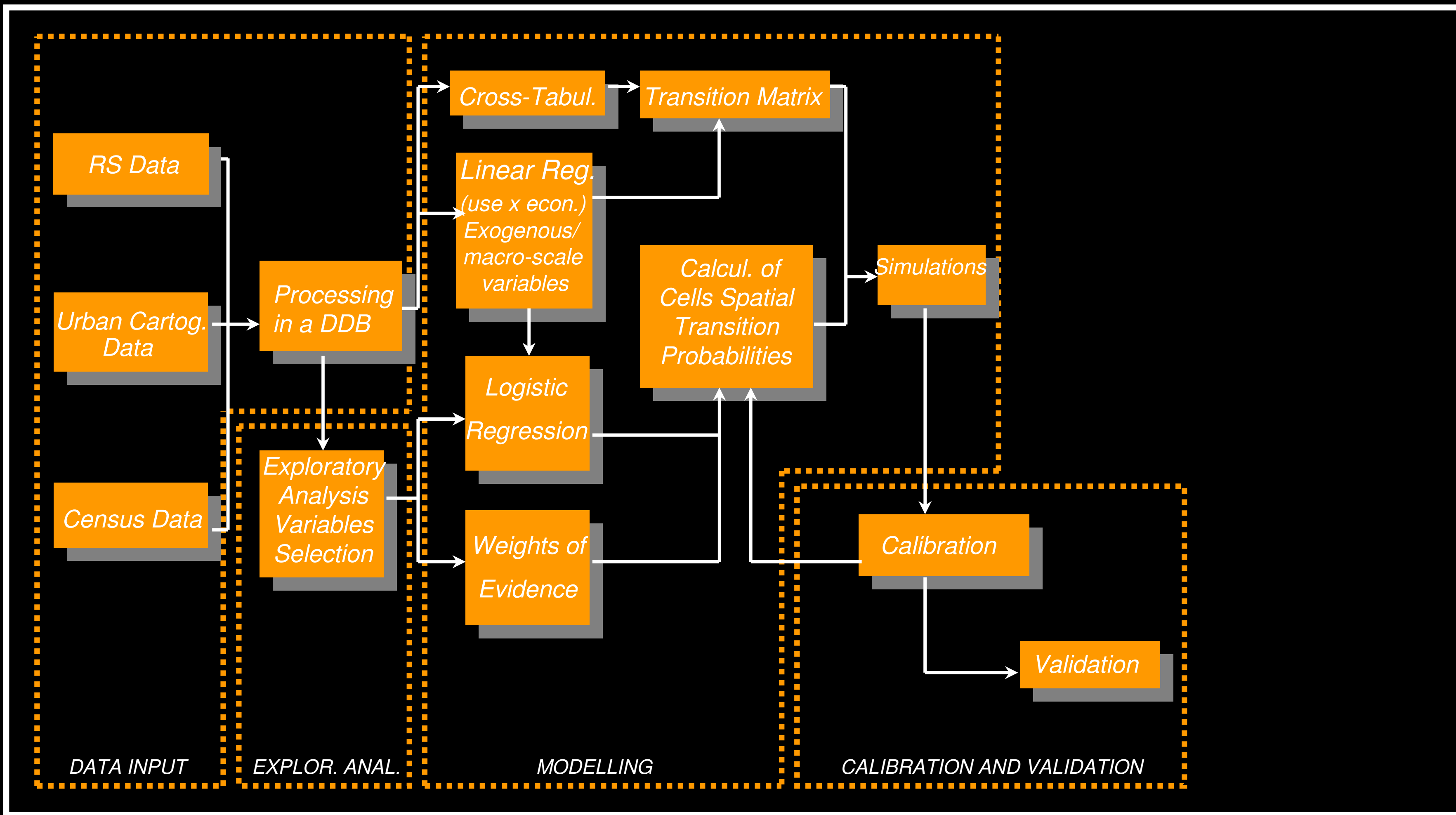
METHODOLOGICAL FLOWCHART



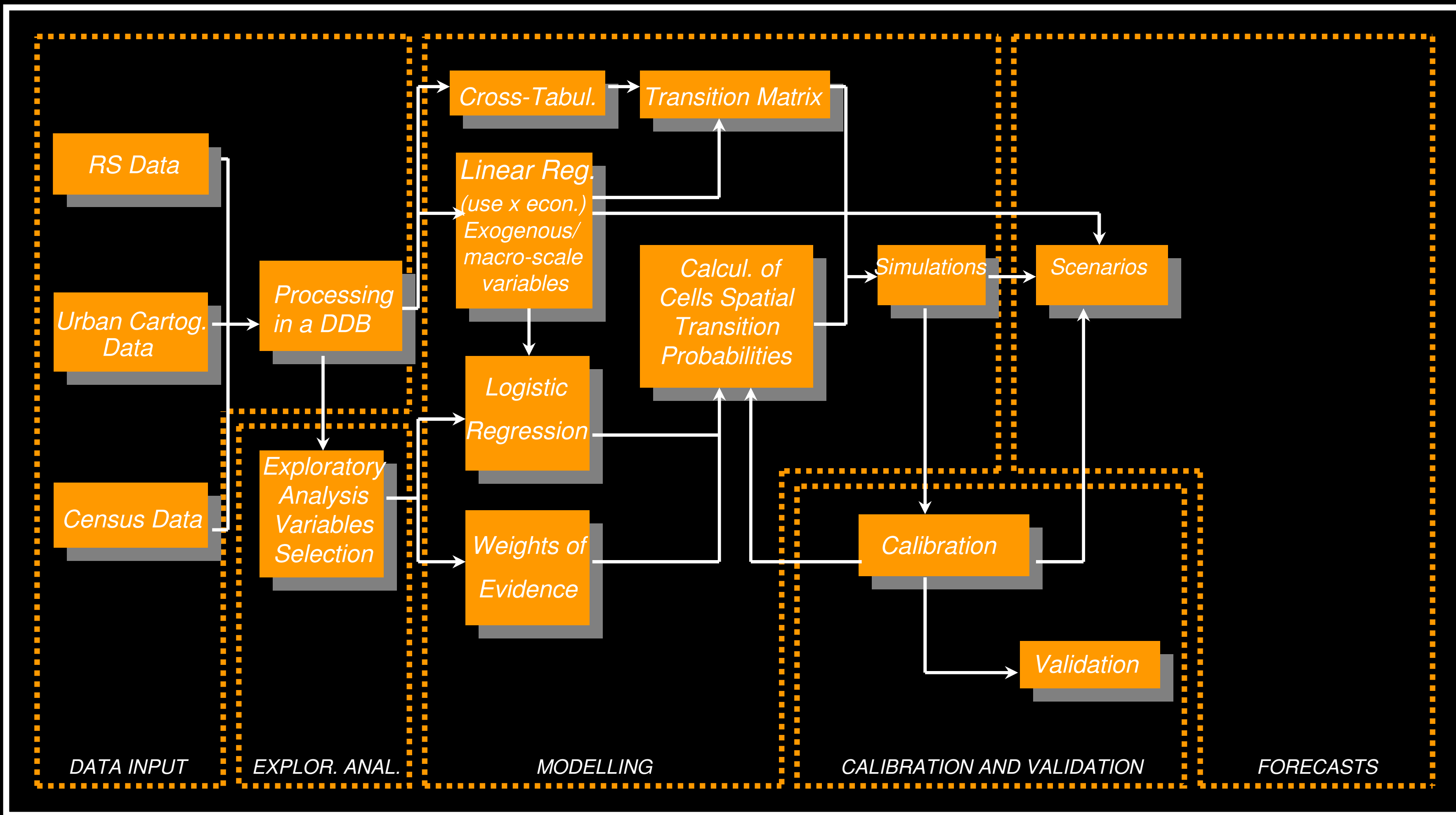
METHODOLOGICAL FLOWCHART



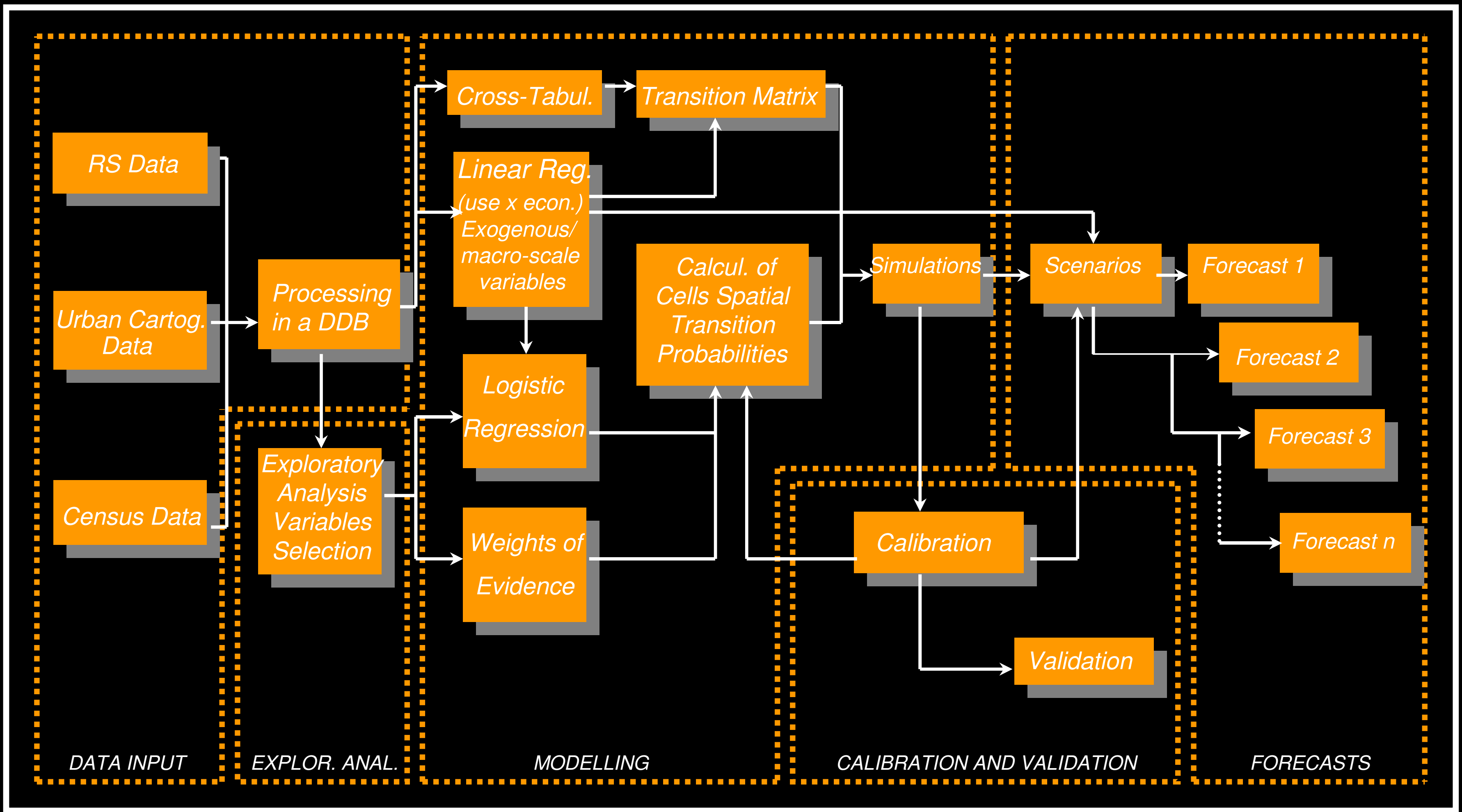
METHODOLOGICAL FLOWCHART



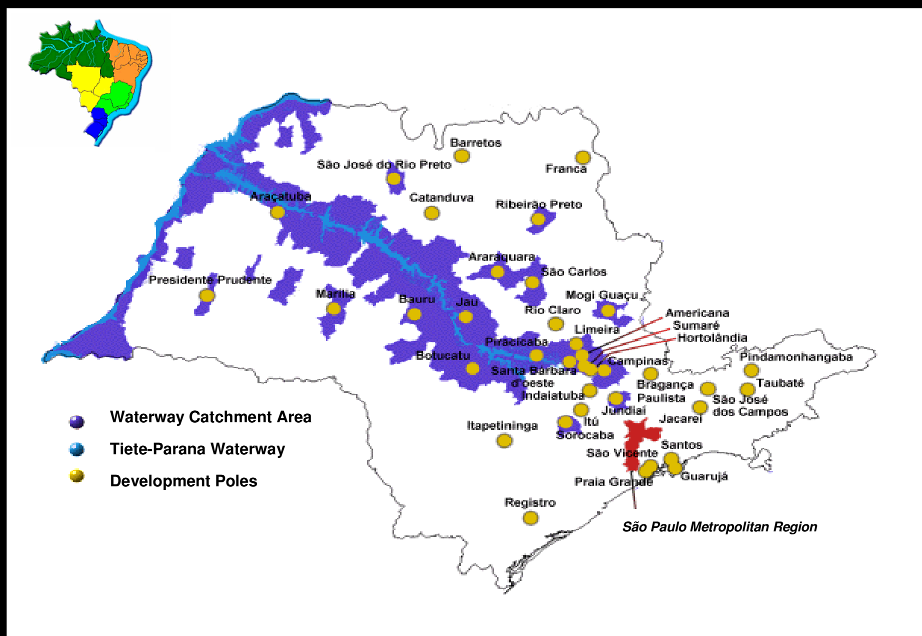
METHODOLOGICAL FLOWCHART



METHODOLOGICAL FLOWCHART



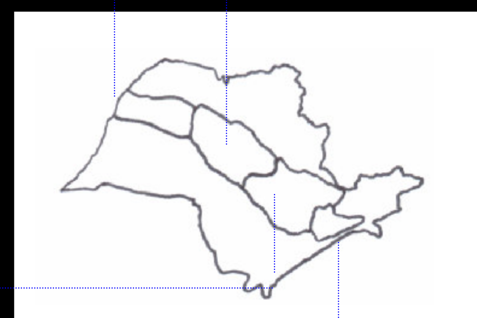
MACRO STUDY AREA



Subdivision of Tietê Watershed

Downstream

Lower Midstream



Upper Midstream

Upstream

Source: CESP, 2000

SIMULATION PERIODS

- *Bauru:*

  1967-1979

  1979-1988

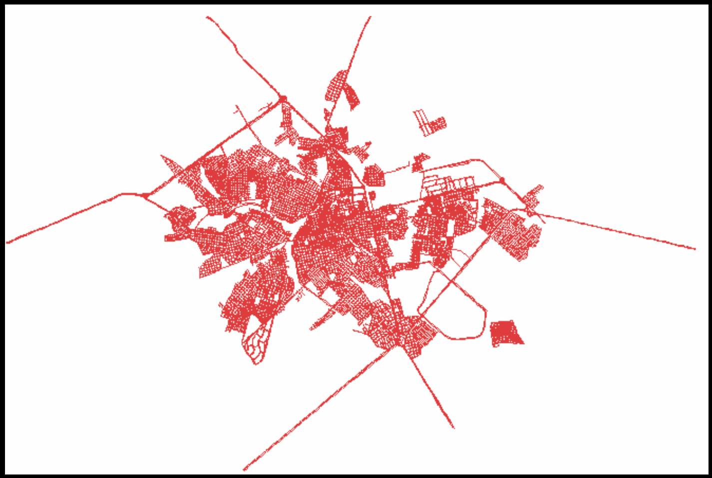
  1988-2000

- *Piracicaba:*

  1962-1985

  1985-1999

STUDY AREA



City Plan: Bauru - 1979

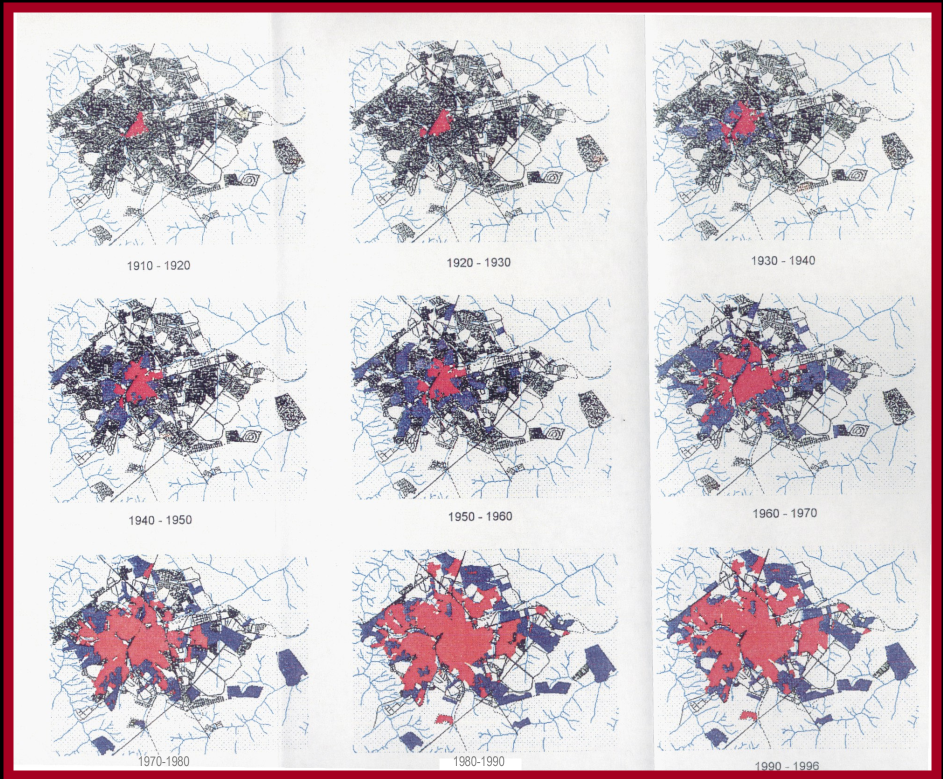
City Plan: Bauru - 1988

STUDY AREA

- Bauru: Evolution of Urban Growth

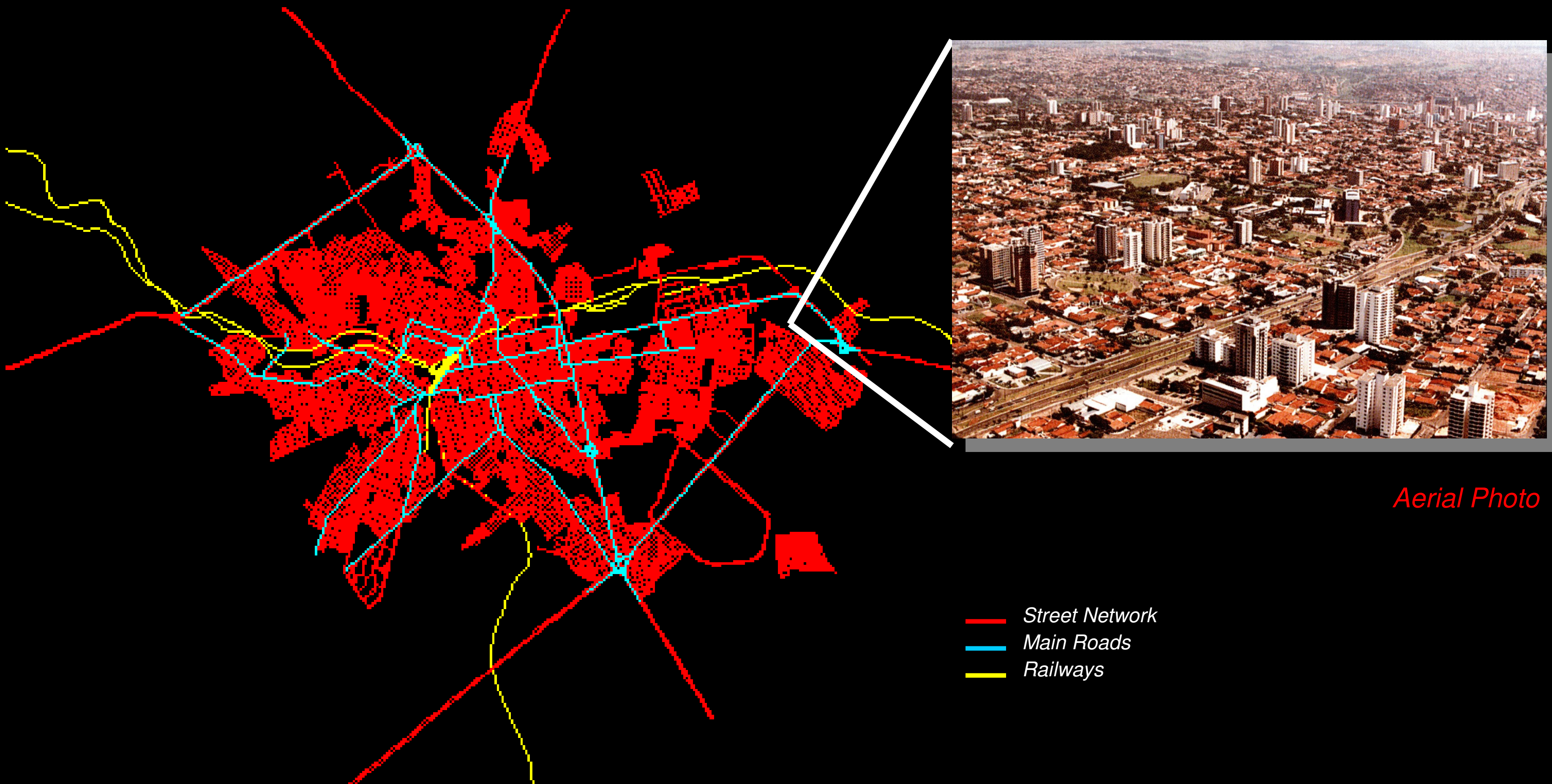
■ Effectively Occupied Area

■ Legalised Settlements



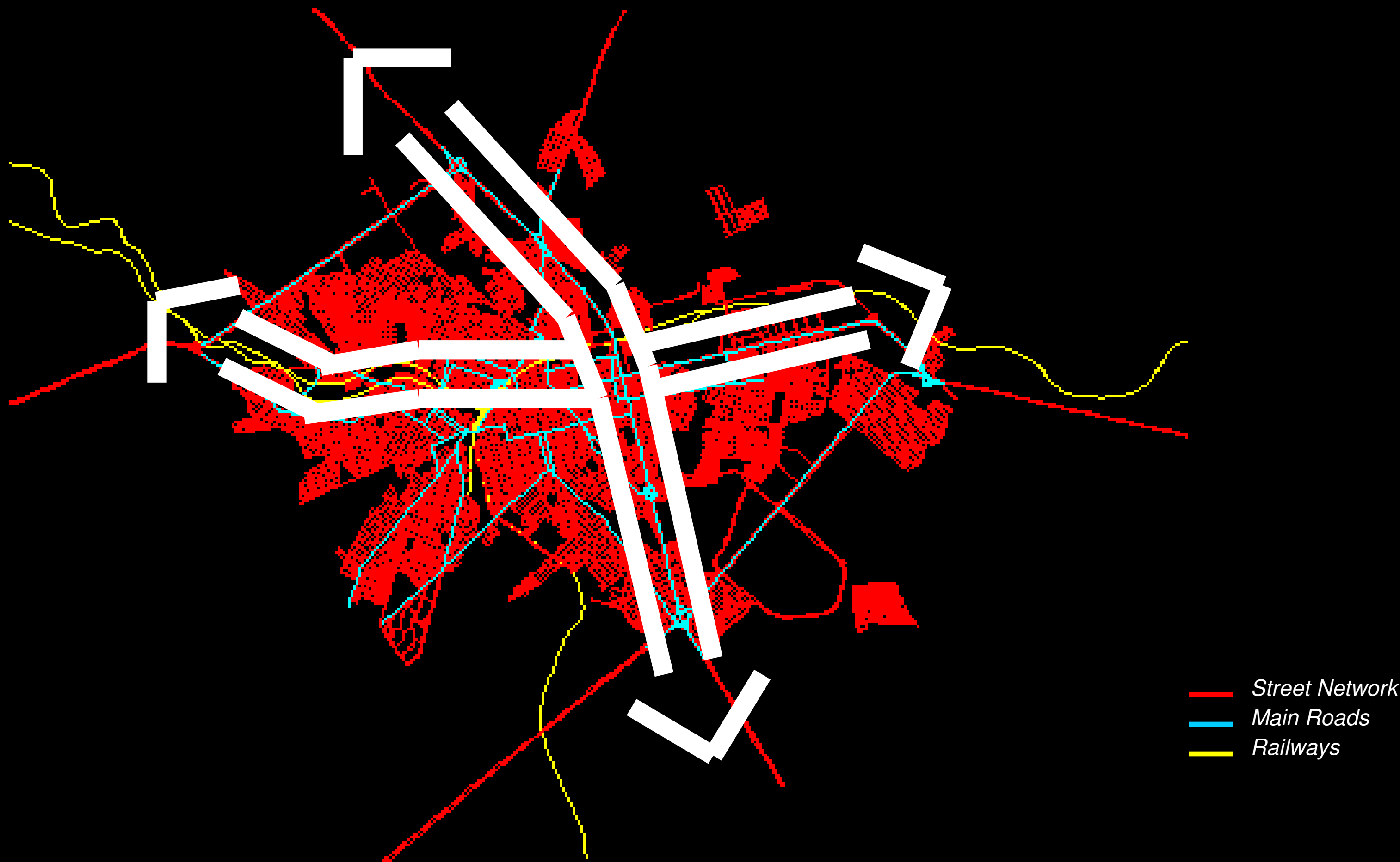
Source: SEPLAN-Bauru, 1996.

INTRAURBAN STRUCTURES



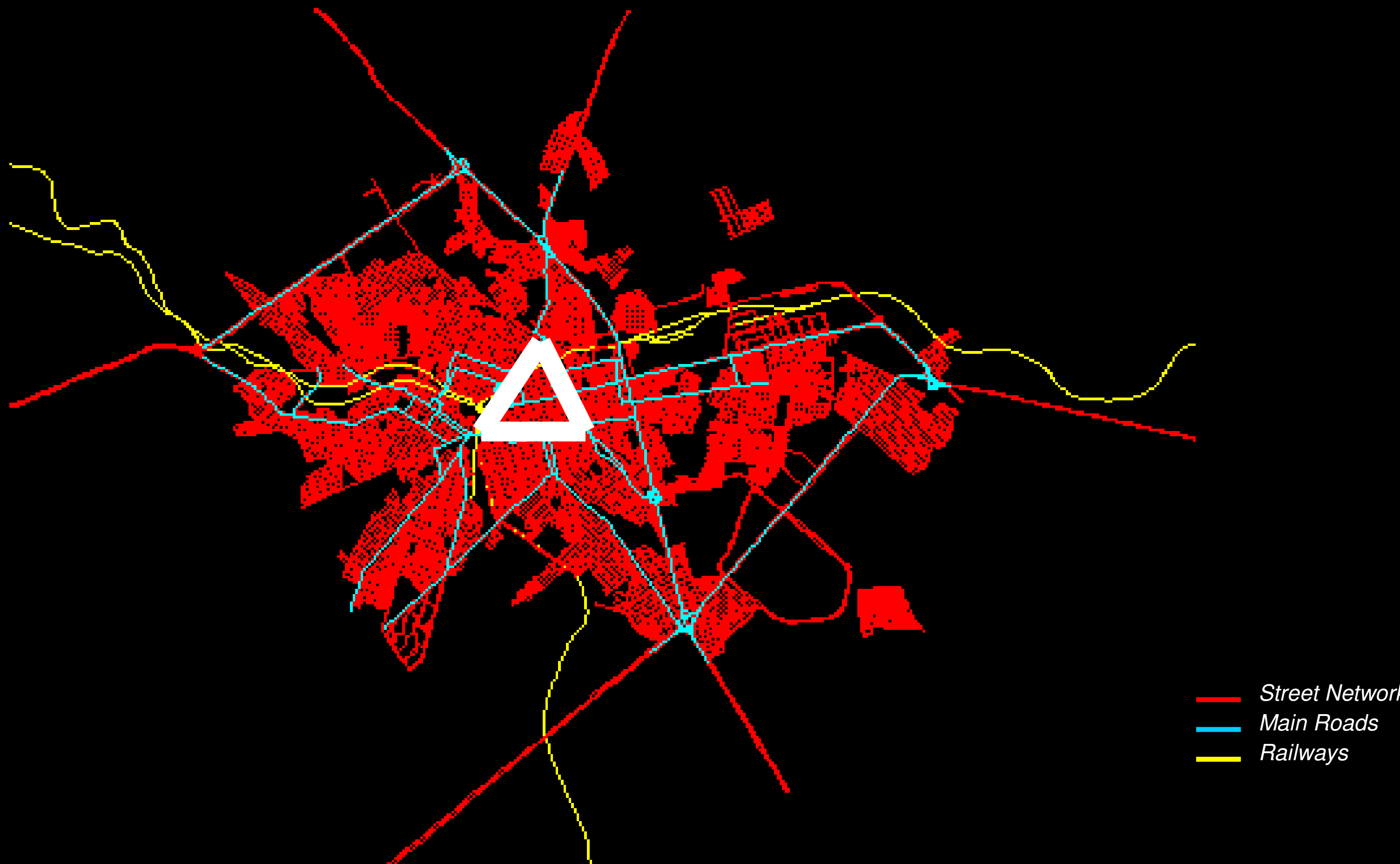
Bauru - 1979: Regional Development Pole - 305,753 inh., 2000

INTRAURBAN STRUCTURES



N/S - E/W Services Axes : Bauru - 1979

INTRAURBAN STRUCTURES

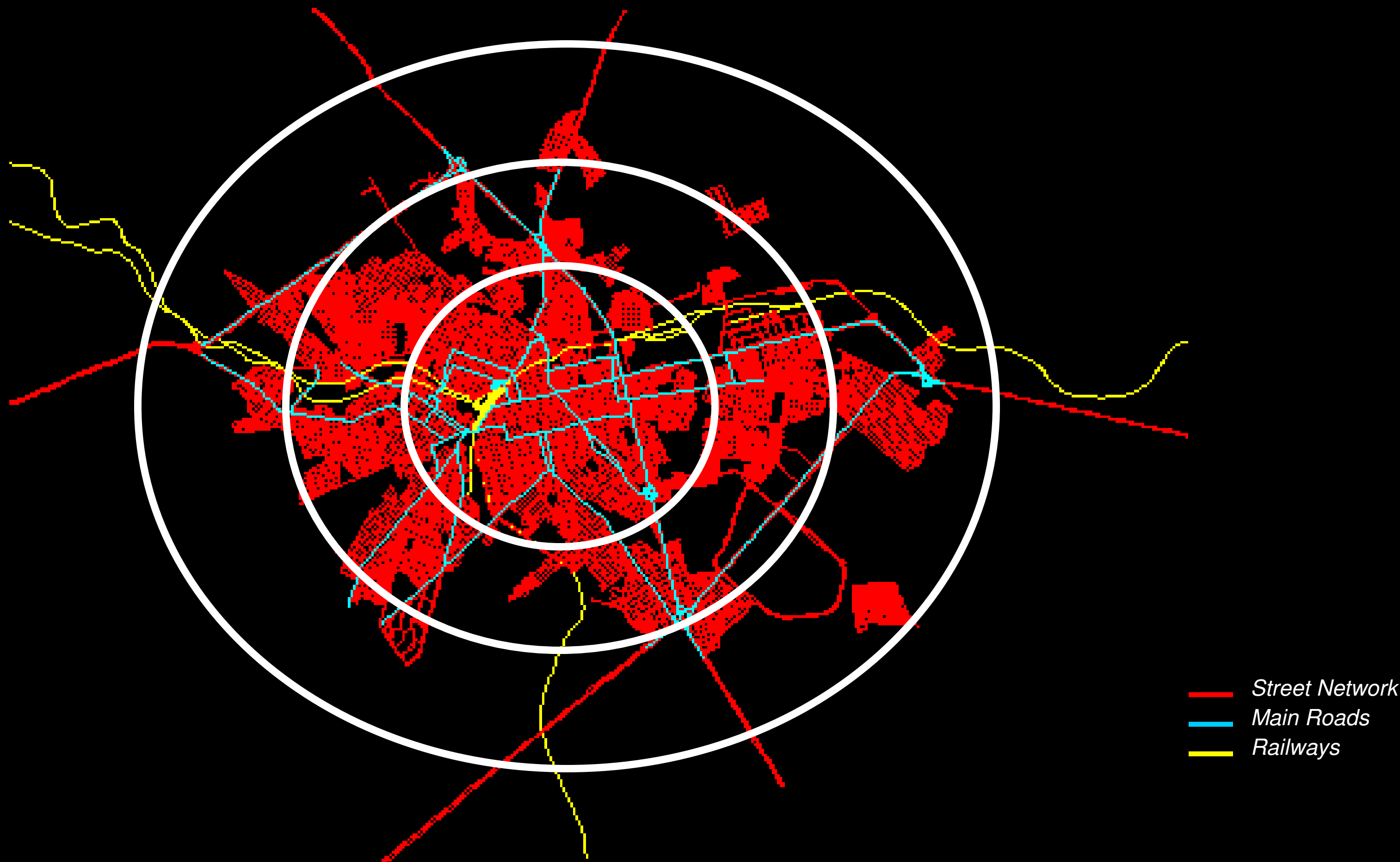


Central Commercial Triangle: Bauru - 1979

INTRAURBAN STRUCTURES

Northeastern Industrial Sector: Bauru - 1979

INTRAURBAN STRUCTURES

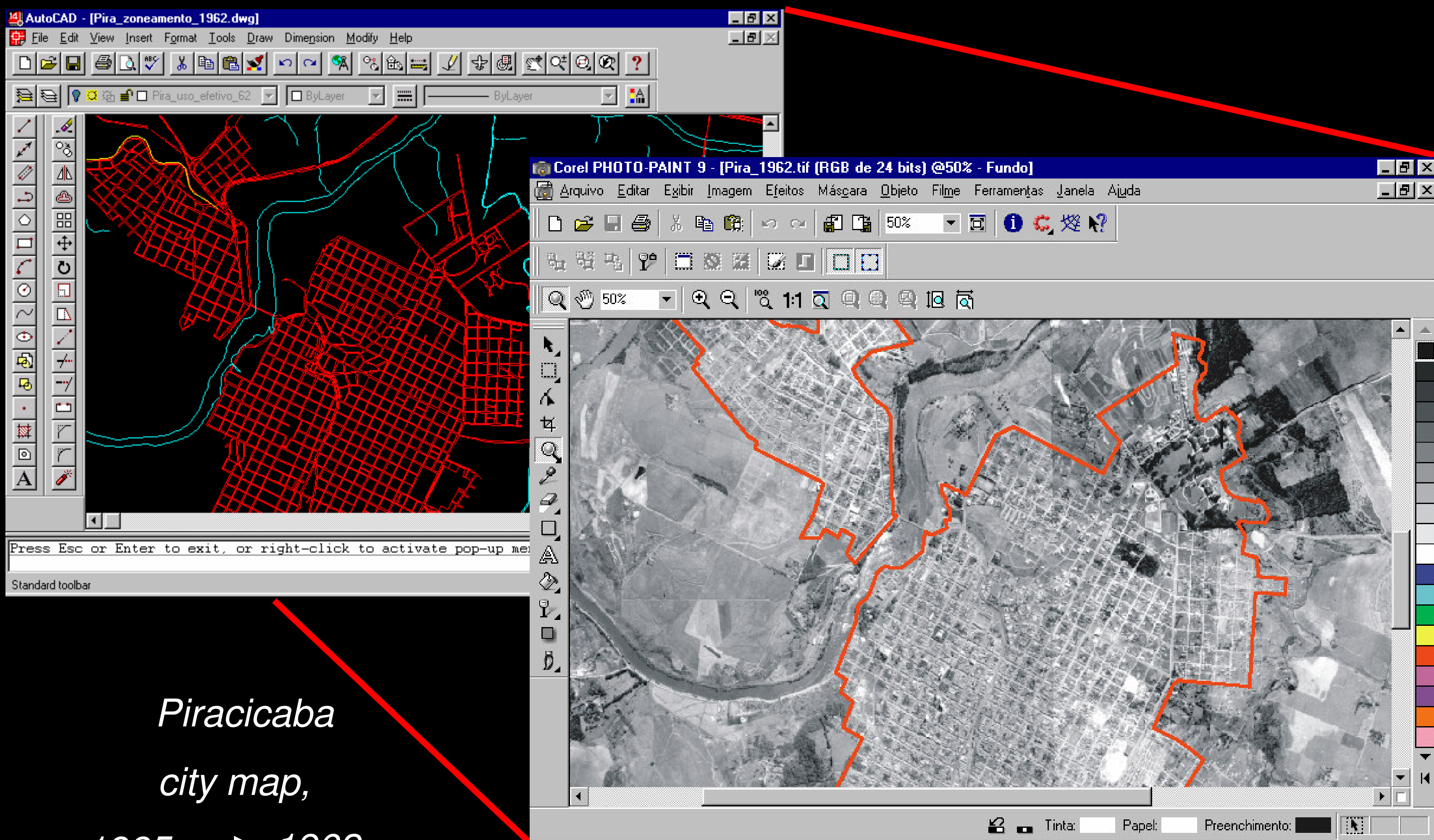


Residential Rings: Bauru - 1979

GENERALISATION: LAND USE MAPS

- *delimitation of zones according to their predominant and effectively existent use;*
- *reclassification of similar zones to only one category, e.g. residential zones of different densities to residential only;*
- *adoption of eight basic categories of land use: residential, comm., instit, industrial, services, mixed zone, leis./recr.;*
- *exclusion of districts segregated from the main urban agglomeration(farther than 10 km from the urban boundary);*
- *desconsideration of the traffic network and minor non-occupied areas .*

CITY MAP RECONSTITUTION



Piracicaba

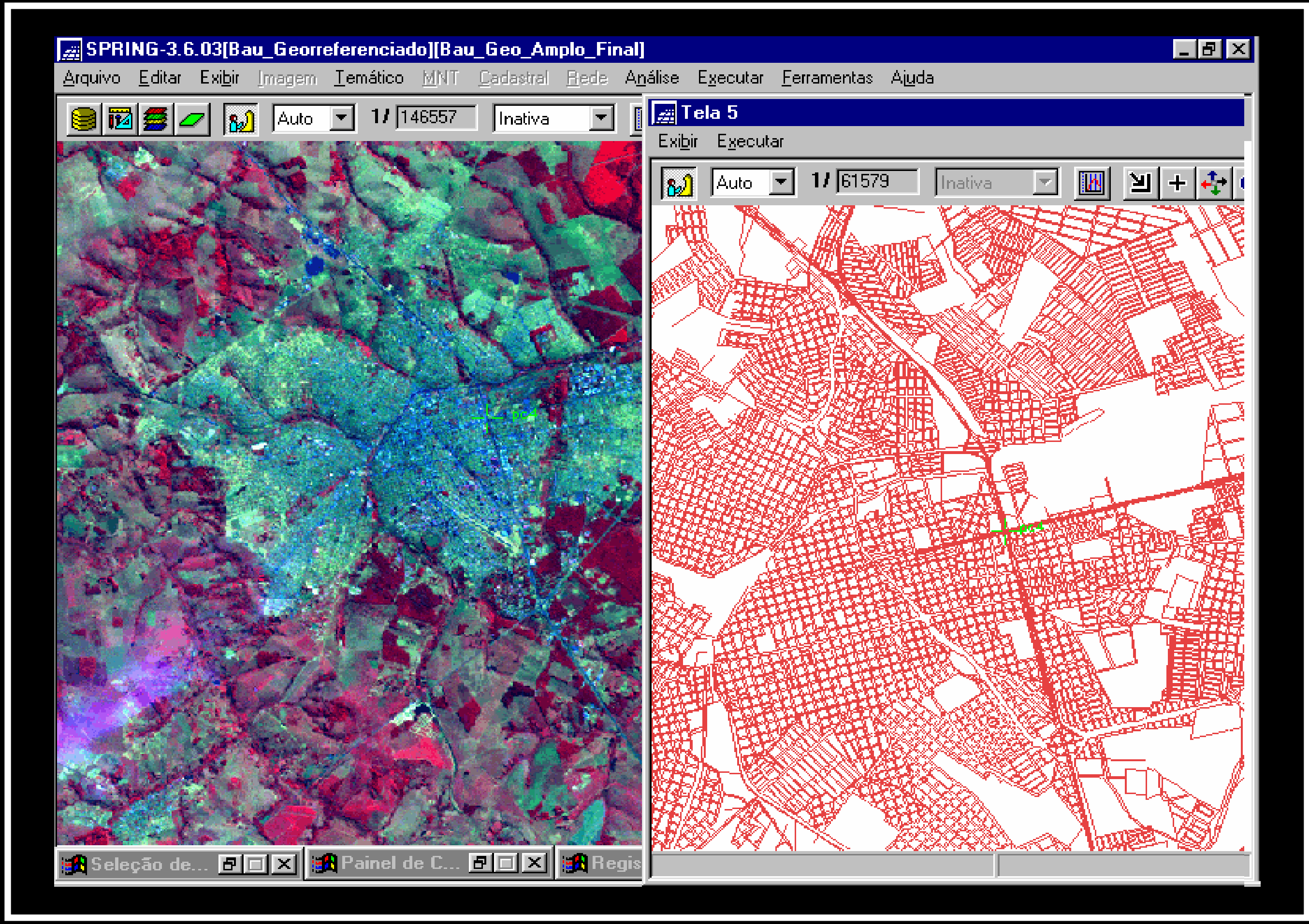
city map,

1985 → 1962

Piracicaba Aerial Photos Mosaic

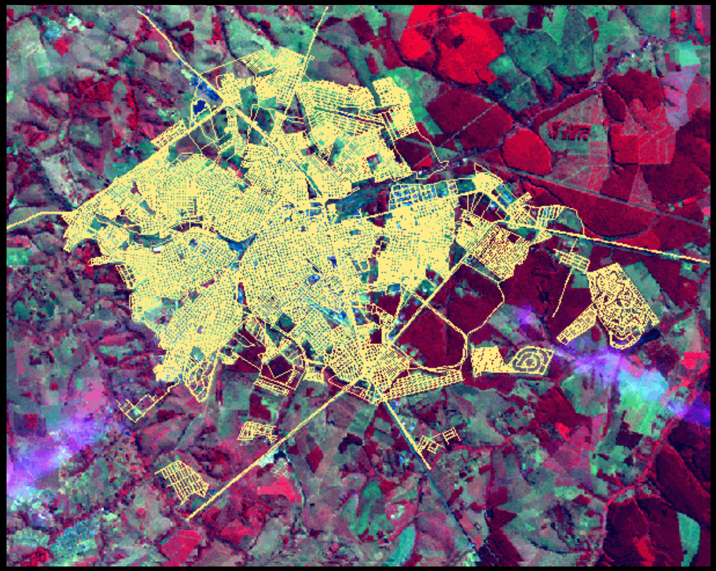
of 1962 (LSN, 2003)

IMAGE TO VECTOR REGISTRATION



Bauru image and city plan of 2000 (LS-5 TM 221/75, Acquisition date: 06/07/00)

IMAGE TO VECTOR REGISTRATION

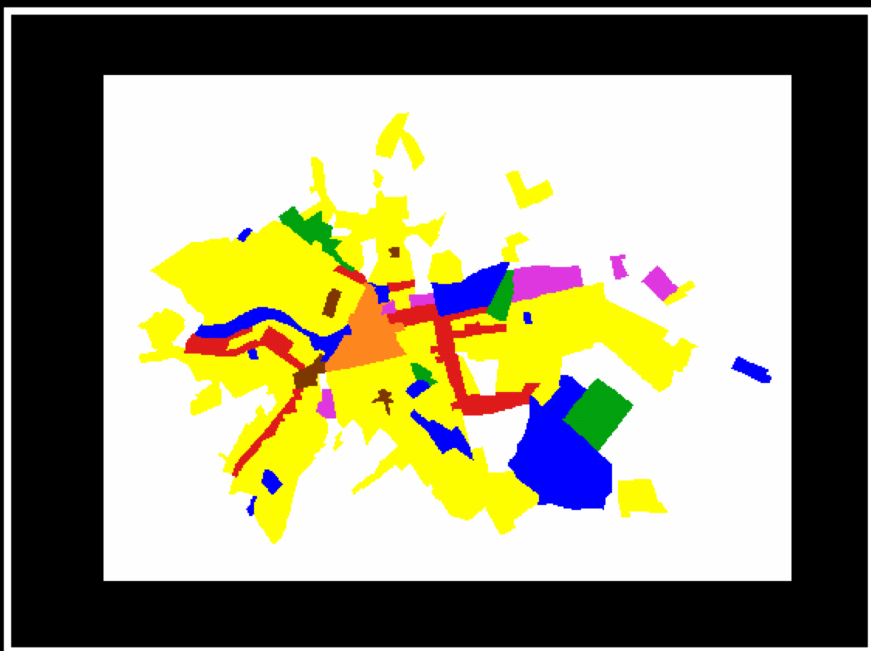


Bauru city plan and image of 2000 (LS-5 TM 221/75, Acquisition date: 06/07/00)

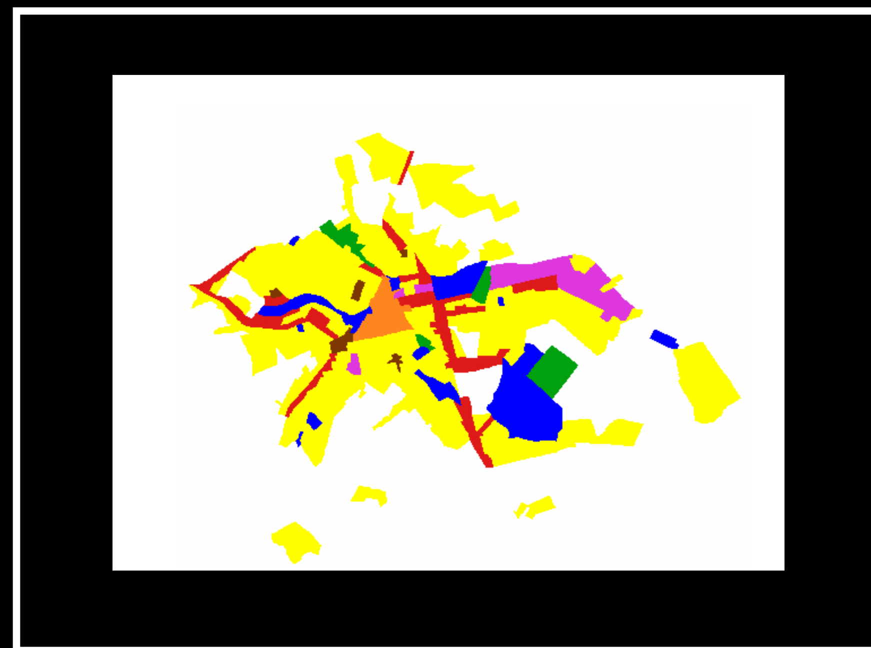
Piracicaba city plan and image of 1999 (LS-5 TM 222/76, Acquisition date: 07/16/99)

STUDY AREA

179,823 inh.



232,005 inh.



Residential Use
Commercial Use
Industrial Use
Leis./Recreation
Services Use
Institutional Use
Mixed Use
Non-Urban Use

Initial and Final Land Use Maps: Bauru - 1979 and 1988

INTERVENING VARIABLES

- *Endogenous Variables:*

- *zoning and urban legislation;*
- *technical and social infrastructure;*
- *topography;*
- *protection/conservation areas;*
- *floodable plains; improper areas for urban occupation;*
- *socio-economic level and land use in the surroundings;*
- *real state market;*
- *jobs availability;*
- *proximity to quaternary centres (universities and research institutes);*
- *great polarising achievements, such as industrial parks, big malls, resorts, thematic parks; etc.*

INTERVENING VARIABLES

- *Technical Infrastructure: the underlying or hard framework of a town, consisting of:*

  - traffic and transport systems;

  - energy supply systems;

  - water supply and sewage disposal and treatment systems;

  - telecommunications (e.g. radio, TV, internet connections);

  - solid waste collection, disposal and treatment;

  - cemiteries; etc.

INTERVENING VARIABLES

- *Social Infrastructure: the soft framework necessary for the functioning of a town, such as:*

  - educational system;

  - health care system;

  - public institutions;

  - religious institutions;

  - security systems;

  - commercial and services activities;

  - sports facilities;

  - leisure /entertainment and green areas systems;

  - social care facilities (kindergartens, youth centres, retirement homes);

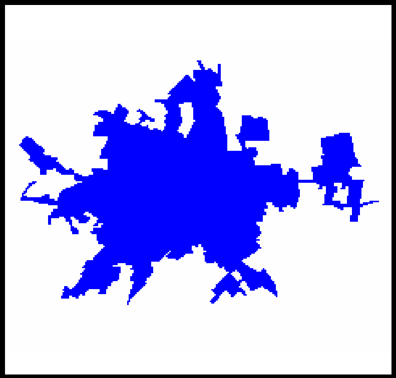
  - cultural institutions (museums, libraries, cultural centres,etc.); etc.

INTERVENING VARIABLES

- *Exogenous Variables:*

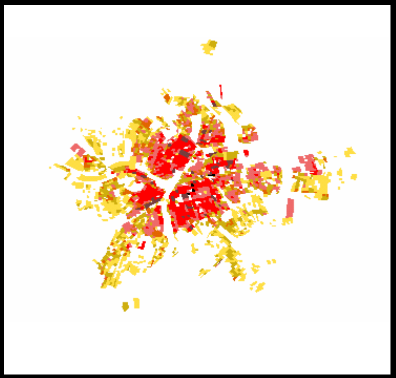
- *Breakages in the general economic trends (economic or financial crises, energetic shortages, etc.);*
- *meteorologic disturbances which affect tillage or tourism activities;*
- *local or regional policies that may impact the expected performance of the different economic sectors; etc.*

EXPLORATORY ANALYSIS

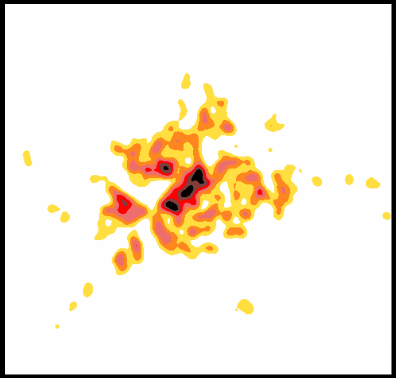


Water Supply

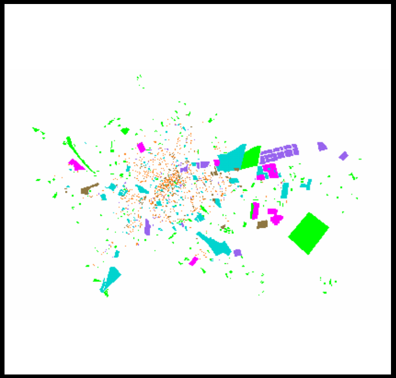
Distances to Railways



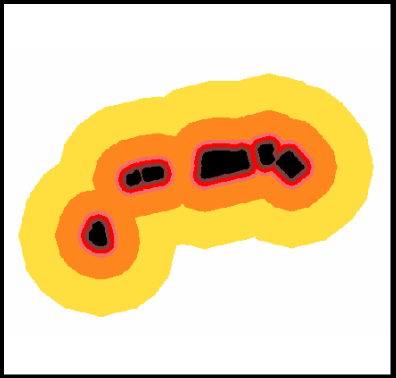
Occupation Density



Commerce - Kernel Est.



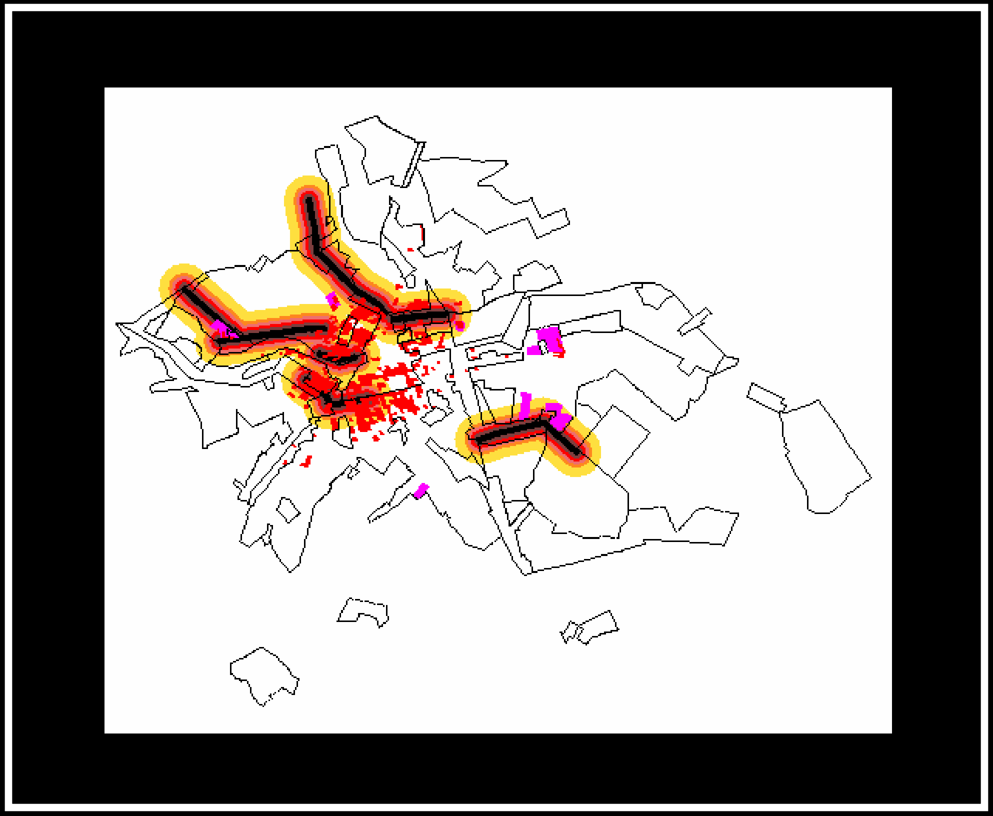
Social Equipments



Distances to Industries

EXPLORATORY ANALYSIS

- *Overlay of evidences maps on the final land use map boundaries*



SPRING

Zones Limits

Medium-High Density

Social Housing

Dist. to Planned Roads

EXPLORATORY ANALYSIS

- *Only valid if:*

evidences are independent amongst themselves

or

independent variables are uncorrelated amongst themselves

EXPLORATORY ANALYSIS

- *Weights of Evidence Method: Measures of Association between Pairs of Evidences Maps* (Bonham-Carter, 1994)

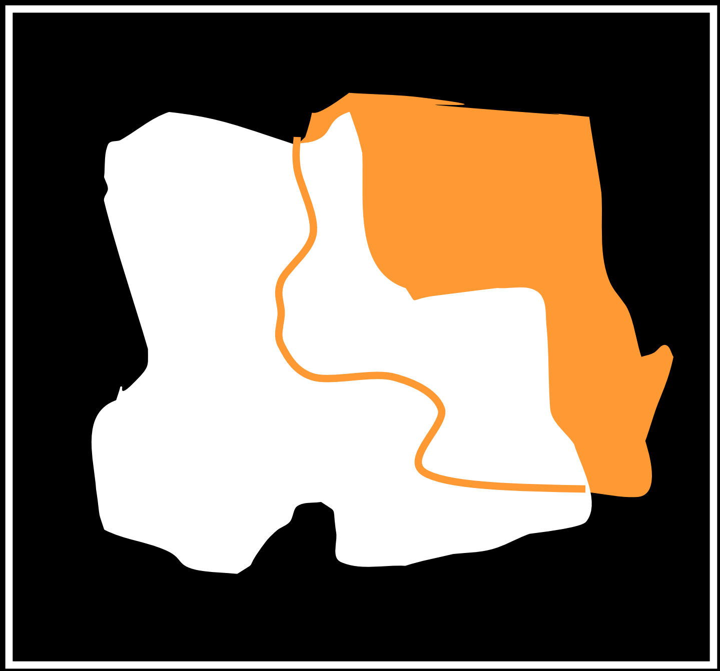
  - *Cramers Coefficient:*

  Deals with absolute values for overlap areas between pairs of evidences.

  - *"Joint Information Uncertainty":*

  Deals with percentage values for overlap areas between pairs of evidences.

Study Area



Evidence A *Evidence B*

EXPLORATORY ANALYSIS

- *Weights of Evidence Method* *(Bonham-Carter, 1994)*
  - *Cramers Coefficient:*

$$V = \sqrt{\frac{\chi^2}{T..\,M}}$$

  - *"Joint Information Uncertainty":*

$$U(A,I) = 2\left[\frac{H(A) + H(I) - H(A,I)}{H(A) + H(I)}\right]$$

EXPLORATORY ANALYSIS

- *Logistic Regression Method*
  - *Correlation Index:*

$$\Lambda_{a,b} = 1/N \sum_{i=1}^{N} \left(x_a(i) - \overline{x_a}(i)\right)\left(x_b(i) - \overline{x_b}(i)\right)$$

EXPLORATORY ANALYSIS

	NU_RES	NU_IND	NU_SERV	RES_SER	RES_MIX
water				✓	
mh_dens					✓
soc_hous					✓
com_kern	✓		✓		
dist_ind		✓			
dist_res			✓		
per_res	✓				
dist_inst	✓				
exist_rds	✓				
serv_axes		✓	✓	✓	
plan_rds					✓
per_rds	✓				✓

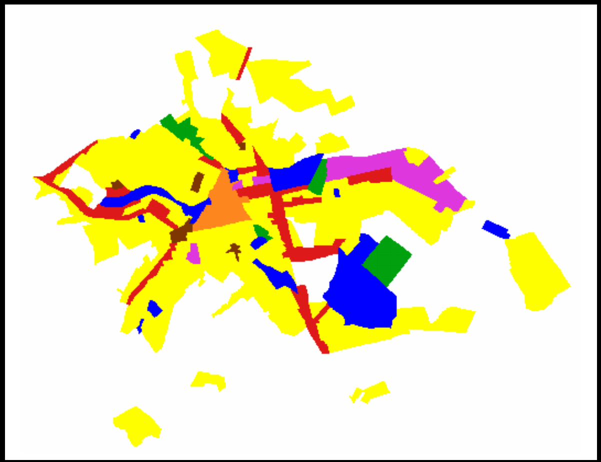
EXPLORATORY ANALYSIS

		WE		LR
Variable A	Variable I	$V_{A,I}$	$U_{A,I}$	$\Lambda_{A,I}$
water	serv_axes	0,3257	0,0767	-0,3060
mh_dens	conj_hab	0,0460	0,0017	0,0530
	vias_plan	0,2617	0,0701	-0,1600
	vias_perf	0,0201	0,0003	-0,0560
soc_hous	vias_plan	0,1174	0,0188	-0,0760
	vias_perf	0,0480	0,0047	-0,0440
com_kern	dist_res	0,4129	0,3447	0,9050
	pol_res	0,1142	0,0310	0,1580
	clas_inst	0,1218	0,0520	-0,2030
	vias_exist	0,2685	0,1499	0,7670
	eixo_simp	0,2029	0,1099	0,7060
	vias_perf	0,0434	0,0064	0, 4490
dist_ind	eixo_simp	0,1466	0,0477	0,5630
dist_res	eixo_simp	0,2142	0,1002	0,7900
per_res	clas_inst	0,1487	0,0559	0,7070
	vias_exist	0,0592	0,0078	0,1860
	vias_perf	0,1733	0,0553	0,5380
dist_inst	vias_exist	0,0601	0,0108	-0,1190
	vias_perf	0,0765	0,0238	0,2170
exist_rds	vias_perf	0,0239	0,0019	0,3090
plan_rds	vias_perf	0,0247	0,0029	0,0658

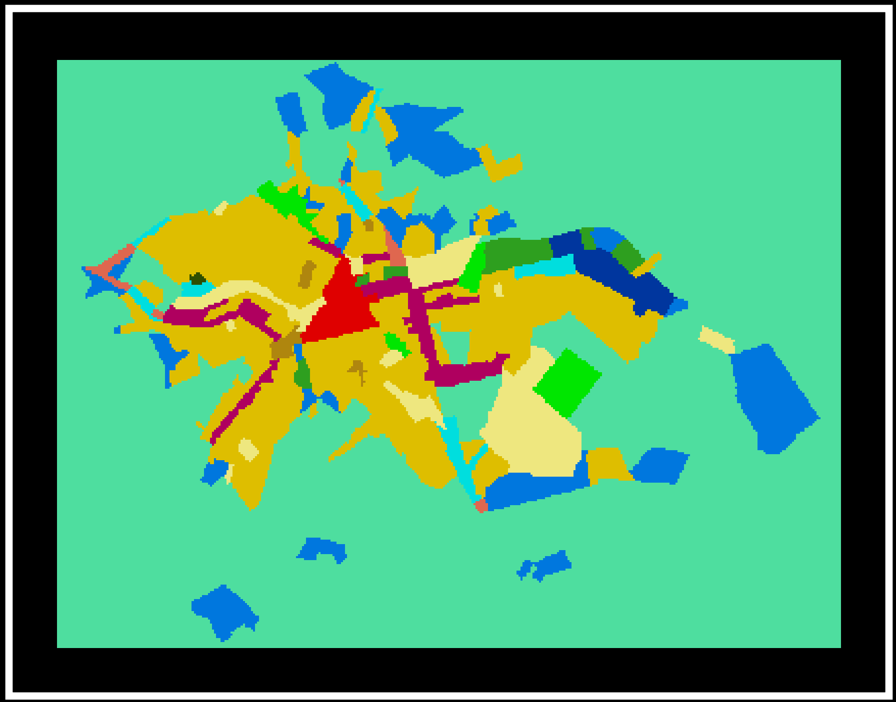
TRANSITION PROBABILITIES

Bauru: Land Use 79

Bauru: Land Use 88



Cross-Tabulation Map: 1979x1988



GLOBAL TRANSITION RATES

- *Global Transition Matrix:*

	Non-Urban	Residential	Commercial	Industrial	Institutional	Services	Mixed Zone	Leis./Recr.
Non-Urban	0,91713	0,06975	0	0,00953	0	0,00358	0	0
Residential	0	0,93798	0	0	0	0,05975	0,00226	0
Commercial	0	0	1,00000	0	0	0	0	0
Industrial	0	0	0	1,00000	0	0	0	0
Institutional	0	0	0		1,00000	0	0	0
Services	0	0	0	0	0	1,00000	0	0
Mixed Zone	0	0	0	0	0	0	1,00000	0
Leis./Recr.	0	0	0	0	0	0	0	1,00000

BAYES THEOREM

Study Area, A

Evidence: Water Supply, S = pres.

Event: Non-Urb_Residential Use, R

Evidence: Water Supply, $\bar{S}$ = abs.

$$P\{R/S\} = \frac{P\{R \cap S\}}{P\{S\}}$$

$$P\{S/R\} = \frac{P\{S \cap R\}}{P\{R\}}$$

WEIGHTS OF EVIDENCE

$$P\{R/S\} = \frac{P\{R\}\,P\{S/R\}}{P\{S\}}$$

$$\frac{P\{R/S\}}{P\{\bar{R}/S\}} = \frac{P\{R\}\,P\{S/R\}}{P\{\bar{R}/S\}\,P\{S\}}$$

$$\frac{P\{R/S\}}{P\{\bar{R}/S\}} = \frac{P\{R\}}{P\{\bar{R}\}}\;\frac{\cancel{P\{S\}}}{\cancel{P\{S\}}}\;\frac{P\{S/R\}}{P\{S/\bar{R}\}}$$

$$O\{R/S\} = O\{R\}\,\frac{P\{S/R\}}{P\{S/\bar{R}\}}$$

WEIGHTS OF EVIDENCE

Sufficiency Ratio LS

$$O\{R/S\} = O\{R\}\,\frac{P\{S/R\}}{P\{S/\overline{R}\}}$$

$$\text{logit}\,\{R/S\} = \text{logit}\,\{R\} + W+$$

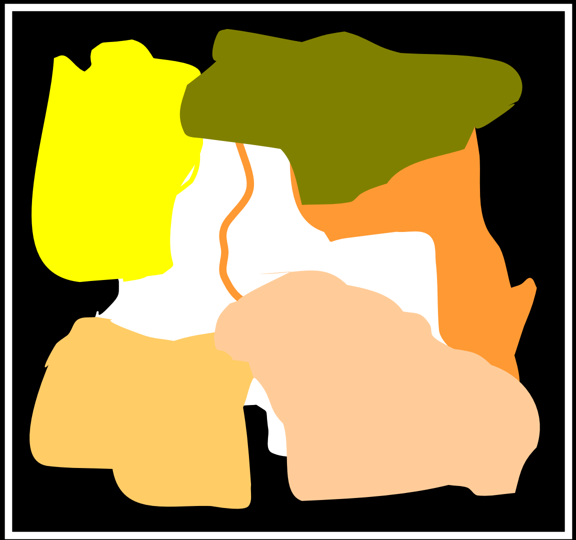
Necessity Ratio LN

$$O\{R/\overline{S}\} = O\{R\}\,\frac{P\{\overline{S}/R\}}{P\{\overline{S}/\overline{R}\}}$$

$$\text{logit}\,\{R/\overline{S}\} = \text{logit}\,\{R\} + W-$$

WEIGHTS OF EVIDENCE

Odds



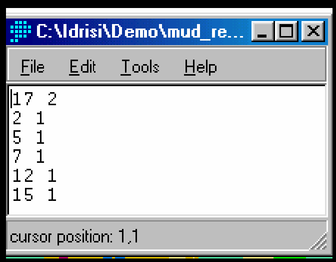
$$O\,\{R\,/M_1 \cap M_2 \cap M_3 \cap \ldots \cap M_n\} = O\,\{R\}\,.\,\prod_{i=1}^{n} LS_i$$

$$logit\,\{R\,/M_1 \cap M_2 \cap M_3 \cap \ldots \cap M_n\} = logit\,\{R\} + \sum_{i=1}^{n} W^{+}{}_i$$

Logits

TRANSITION PROBABILITIES

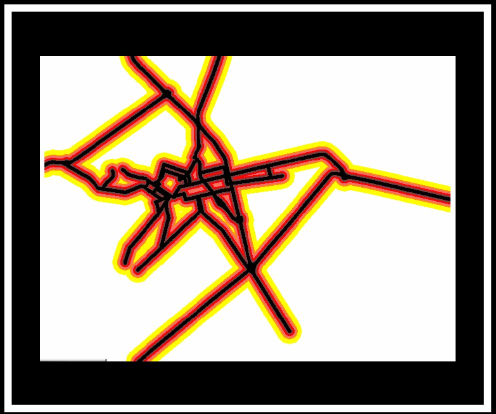
- *Table "Edit" and Map of Transition Non-Urban - Residential:*



TRANSITION PROBABILITIES - WE

- *Partial Cross-Tabulation ("Ermatt") and Numerical Output Table:*

X



vext_dist_res_serv.txt - Bloco de notas

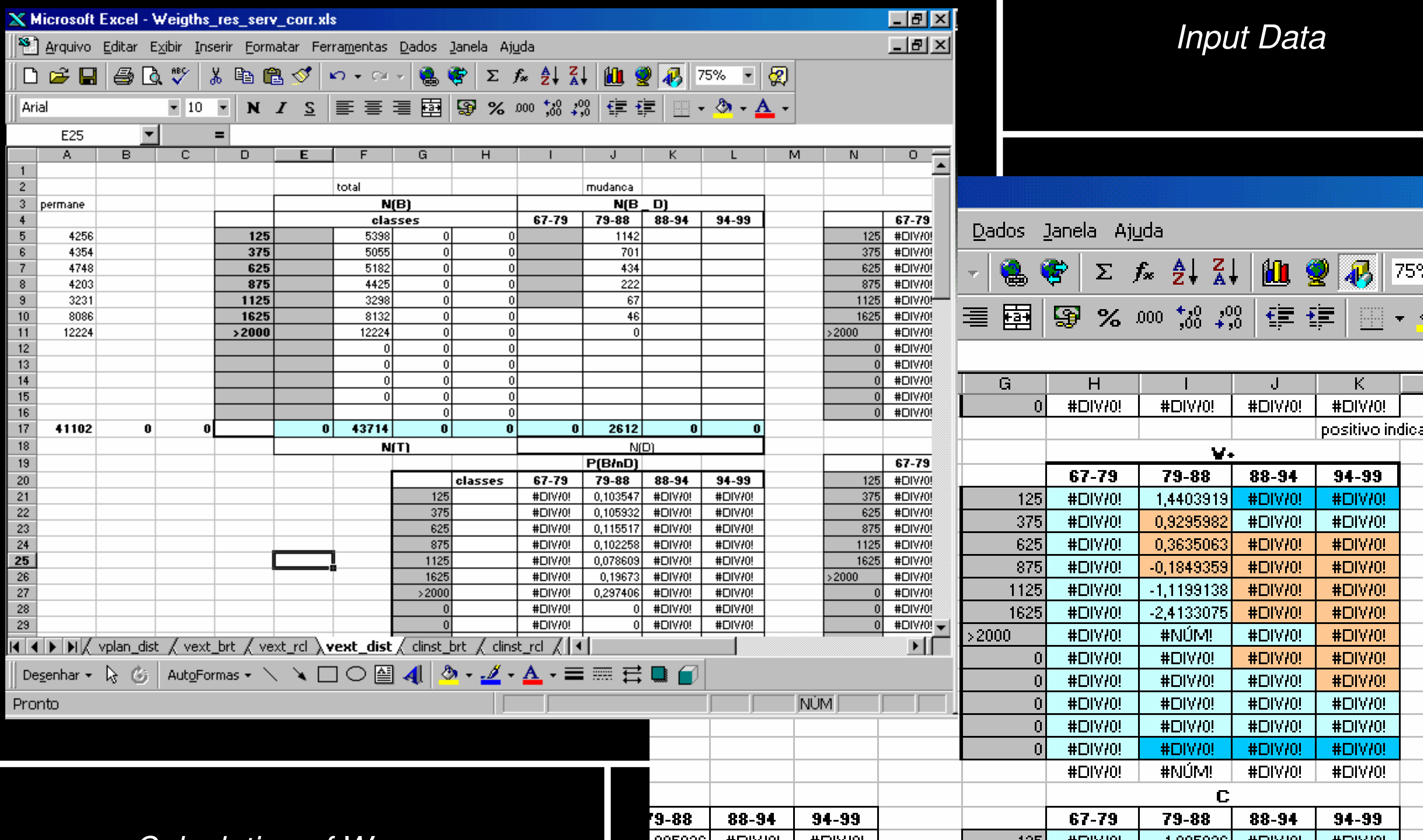
Arquivo Editar Pesquisar Ajuda

Error Matrix Analysis of MUDANCAS_RES_SERV (columns : truth) against VIAS_EXIST_DIST79

	1	2	Total	ErrorC
1	4256	1142	5398	0.2116
2	4354	701	5055	0.8613
3	4748	434	5182	1.0000
4	4203	222	4425	1.0000
5	3231	67	3298	1.0000
6	8086	46	8132	1.0000
7	12223	0	12223	1.0000
Total	41101	2612	43713	
ErrorO	0.8965	0.7316		0.8866

TRANSITION PROBABILITIES - WE

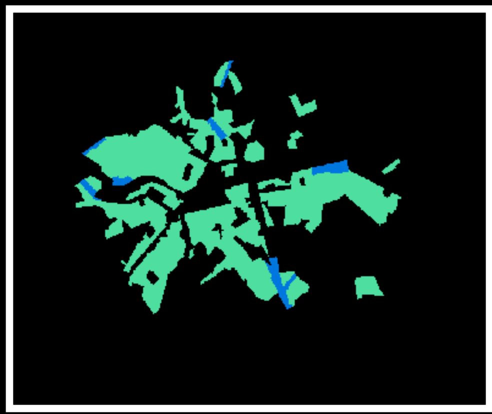
Input Data

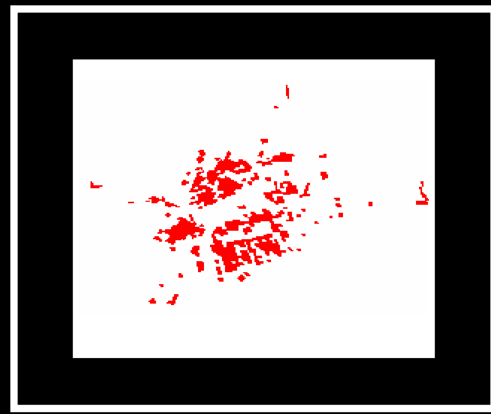


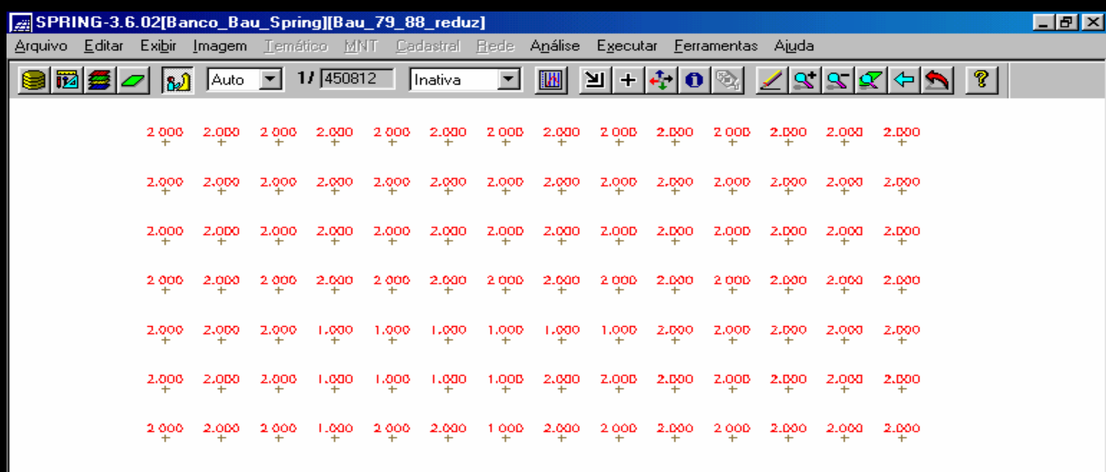
Calculation of W+

TRANSITION PROBABILITIES - LR

- *Conversíon of Maps of Dependent and Independent Variables into Numerical Grids:*



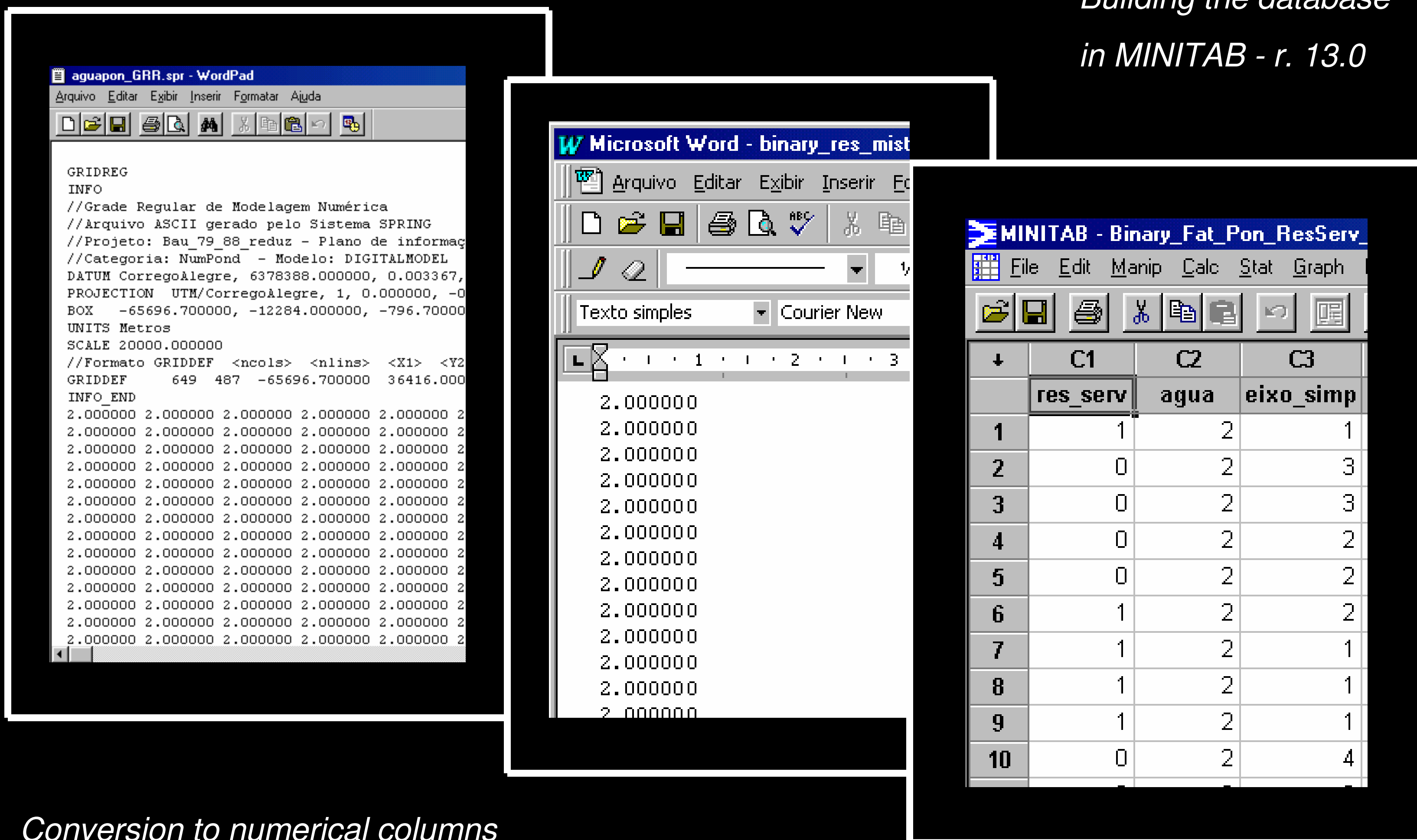




TRANSITION PROBABILITIES - LR

Building the database

in MINITAB - r. 13.0



Conversion to numerical columns

TRANSITION PROBABILITIES - WE

- *Weights of Evidence:*

$$logit\,\{R / S_1 \cap S_2 \cap S_3 \cap \ldots \cap S_n\} = logit\,\{R\} + \sum_{i=1}^{n} W^{+}_{i}$$

Natural logarithm of the ratio between the probability of occurring the event R and the probability of not occurring R, in face of the previous occurrence of evidences S_1-S_n.

TRANSITION PROBABILITIES

- *Weights of Evidence (Dinamica - CSR/UFMG):*

$$P_{x,y}\{(n,r)/(s_1 \ldots s_n)\} = \frac{O(R) \,.\, e^{\sum_{i=1}^{n} W^{+}_{x,y}}}{1 + O(R) \,.\, \sum_{j=1}^{t} e^{\sum_{i=1}^{n} W^{+}_{x,y}}}$$

$$W^{+} = \log_e \frac{P\{S/R\}}{P\{S/\bar{R}\}}$$

S = Water Supply (Evidence)

R = Non-Urb._Resid. (Event)

Similarity with the logistic function, where the linear regression equation has been replaced by the cumulative sum of W+.

TRANSITION PROBABILITIES - LR

- *Logistic Regression: Applicable in the cases where the dependent variable are dichotomous or binary (0 or 1).*

$$P\,(i,j)(x,y) = \frac{e^{\gamma_{i,j}\,.\,V_{x,y}}}{1 + \sum_{k=1}^{t} e^{\gamma_{i,j}\,.\,V_{x,y}}}$$

Vector of Variables

Vector of Coefficients

$$\gamma_{i,j} = [\;a_1\;\;b_1\;\;c_1]$$

$$V_{x,y} = \begin{bmatrix} r_{x,y} \\ u_{x,y} \\ t_{x,y} \end{bmatrix}$$

TRANSITION PROBABILITIES - LR

- Bauru: 1979-1988

Variables	Nu_Res		Nu_Ind		Nu_Serv		Res_Serv		Res_Mix	
	β_k	P	β_k	P	β_k	P	β_k	P	β_k	P
Constant β_0	7,646900	0,000	5,274530	0,000	4,865300	0,000	-1,551900	0,000	3,901200	0,000
water	#	#	#	#	#	#	1,708810	0,000	#	#
mh_dens	#	#	#	#	#	#	#	#	0,383300	0,232
soc_hous	#	#	#	#	#	#	#	#	-1,068800	0,000
com_kern	-0,924990	0,000	#	#	-1,461660	0,000	#	#	#	#
dist_ind		#	-1,048320	0,000	#	#	#	#	#	#
dist_res	#	#	#	#	0,027680	0,442	#	#	#	#
per_res	-0,392090	0,000	#	#	#	#	#	#	#	#
dist_inst	-0,405525	0,000	#	#	#	#	#	#	#	#
exist_rds	0,051476	0,000	#	#	#	#	#	#	#	#
serv_axes	#	#	-0,741110	0,000	-0,974470	0,000	-0,929550	0,000	#	#
plan_rds	#	#	#	#	#	#	#	#	-1,865200	0,000
per_rds	-0,309469	#	#	#	#	#	#	#	-0,521040	0,000

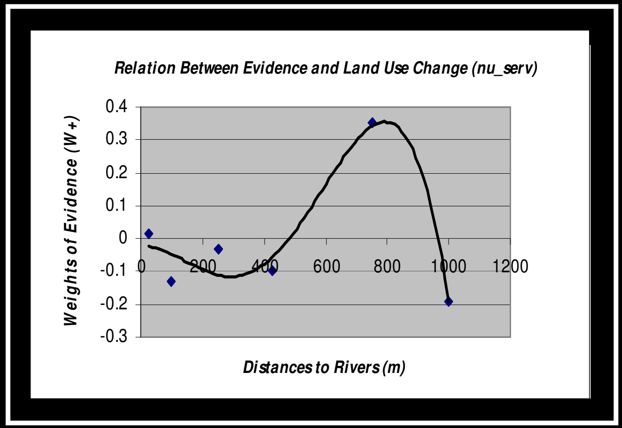
EXPLORATORY ANALYSIS

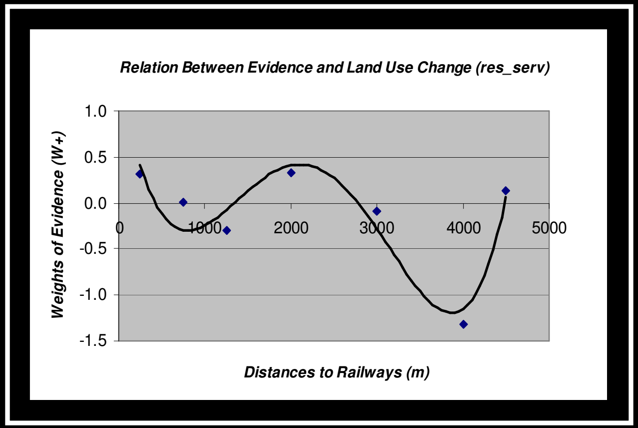
- *Hosmer & Lemeshow, 1989:*

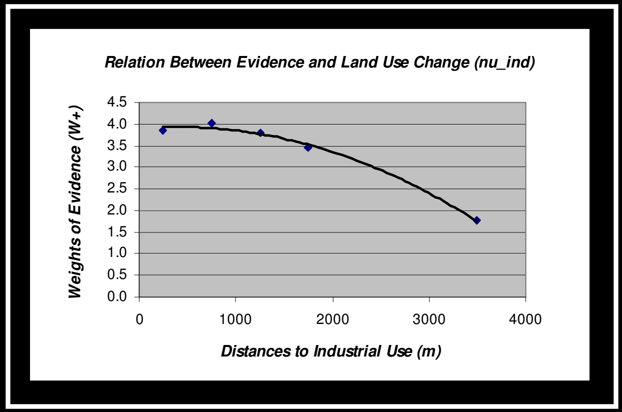
"... we must not base our models entirely on tests of statistical significance ...there are numerous other considerations that will influence our decision to include or exclude variables from a model."

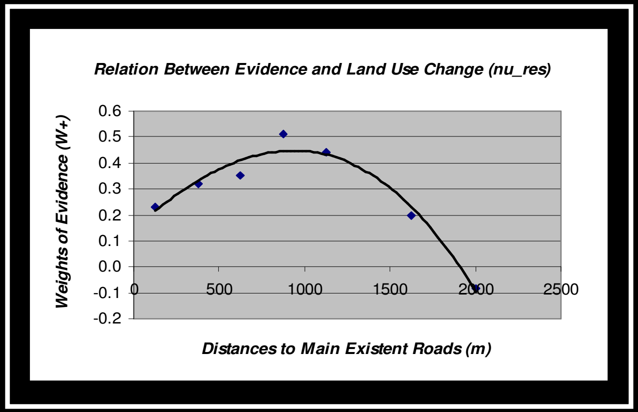
MODEL CALIBRATION

- *Empirical procedure: scatter plots analysis*



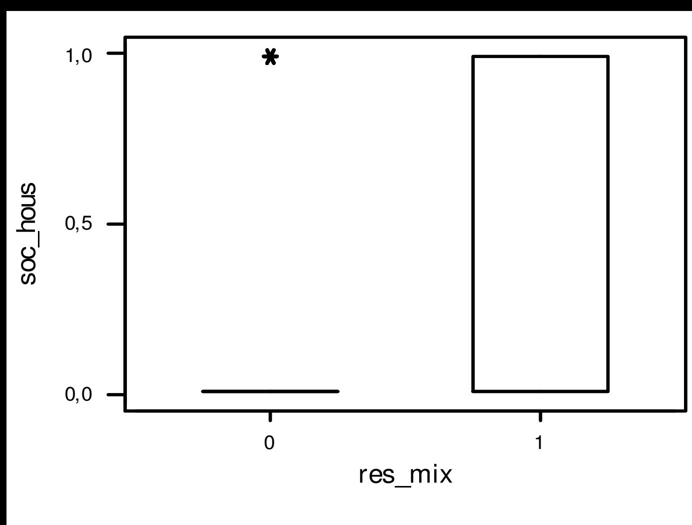




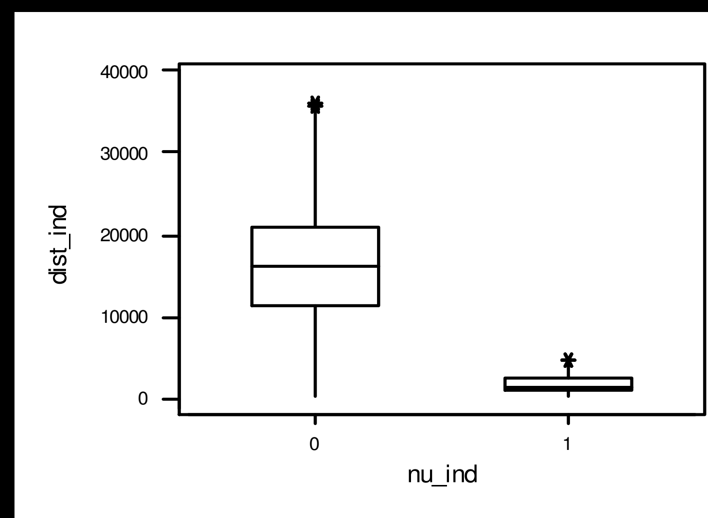


EXPLORATORY ANALYSIS

- *Boxplots Analyses:*



res_mix x soc_hous



nu_ind x dist_ind

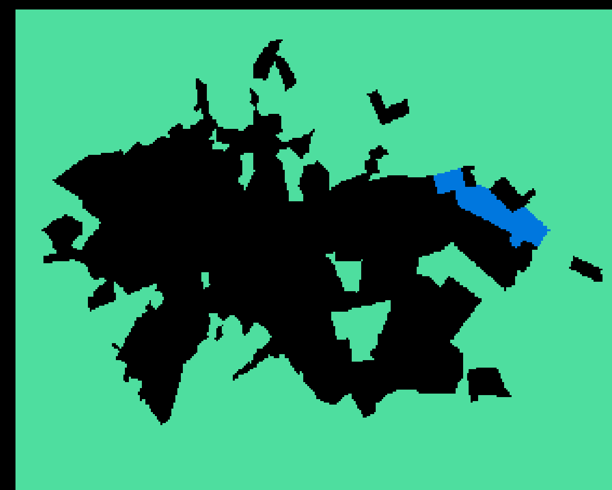
EXPLORATORY ANALYSIS

- *Couclelis, 1997:*

"To take full advantage of CA models as qualitative forecasting tools, planners and others need to rely as much on their right-brain powers of pattern recognition and relationship perception as on left-brain analyses of the inevitably inaccurate quantitative outputs."

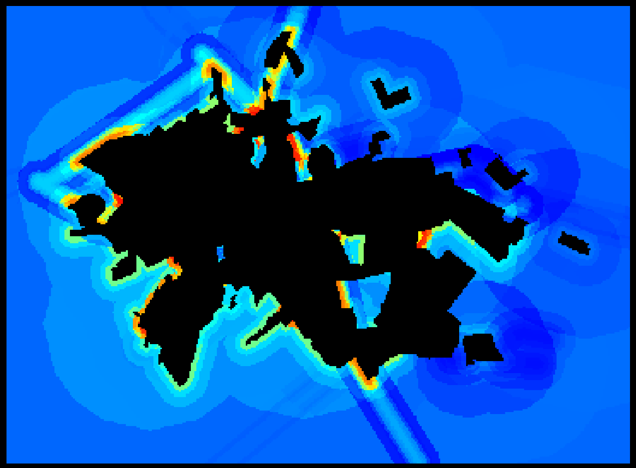
MAP OF TRANSITION PROBABILITIES - WE

Map of Probabilities



Map of Transition 79-88: nu_ind

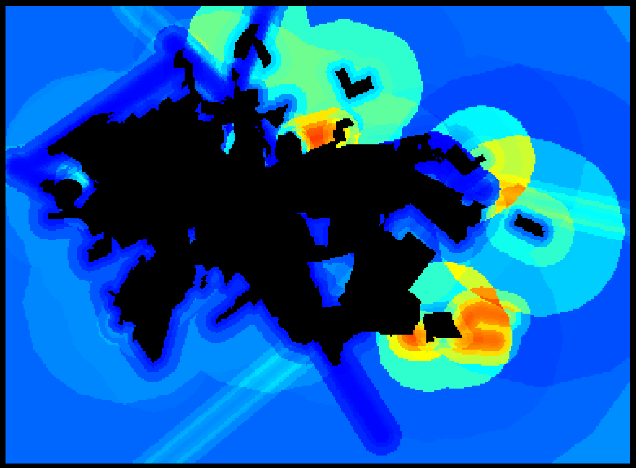
MAP OF TRANSITION PROBABILITIES - WE



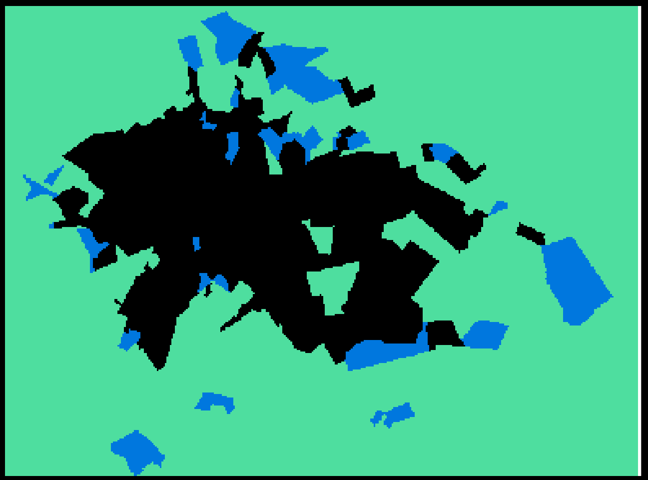
Map of Probabilities

Map of Transition 79-88: nu_serv

MAP OF TRANSITION PROBABILITIES - WE

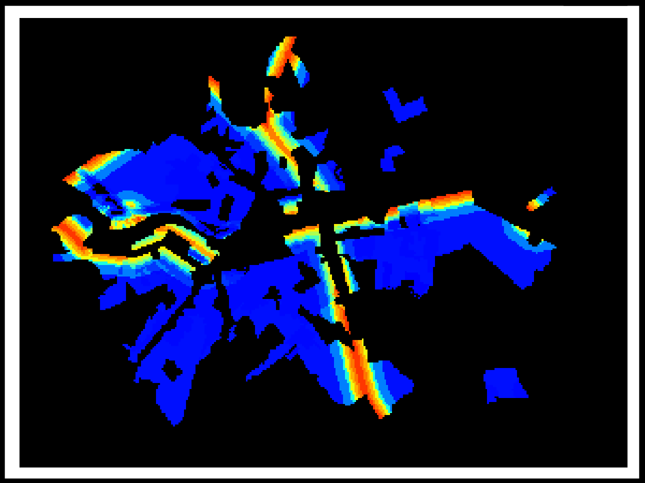


Map of Probabilities

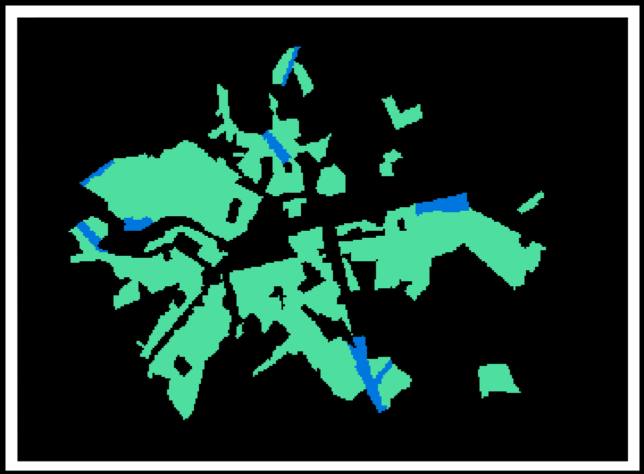


Map of Transition 79-88: nu_res

MAP OF TRANSITION PROBABILITIES - WE

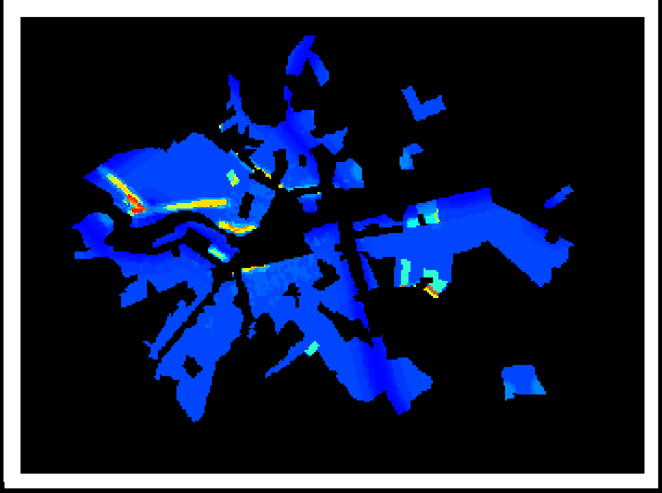


Map of Probabilities



Map of Transition 79-88: res_serv

MAP OF TRANSITION PROBABILITIES - WE

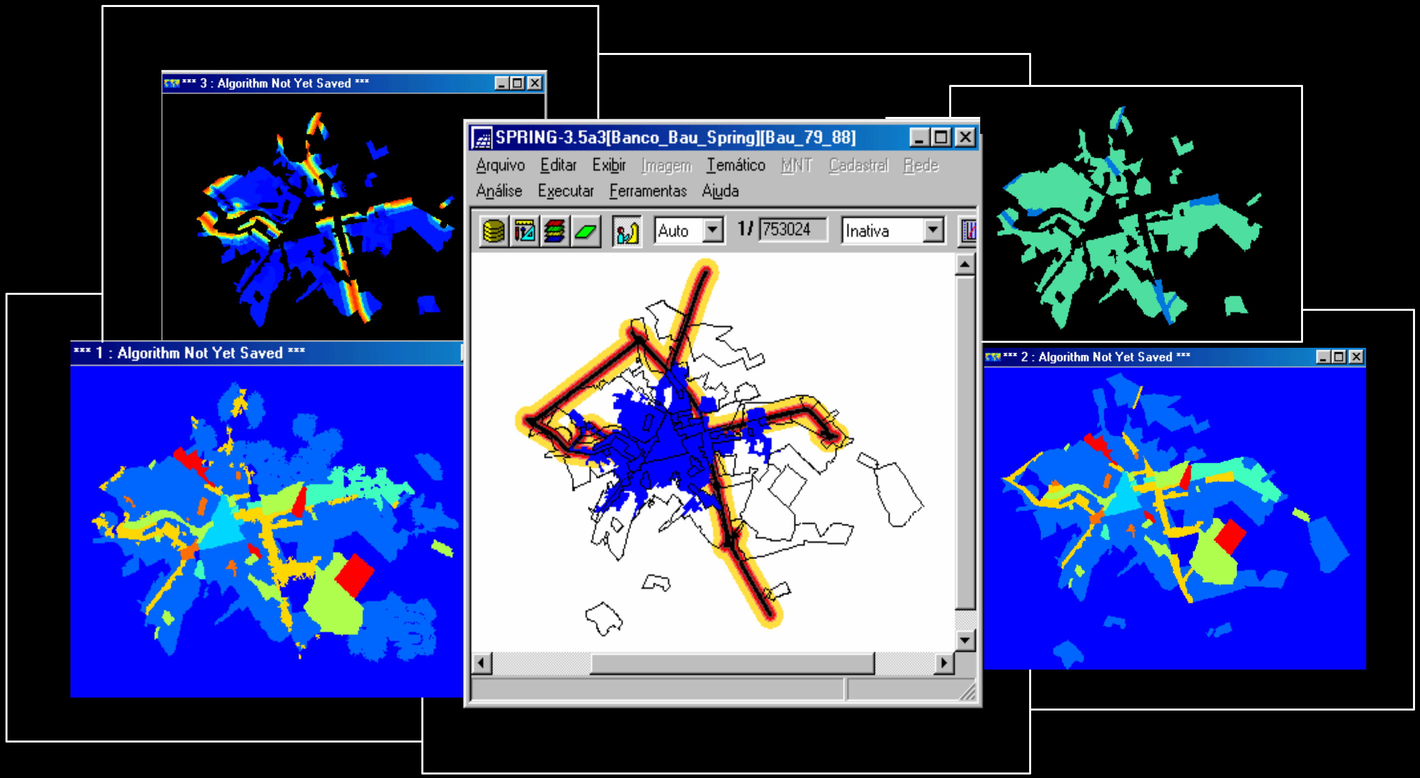


Map of Probabilities

Map of Transition 79-88: res_mix

MODEL CALIBRATION

- *Empirical procedure: visual comparative analysis*

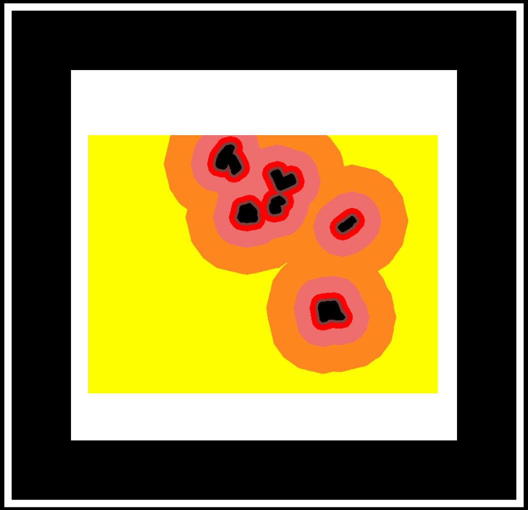


MODEL CALIBRATION

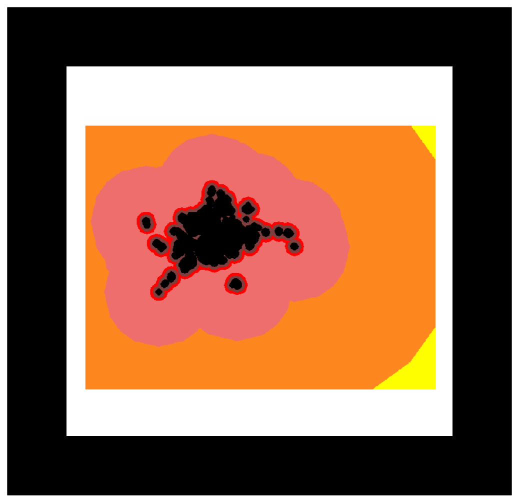
- *Final Sets of Evidence Maps for Each Type of Land Use Change:*

	NU_RES	NU_IND	NU_SERV	RES_SERV	RES_MIX
water				✓	
mh_dens					✓
soc_hous					✓
com_kern	✓		✓		
dist_ind		✓			
dist_res			✓		
per_res	✓				
dist_inst	✓				
exist_rds	✓				
serv_axes		✓	✓	✓	
plan_rds					✓
per_rds	✓				✓

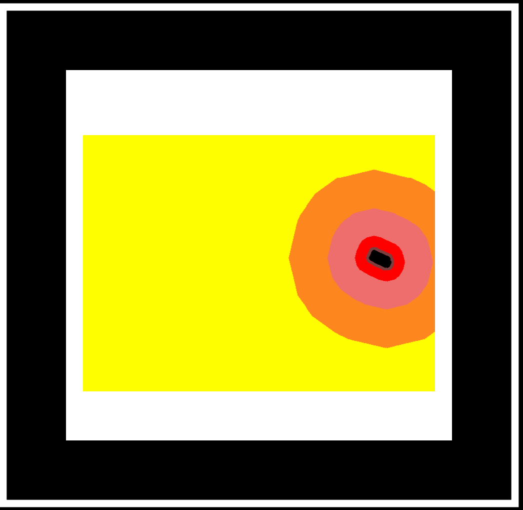
EVIDENCES MAPS: NU_RES



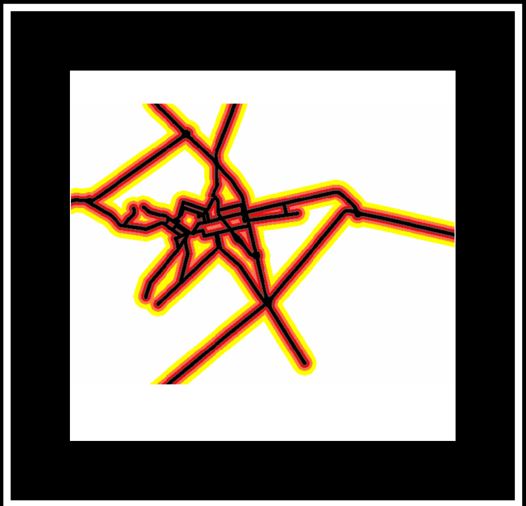
Distances to Periph. Residential Settlements



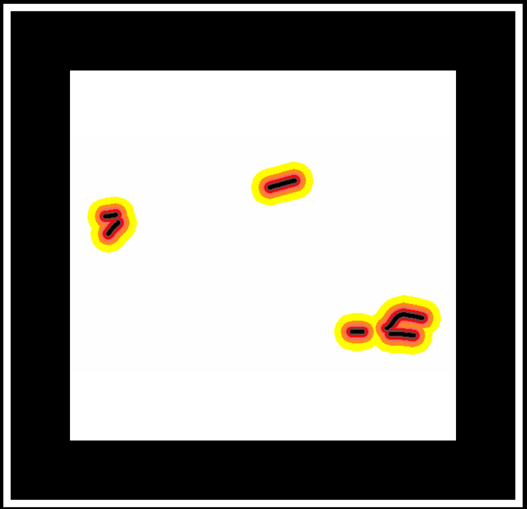
Distances to Ranges of Commercial Clusters



Distances to Periph. Institutional Equipments

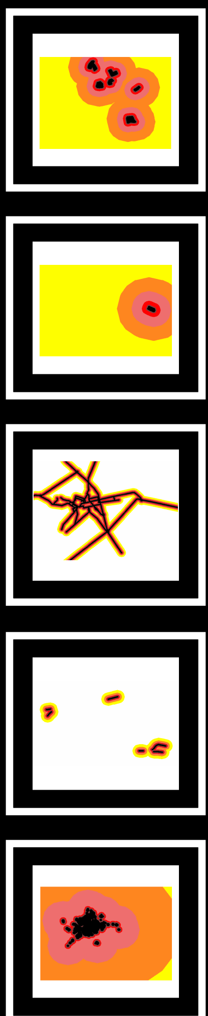


Distances to Main Roads



Distances to Peripheral Roads

EVIDENCES MAPS: NU_RES



- *previous existence of residential settlements in the surroundings*

  POSSIBILITY OF EXTENDING BASIC INFRASTRUCTURE

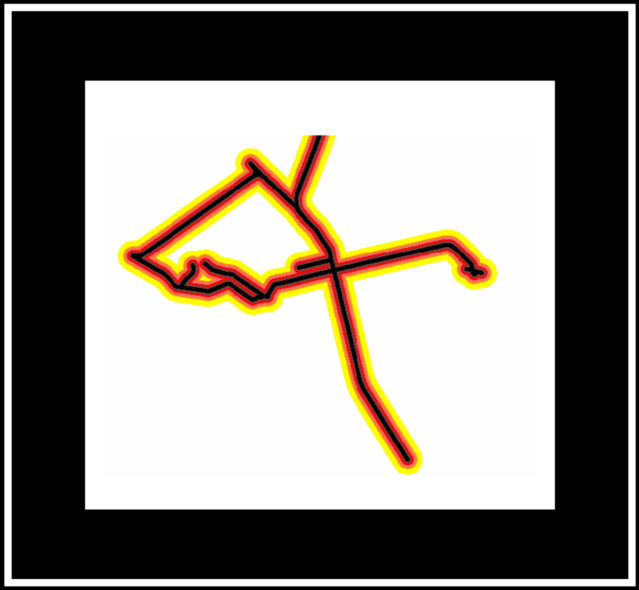
- *accessibility to such areas*

  NEED OF COMMUTING TO WORK IN CENTRAL AREAS

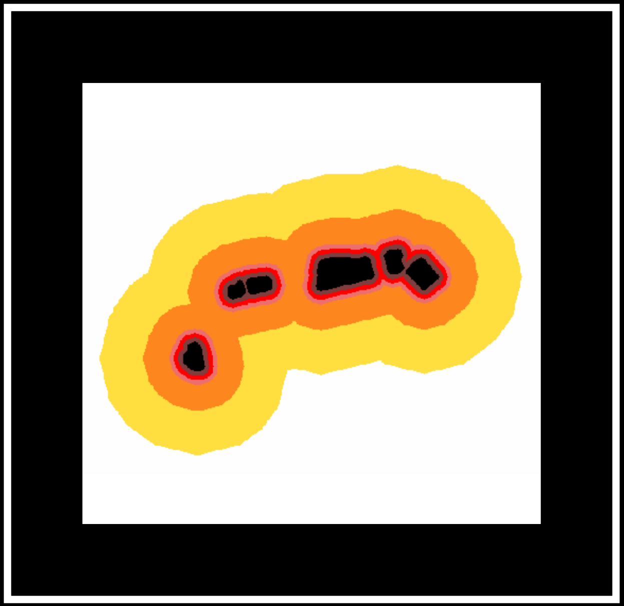
- *proximity to commercial activities clusters*

  WITHIN REASONABLE DISTANCES

EVIDENCES MAPS: NU_IND

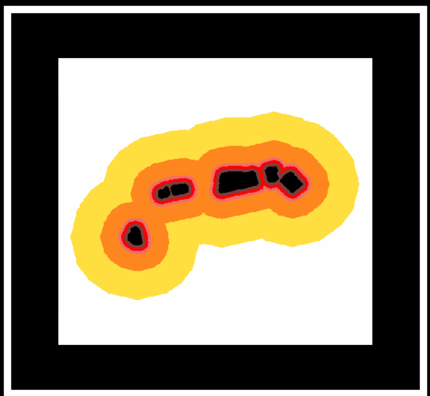


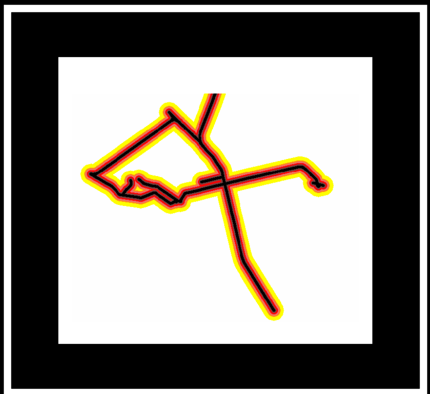
Distances to the Services Axes



Distances to Industrial Use

EVIDENCES MAPS: NU_IND

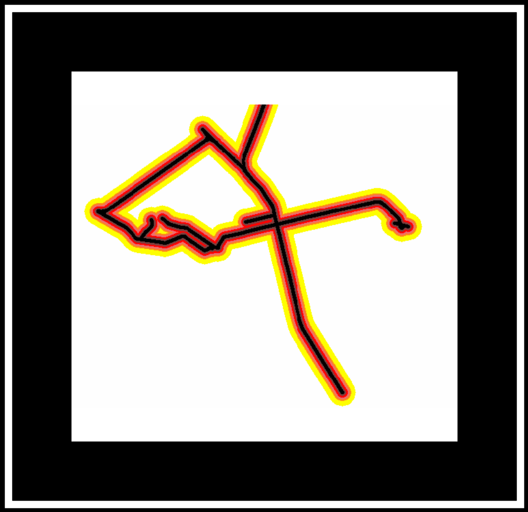




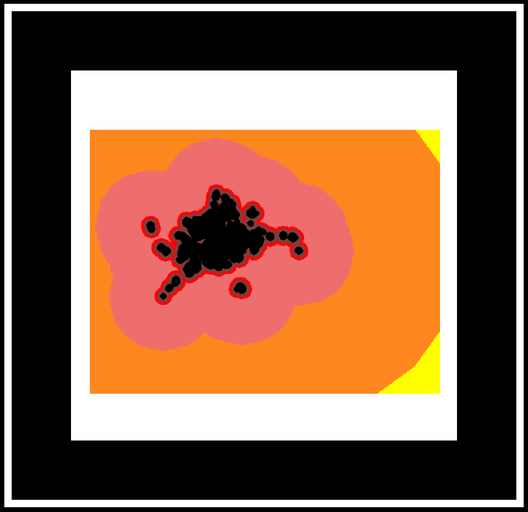
- nearness to previously existent industrial use
- availability of road access

EVIDENCES MAPS: NU_SERV

Distances to Residential Use

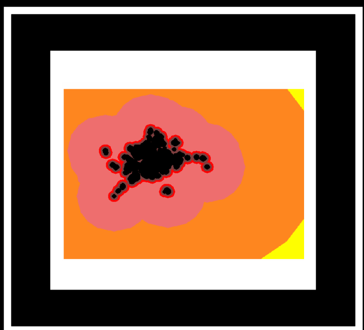


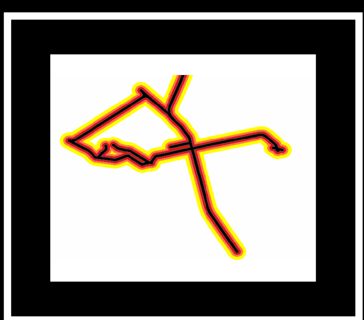
Distances to the Services Axes



Distances to Ranges of Commercial Clusters

EVIDENCES MAPS: NU_SERV.





- *proximity to clusters of commercial activities*

  SUPPLIERS MARKET

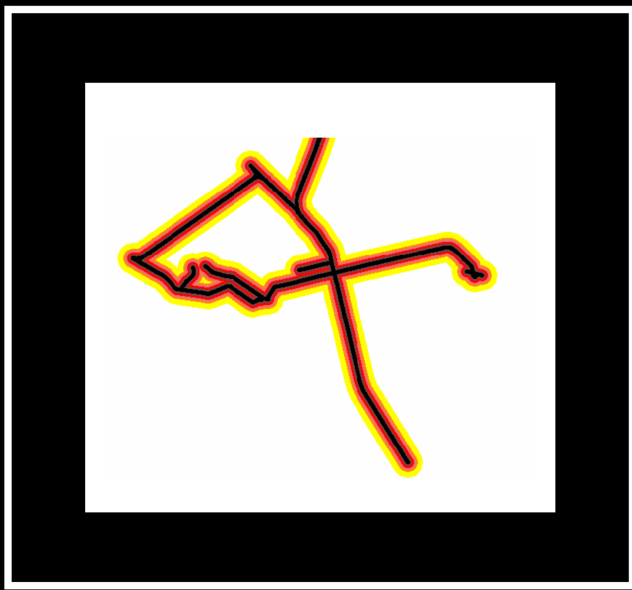
- *closeness to areas of residential use*

  CONSUMERS MARKET

- *strategic location in relation to the N-S/ E-W services axes*

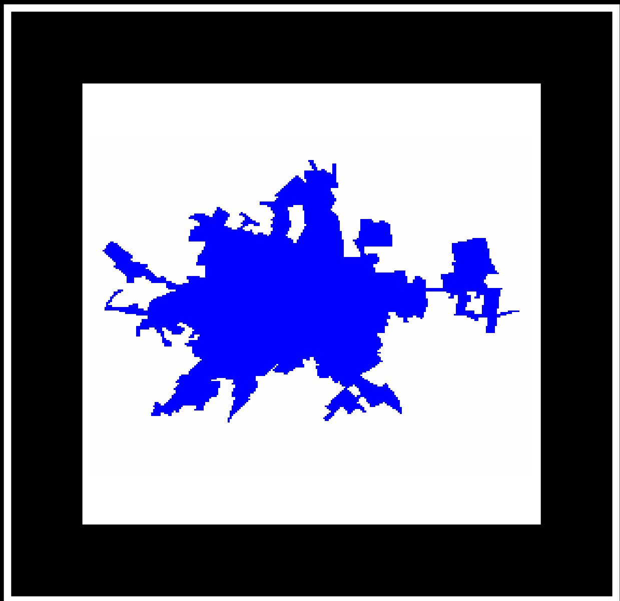
  ACCESSIBILITY TO MARKETS

EVIDENCES MAPS: RES_SERV

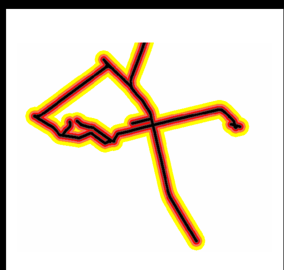


Distances to the Services Axes

Water Supply



EVIDENCES MAPS: RES_SERV.



- *takes place in nearly established urban areas*

  CLOSE TO SUPPLIERS AND CONSUMERS MARKETS

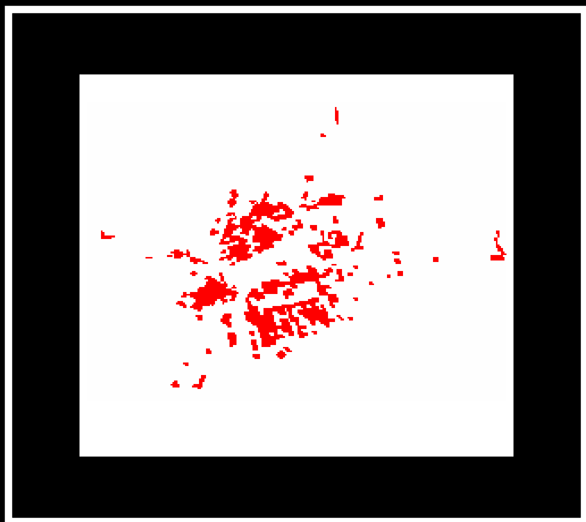
- *strategic location in relation to the N-S/ E-W services axes*

  ACCESSIBILITY

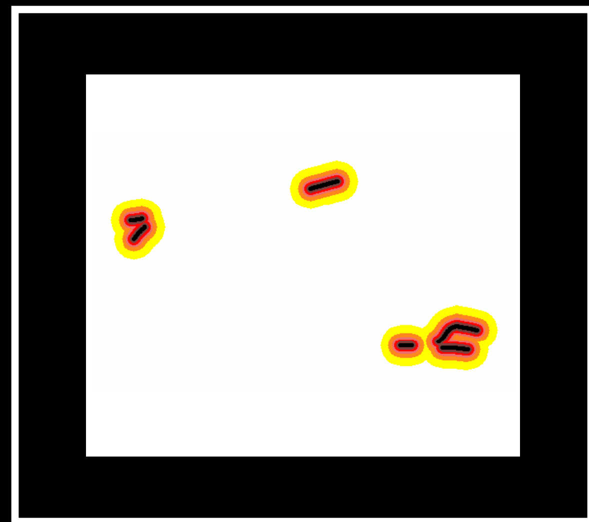
- *absence of water supply (t_i)*

  IMMEDIATE FRINGE OF ESTABLISHED URBAN AREAS

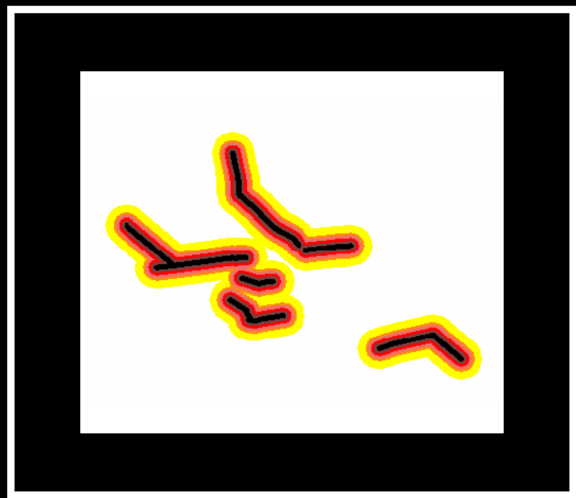
EVIDENCES MAPS: RES_MIX



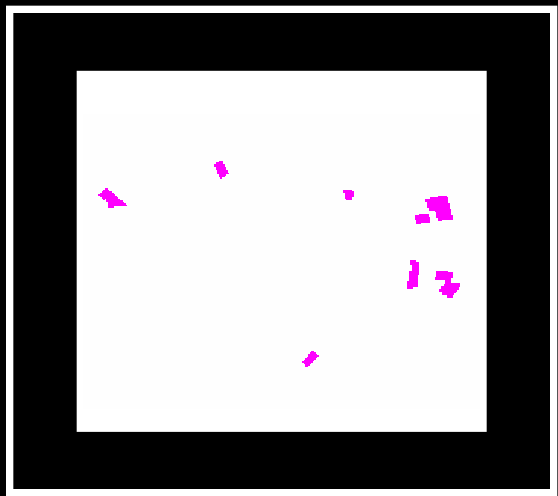
Occurrence of Medium-High Density



Distances to Peripheral Roads

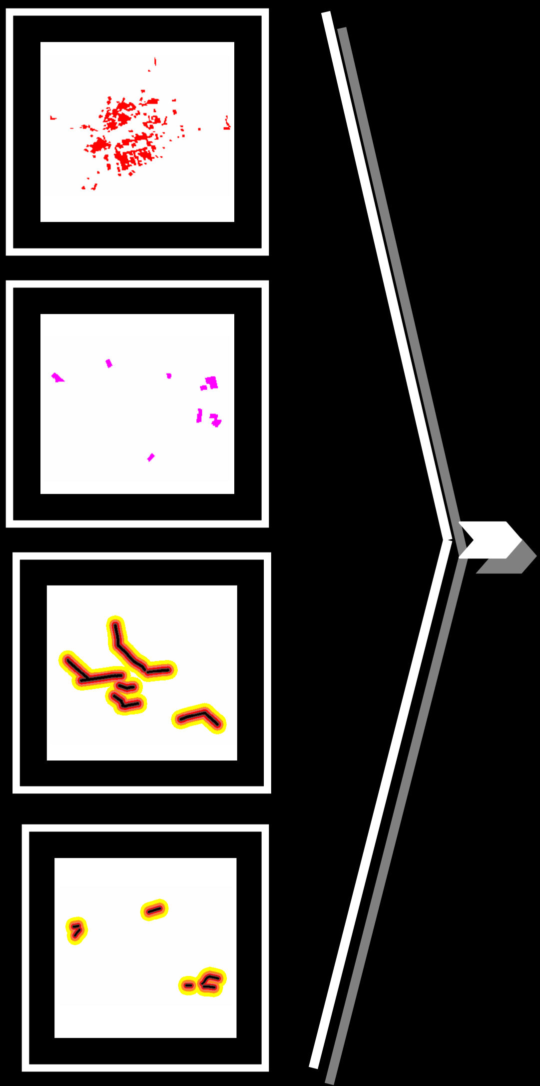


Distances to Planned Roads



Existence of Social Housing

EVIDENCES MAPS: RES_MIX



- *mixed zones play the role of urban sub-centers*

  STRENGTHENING OF FORMER SECONDARY COMMERCIAL CENTRES

- *existence of a greater occupational gathering*

  IMPLIES ECONOMIC SUSTAINABILITY

- *nearness to planned or peripheral roads*

  ACCESSIBILITY IN FARTHER AREAS

EVIDENCES MAPS: CONCLUSIONS

- *Land use transitions show to comply with*

economic theories of urban growth and change (Black and Henderson, 1999; Medda et al., 1999; Papageorgiou and Pines, 2001; Zhou and Vertinsky, 2001), where there is a continuous search for optimal location, able to assure:

- *competitive real state prices,*
- *good accessibility conditions,*
- *rationalization of transportation costs*
- *and a strategic location in relation to suppliers and consumers markets.*

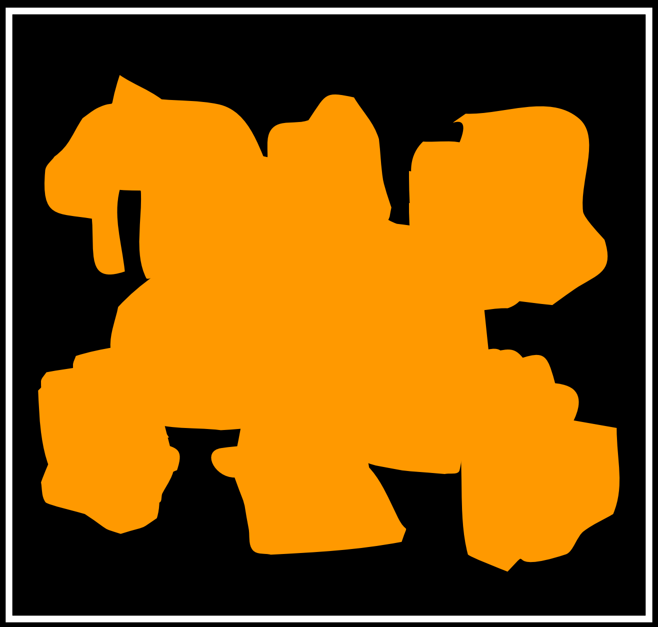
MODEL CALIBRATION

- *Dinamica - Final Parameters:*

Transitions	Average Size of Patches	Variance of Patches	Proportion of "Expander"	Proportion of "Patcher"	Number of Iterations
nu_res	1100	500	0,65	0,35	5
nu_ind	320	1	1,00	0	5
nu_serv	25	2	0,50	0,50	5
res_serv	25	2	0,10	0,90	5
res_mix	35	2	0	1,00	5

TRANSITION ALGORITHMS

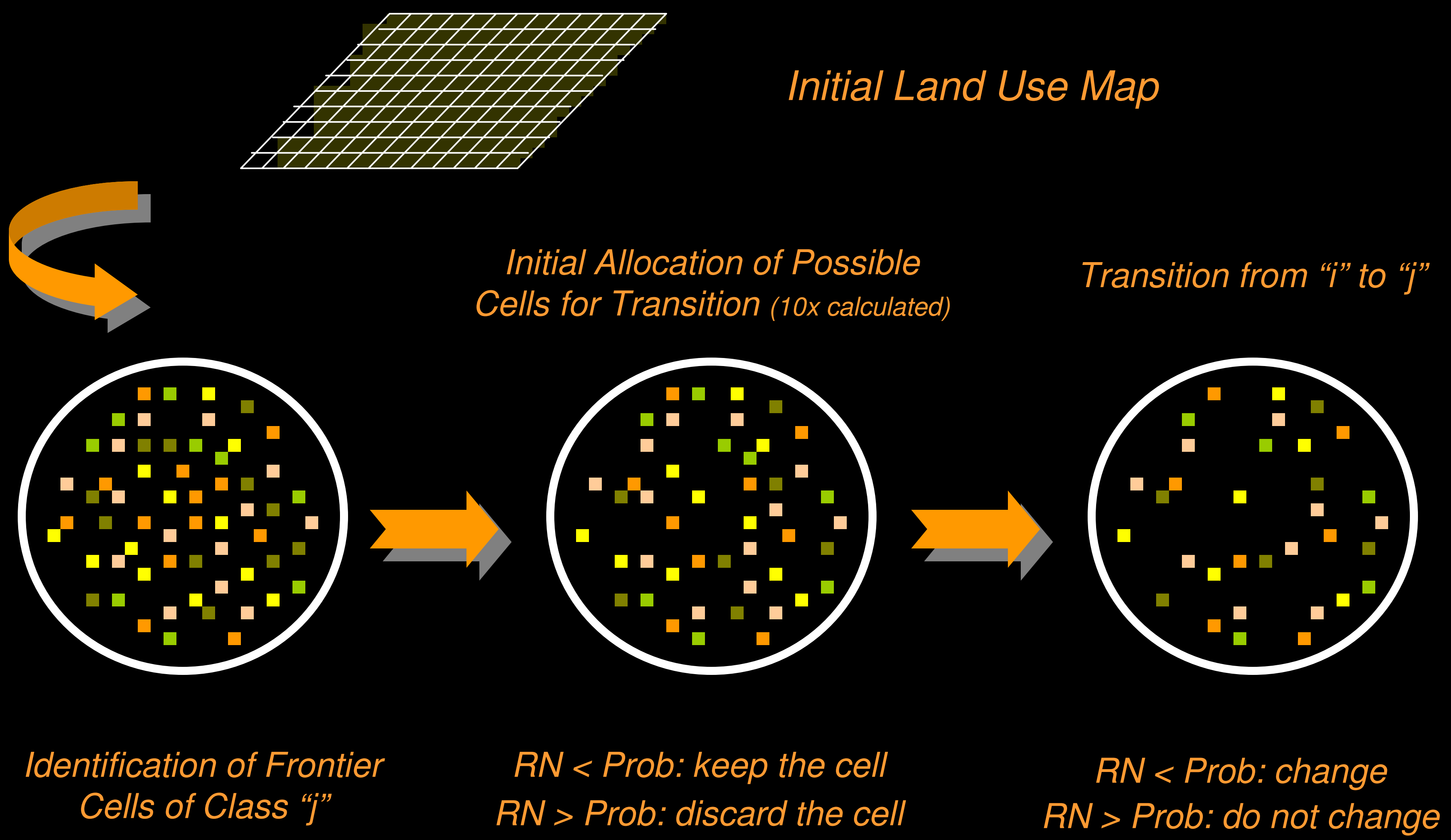
- *"Expander":*



➡ *transitions from "i" to "j ",*

➡ *only in the adjacent vicinities of cells with state "j ".*

“EXPANDER” ALGORITHM

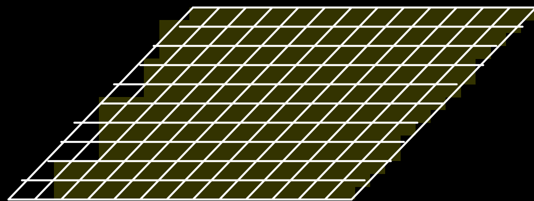


TRANSITION ALGORITHMS

- *"Patcher":*

- *transitions from "i" to "j ",*
- *only in the adjacent vicinities of cells with a state other than "j ".*

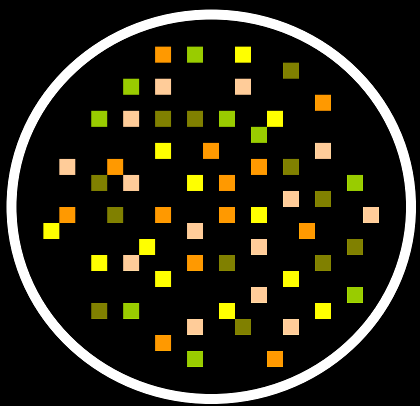
“PATCHER” ALGORITHM

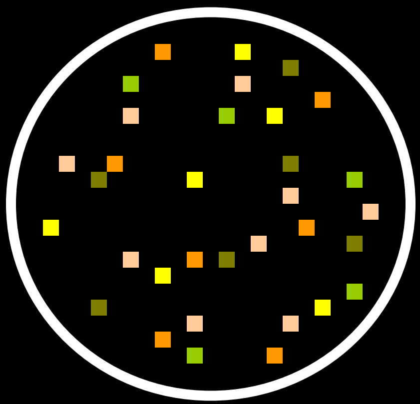


Initial Land Use Map

Initial Allocation of Possible Cells for Transition

Transition from “i” to “j”

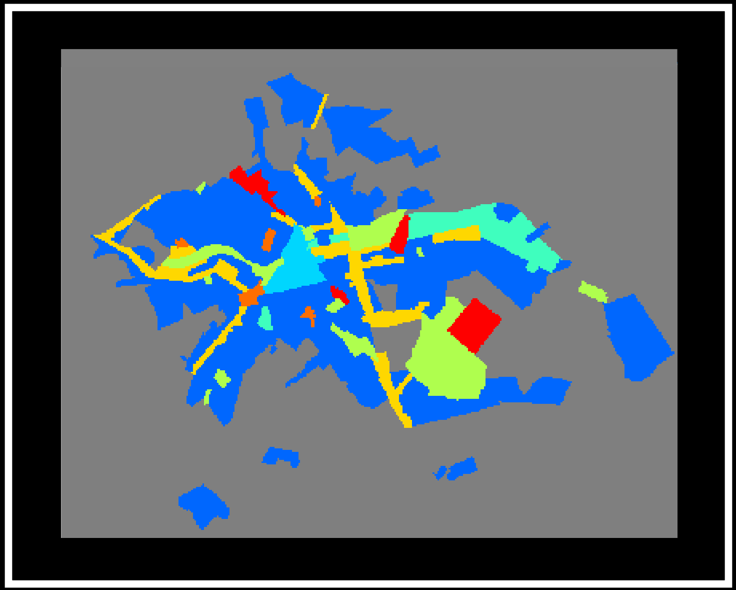




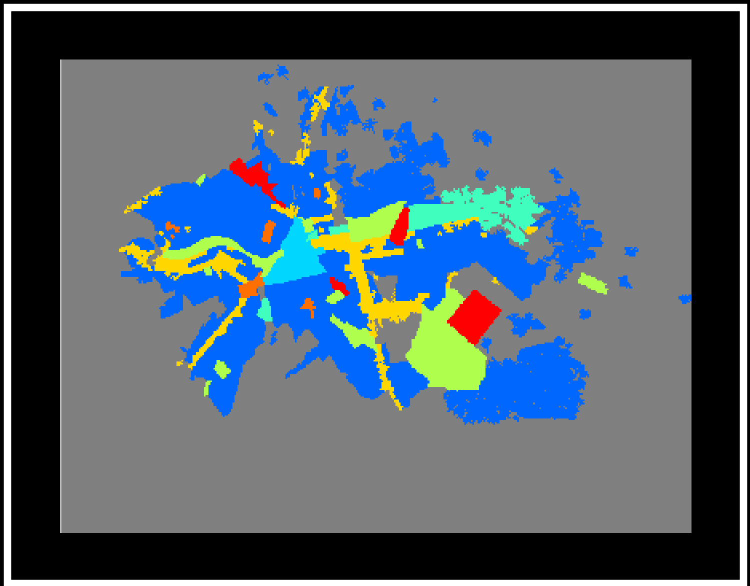
Identification of Cells with Neighbours other than “j”

RN < Prob: change
RN > Prob: do not change

SIMULATION OUTPUTS - WE

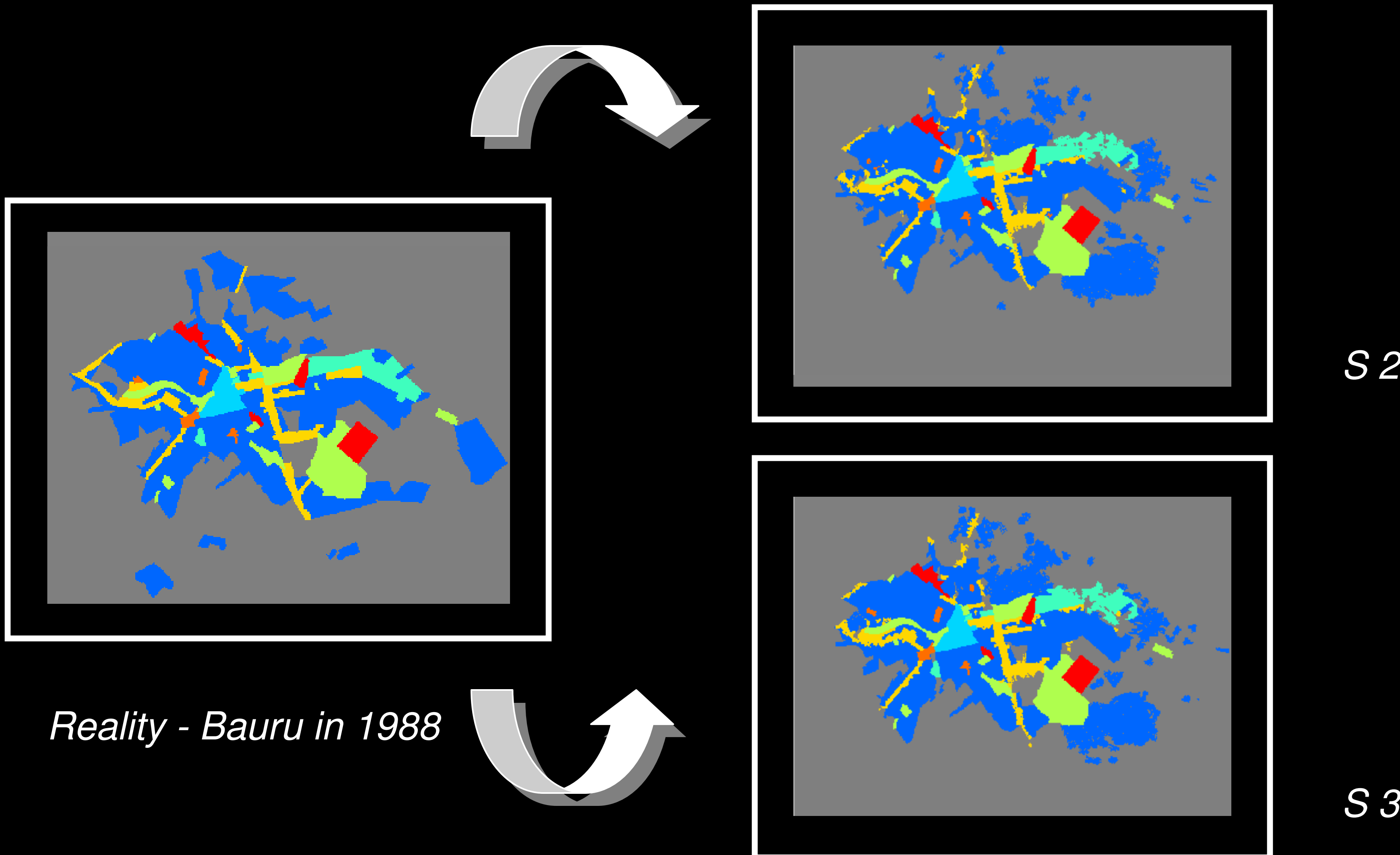


Reality - Bauru Land Use in 1988

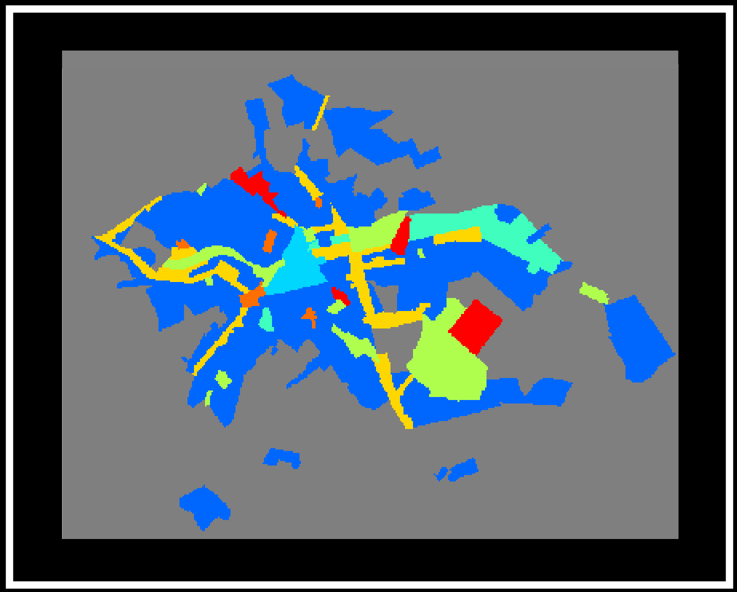


S 1

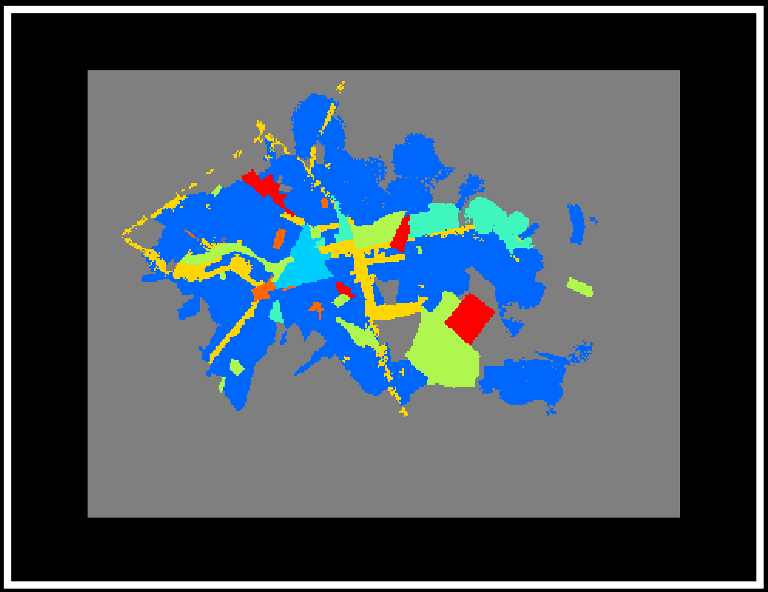
SIMULATION OUTPUTS - WE



SIMULATION OUTPUTS - LR

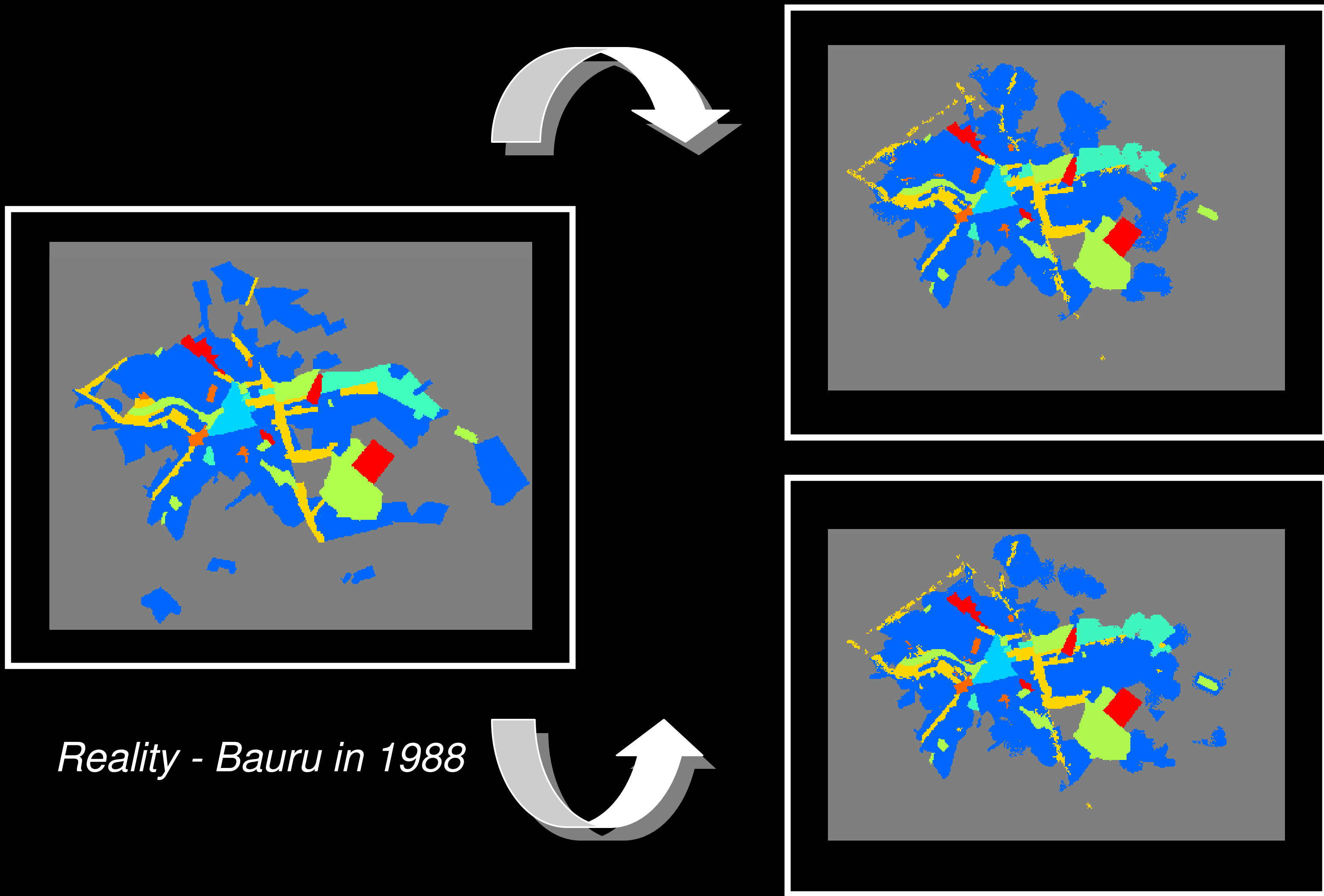


Reality - Bauru in 1988



S 1

SIMULATION OUTPUTS - LR



Reality - Bauru in 1988

S 2

S 3

COMMENTS ON SIMULATIONS

- the services corridors, the industrial area and the mixed use zone were well modelled in all of the three simulations;

- non-urban areas to residential use: the most challenging category for modelling, due to the fact that:

  - boundaries of detached residential settlements are highly unstable factors (merging/split of plots);

  - exact areas for their occurrence is imprecise (landlords' and entrepreneur's decisions);

  - 65% of this type of change is carried out through the expander, in which, after a random selection of a seed cell, its neighbouring cells start to undergo transitions regardless of their transition probability values.

MODEL VALIDATION

- *Multiple Resolution Procedure or "Goodness of Fit"* (Constanza, 1989)

SCENE 1

REAL

1	1	1	1	2	2	2	3	3	3
1	1	1	2	2	2	3	3	3	3
1	1	2	2	2	3	3	3	3	3
3	3	2	2	3	3	3	3	3	3
1	3	3	3	3	3	3	3	3	3
1	1	1	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	3	3
3	3	3	3	3	3	3	3	3	3
3	3	3	3	2	2	3	3	3	3
3	3	3	3	2	2	2	2	3	3

1 x 1 WINDOW

F = 1

2 x 2 WINDOW

F = 1 - 4/8 = 0.50

3 x 3 WINDOW

F = 1 - 6/18 = 0.66

SCENE 2

SIMULATION

1	1	2	2	2	2	2	2	3	3
1	1	1	1	2	3	3	3	3	3
1	1	1	2	3	3	3	3	3	3
3	1	2	2	3	3	3	4	4	4
3	3	3	3	3	3	3	3	3	3
1	1	1	3	3	3	3	3	3	3
1	1	2	2	2	2	2	2	3	3
1	2	2	3	3	2	2	3	3	3
3	3	3	3	2	2	2	3	3	3
3	3	3	3	2	2	2	2	3	3

MODEL VALIDATION

- *Multiple Resolution Procedure or "Goodness of Fit"* (Constanza, 1989)

SCENE 1

REAL

1	1	1	1	2	2	2	3	3	3
1	1	1	2	2	2	3	3	3	3
1	1	2	2	2	3	3	3	3	3
3	3	2	2	3	3	3	3	3	3
1	3	3	3	3	3	3	3	3	3
1	1	1	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	3	3
3	3	3	3	3	3	3	3	3	3
3	3	3	3	2	2	3	3	3	3
3	3	3	3	2	2	2	2	3	3

SCANNING OF A

3 x 3 WINDOW

SCENE 2

SIMULATION

1	1	2	2	2	2	2	2	3	3
1	1	1	1	2	3	3	3	3	3
1	1	1	2	3	3	3	3	3	3
3	1	2	2	3	3	3	4	4	4
3	3	3	3	3	3	3	3	3	3
1	1	1	3	3	3	3	3	3	3
1	1	2	2	2	2	2	2	3	3
1	2	2	3	3	2	2	3	3	3
3	3	3	3	2	2	2	3	3	3
3	3	3	3	2	2	2	2	3	3

GOODNESS OF FIT

- *Multiple Resolution Procedure:*

$$F_w = \frac{\displaystyle\sum_{s=1}^{tw} \left[1 - \sum_{i=1}^{p} \frac{|a_{i1} - a_{i2}|}{2w^2} \right]}{t_w}$$

$$F_t = \frac{\displaystyle\sum_{w=1}^{n} F_w \, e^{-k(w-1)}}{\displaystyle\sum_{w=1}^{n} e^{-k(w-1)}}$$

MODEL VALIDATION - W.E.

- *Results for Windows 3 x 3, 5 x 5 and 9 x 9:*

Simulations	Goodness of Fit (F)
S 1	F = 0.902937
S 2	F = 0.896092
S 3	F = 0.901134

MODEL VALIDATION - L.R.

- *Results for Windows 3 x 3, 5 x 5 and 9 x 9:*

Simulations	Goodness of Fit (F)
S 1	F = 0.905172
S 2	F = 0.907539
S 3	F = 0.907868

ANNUAL TRANSITION RATES

- *Annual Transition Matrix - Principal Components Method* (Bell & Hinoja, 1977):

$$TM_{annual} = H \quad . \quad V^{1/n} \quad . \quad H^{-1}$$

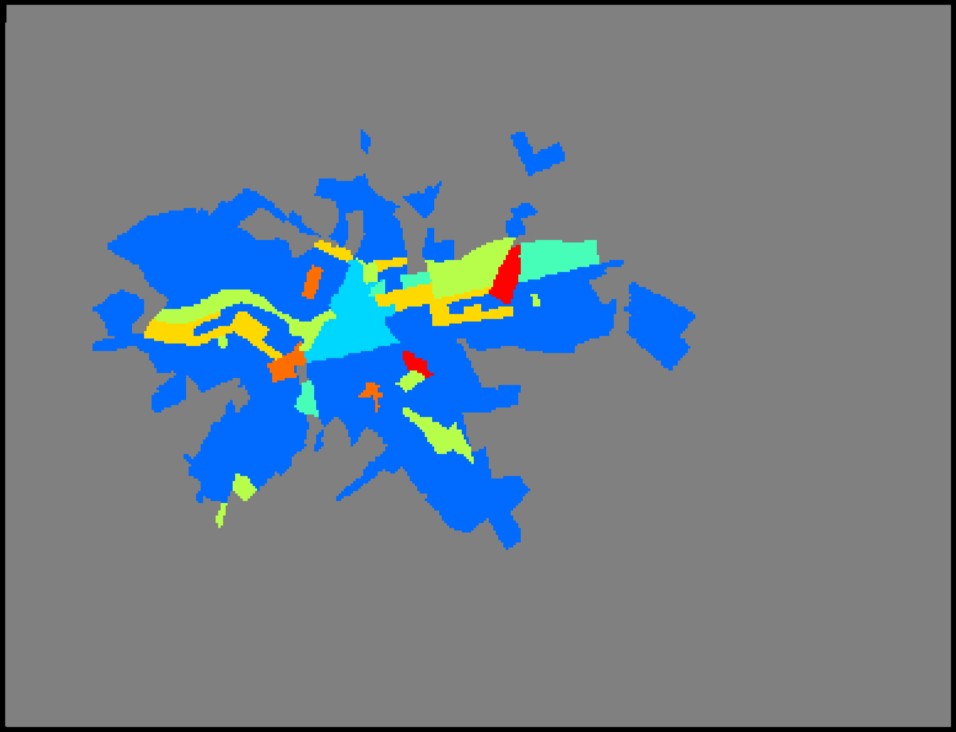
H: Eigen-vector of the global TM

$V^{1/n}$: Eigen-value of the global TM

n= number of steps

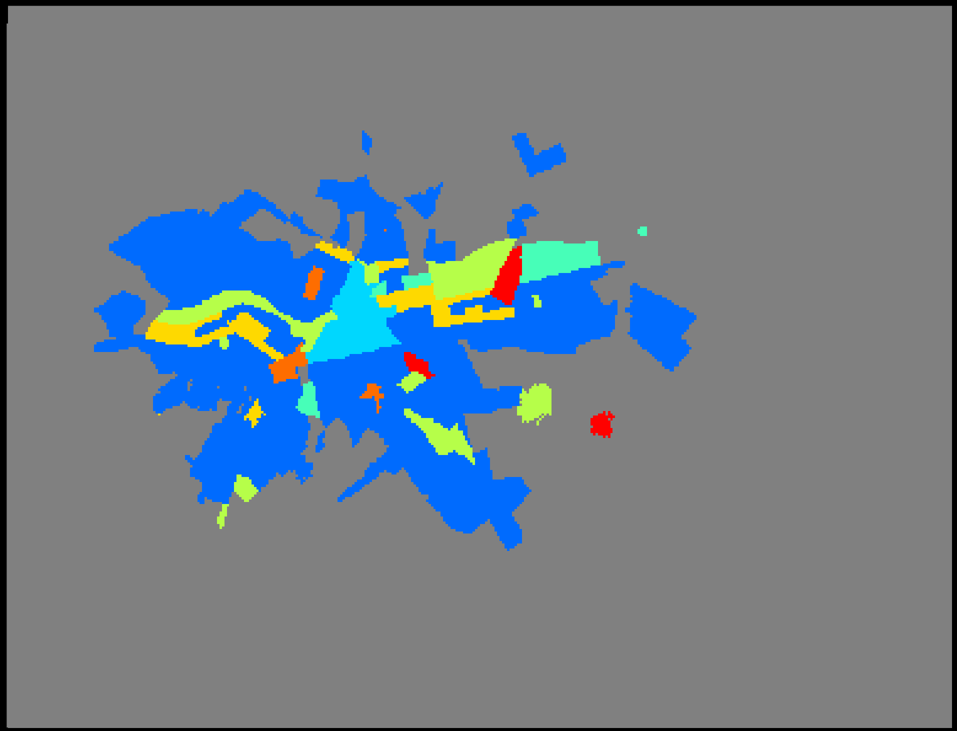
H^{-1}: Inversed eigen-vector of the global TM

ANNUAL SIMULATIONS - BAURU



1967

ANNUAL SIMULATIONS - BAURU



1968

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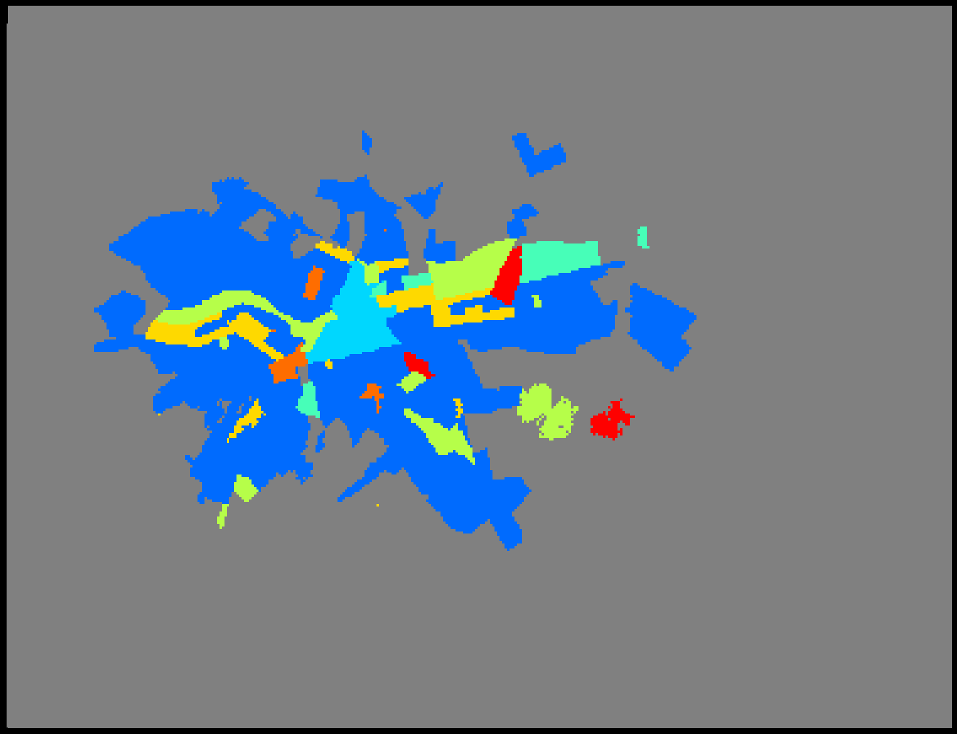

1969

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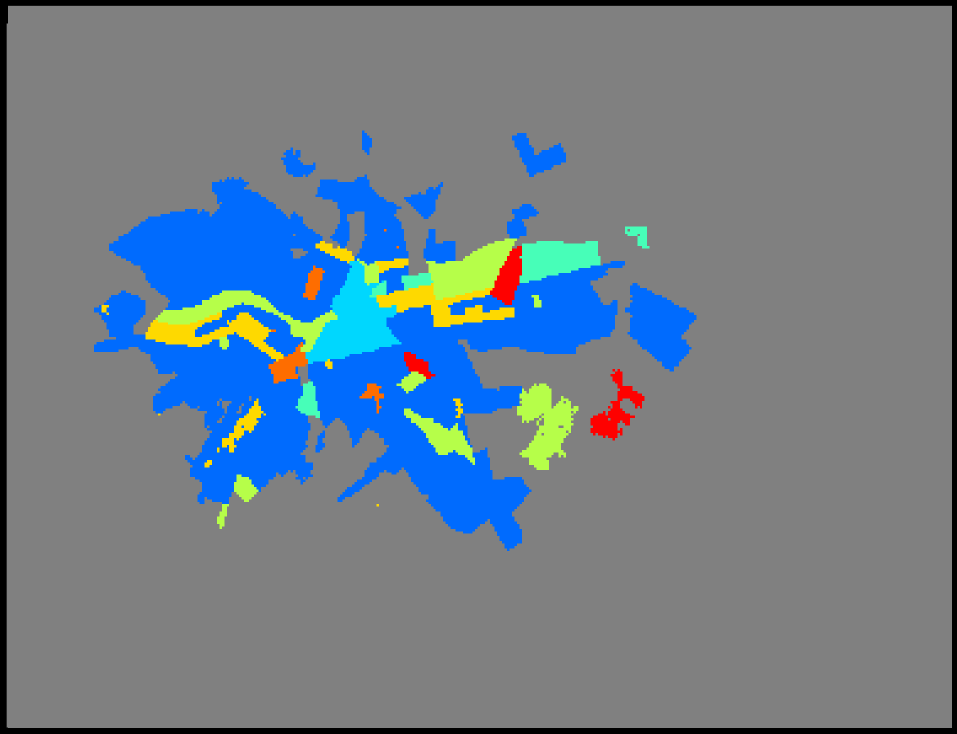
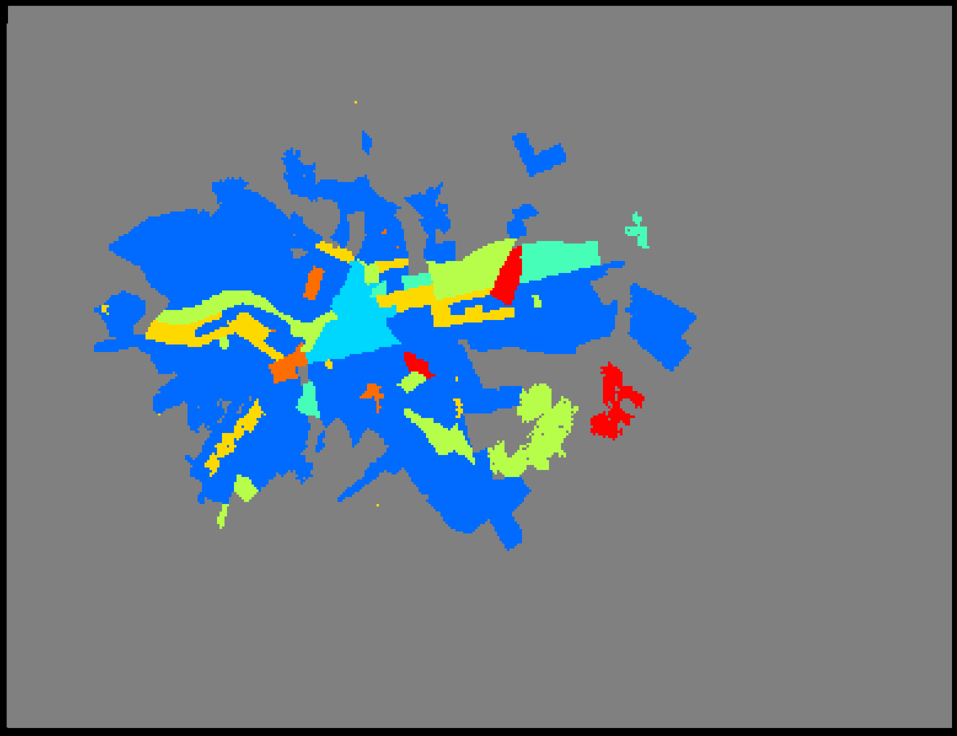


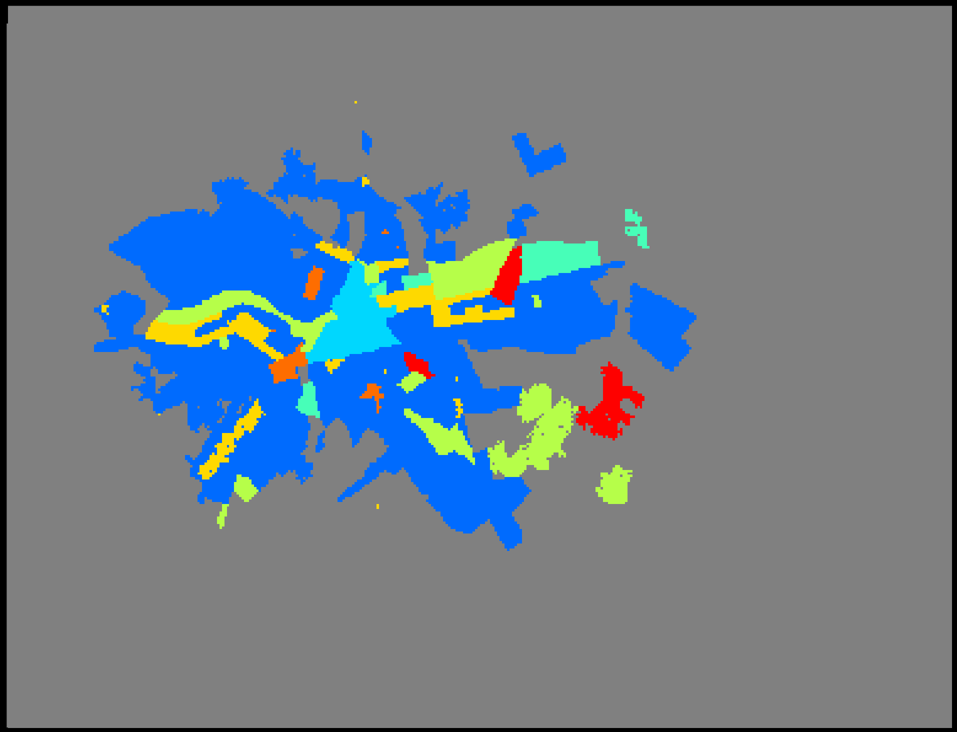
1970

ANNUAL SIMULATIONS - BAURU



1971

ANNUAL SIMULATIONS - BAURU



1972

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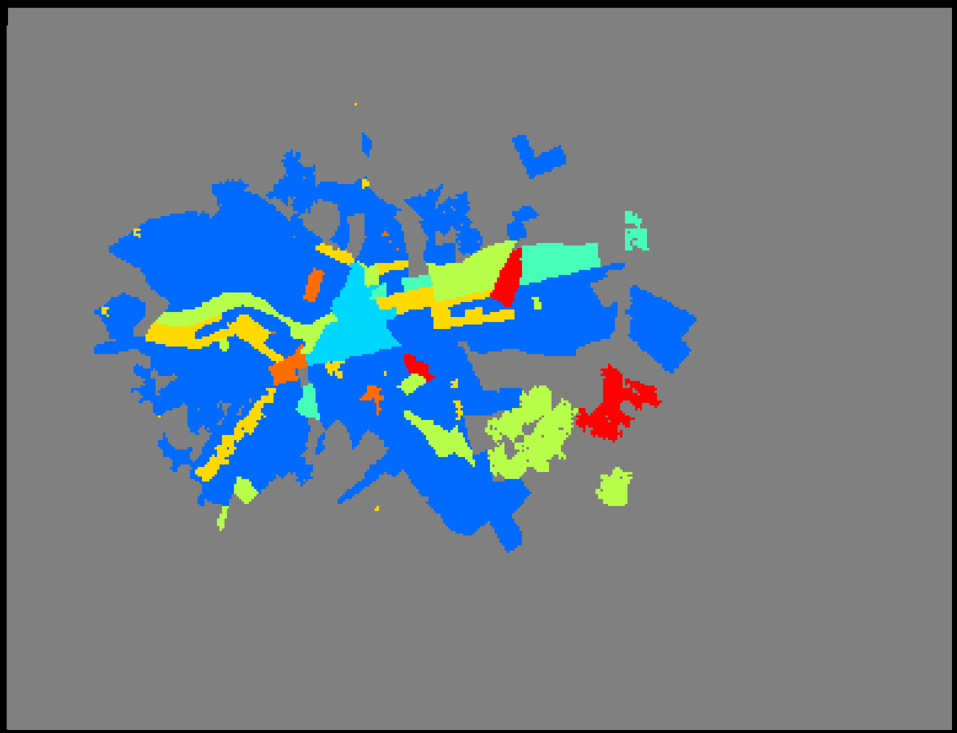
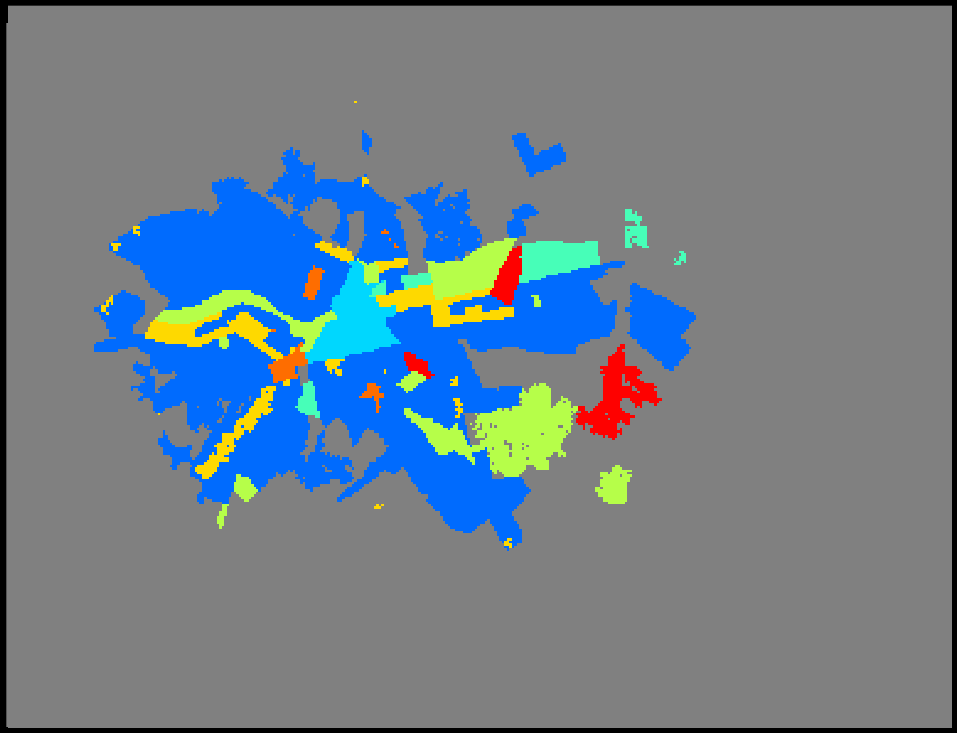


1973

ANNUAL SIMULATIONS - BAURU



1974

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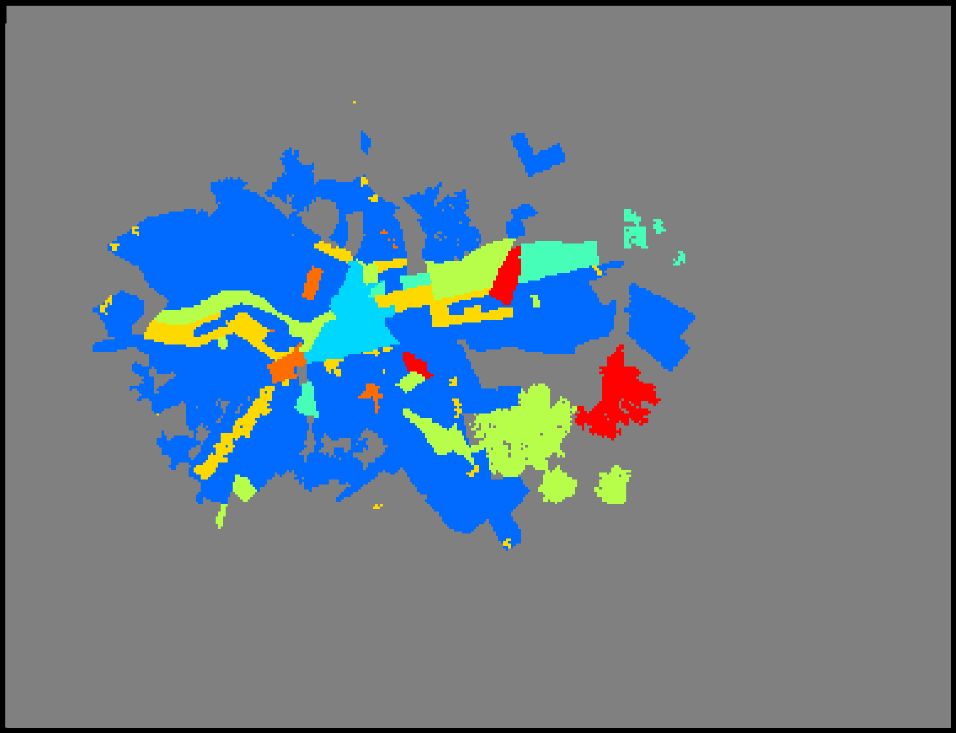

1975

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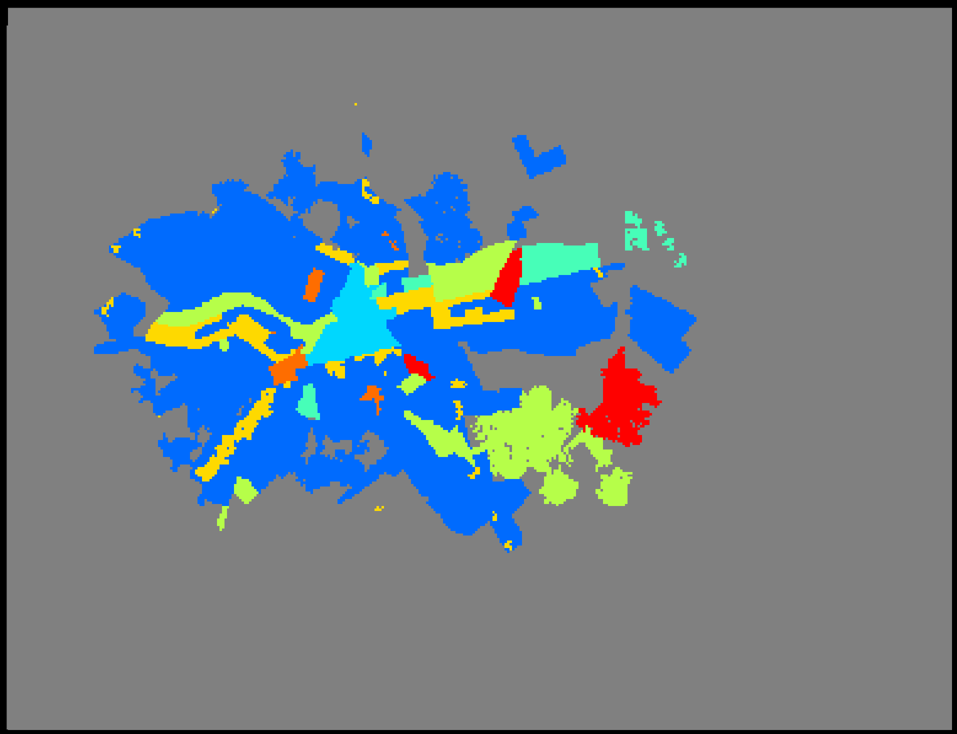

1976

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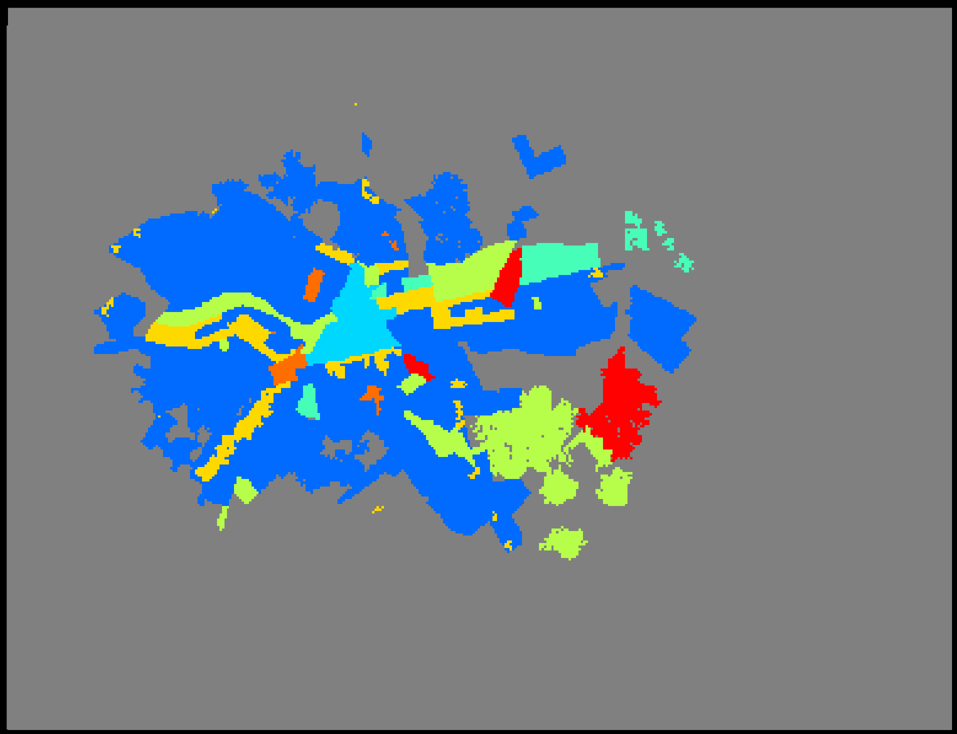

1977

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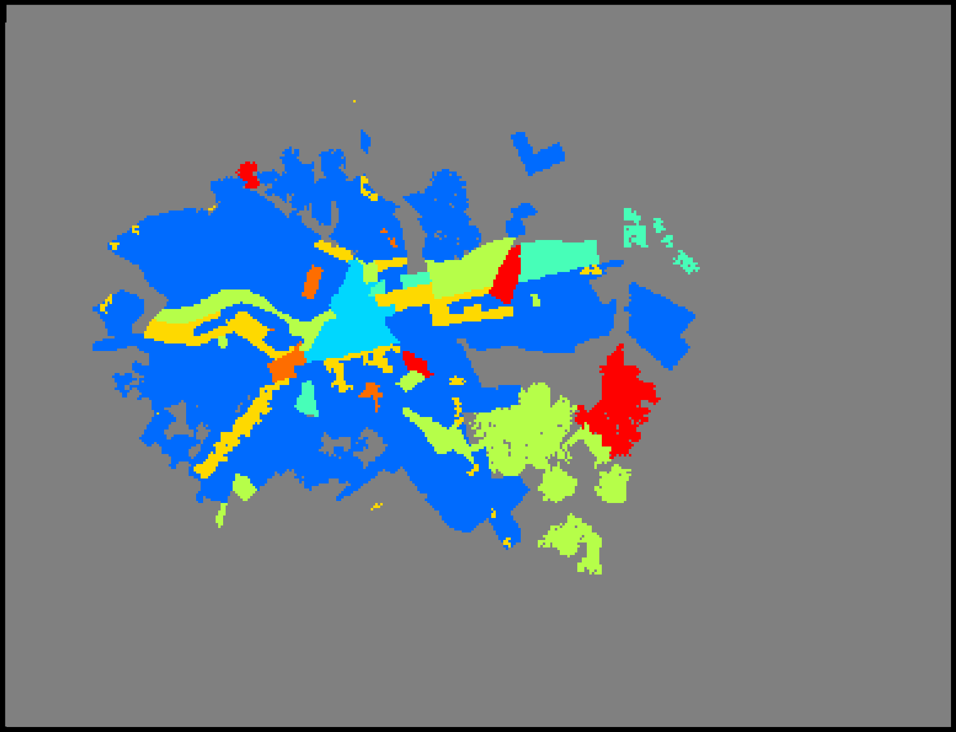

1978

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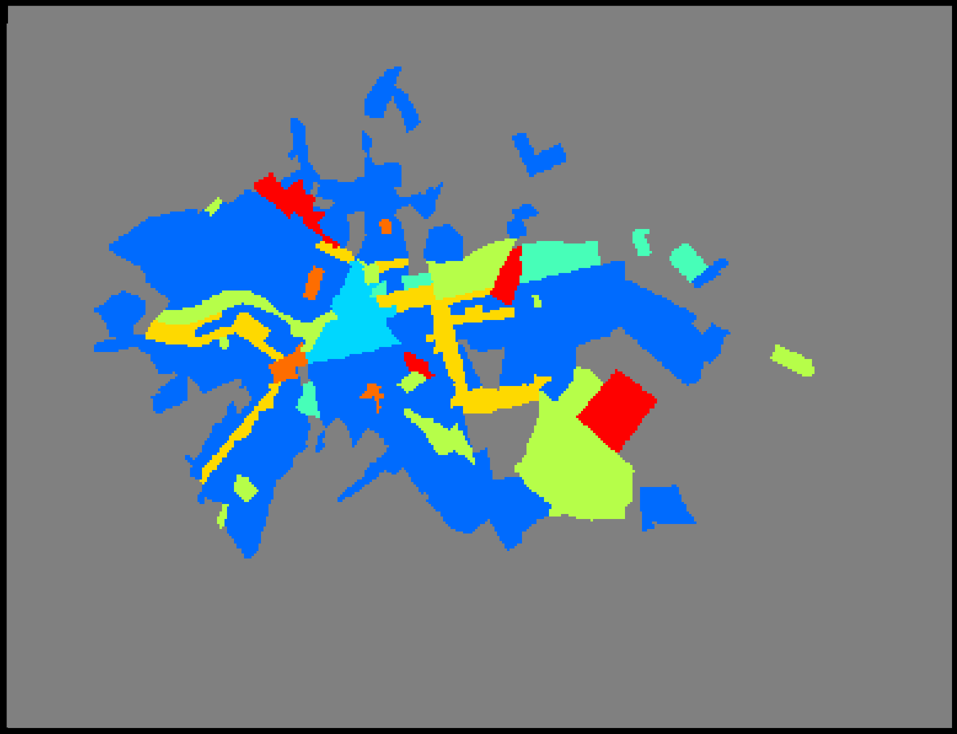

1979

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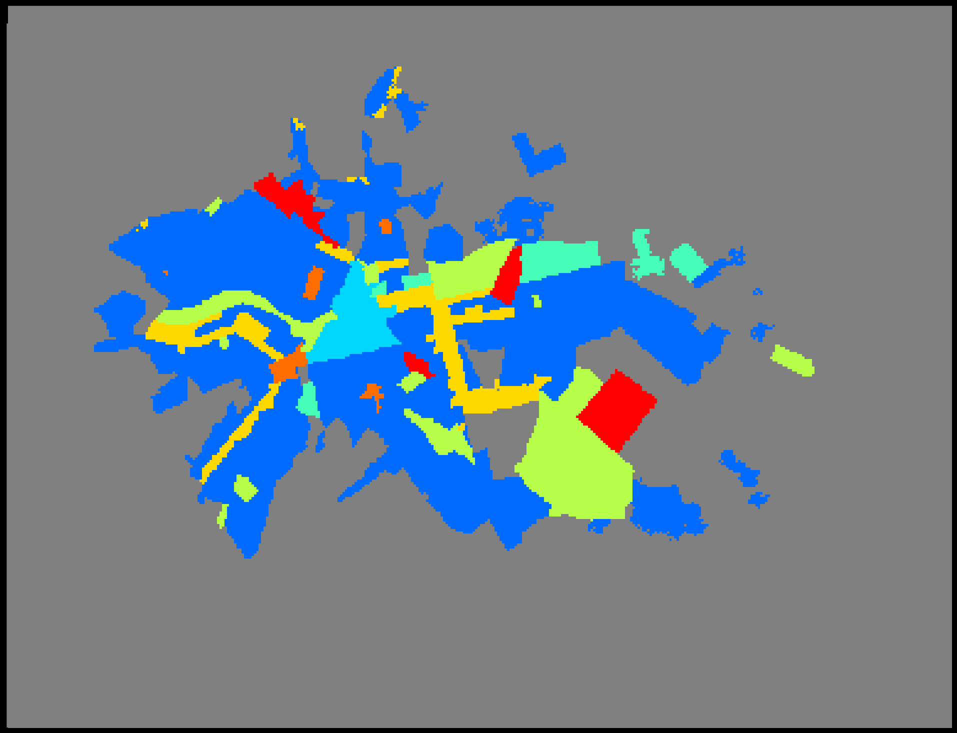

1980

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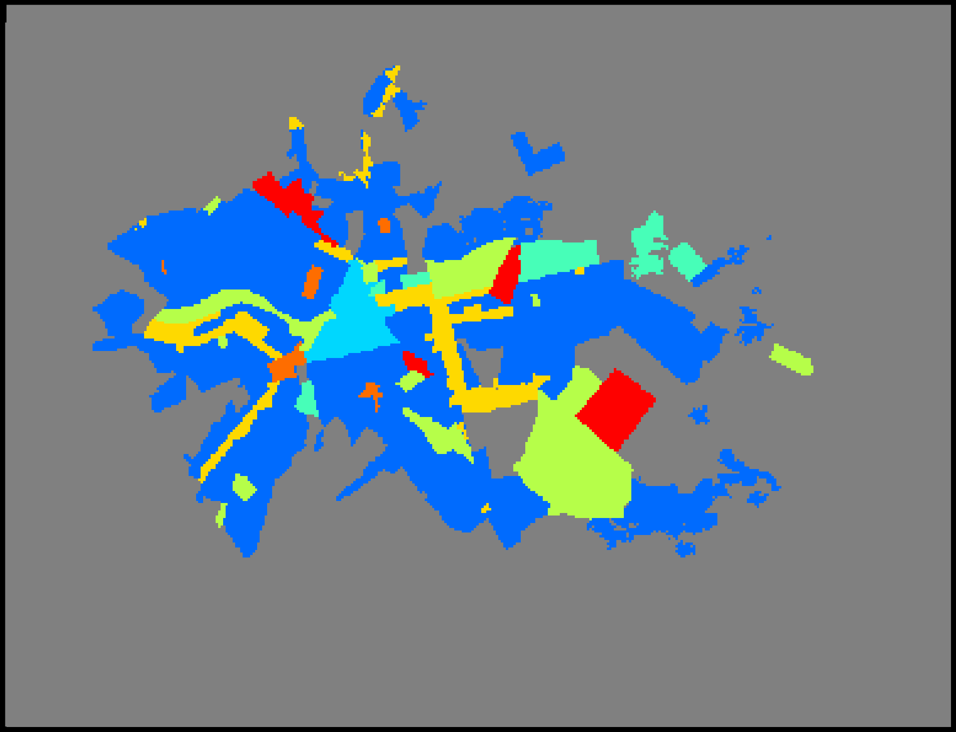

1981

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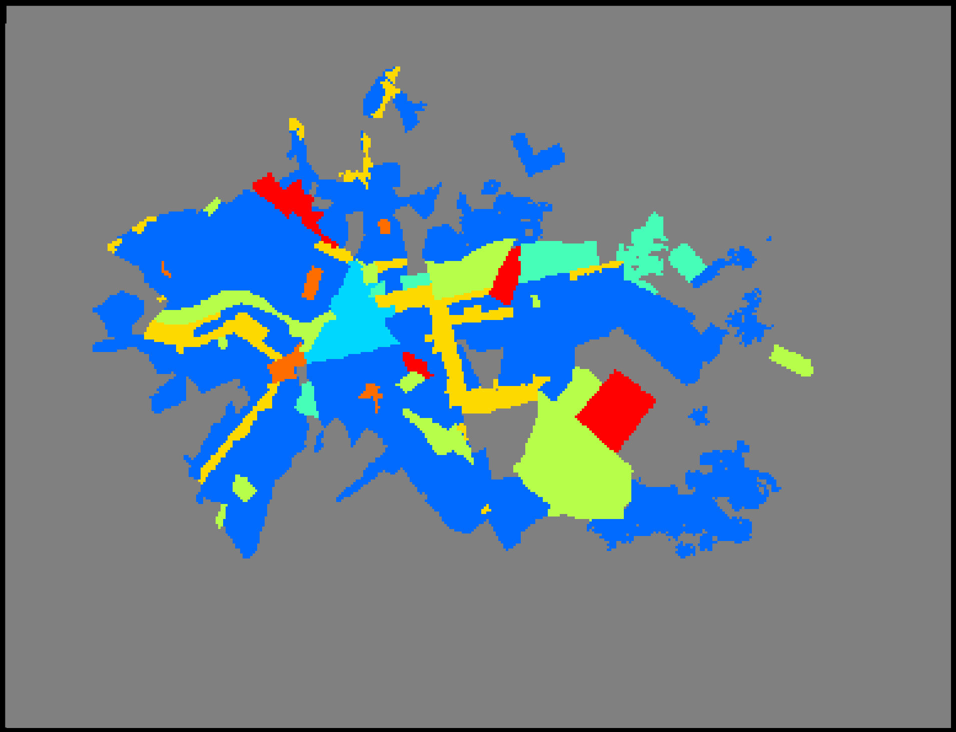

1982

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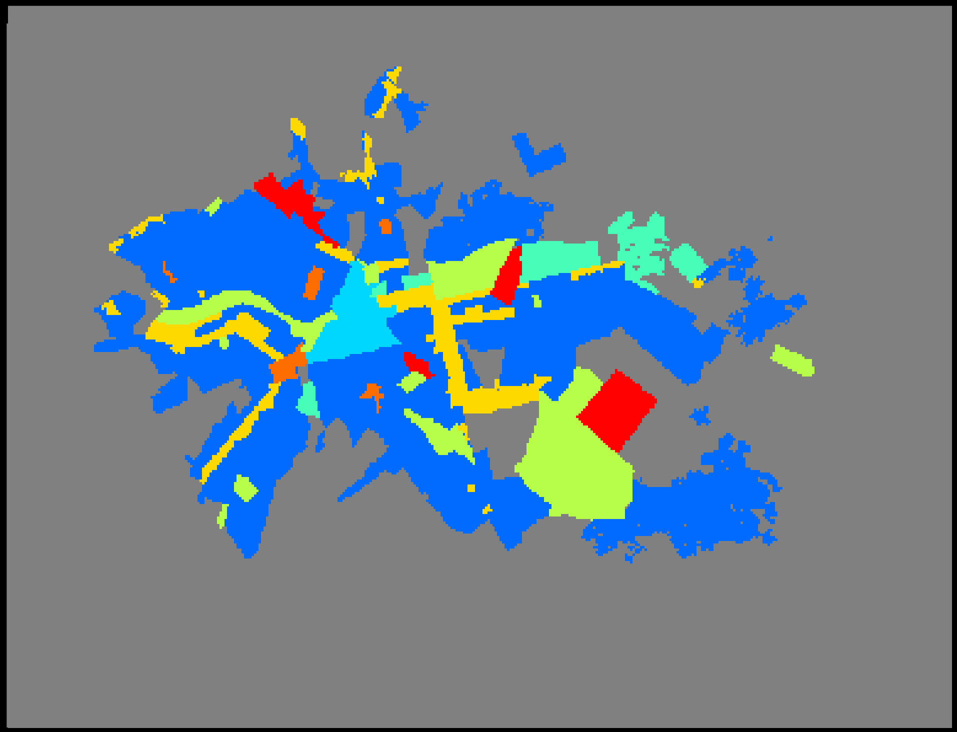

1983

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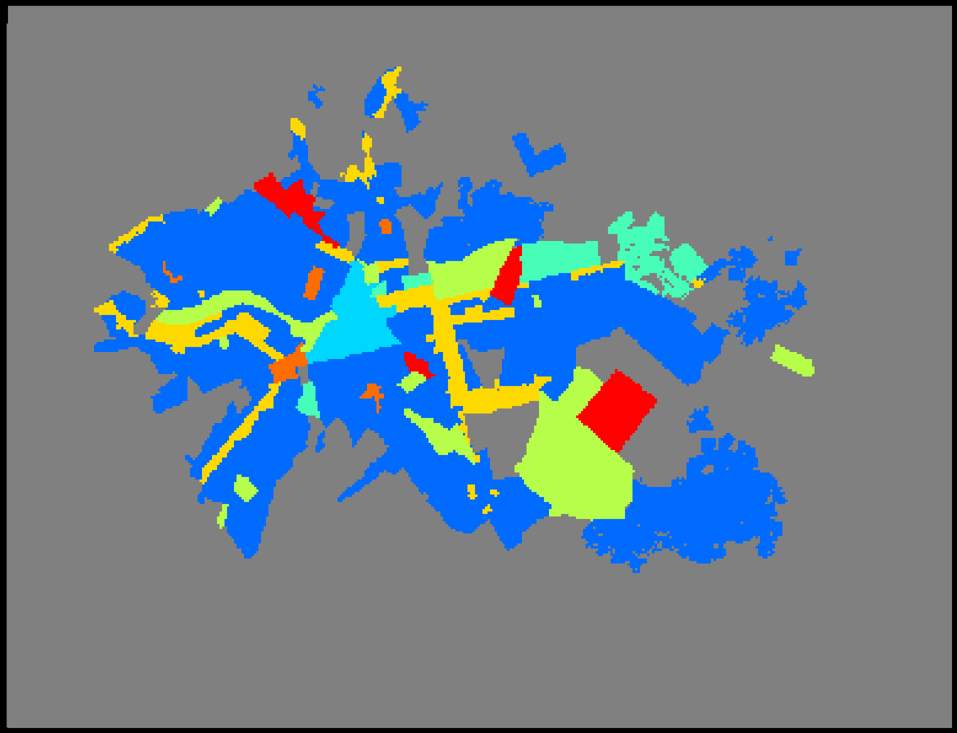

1984

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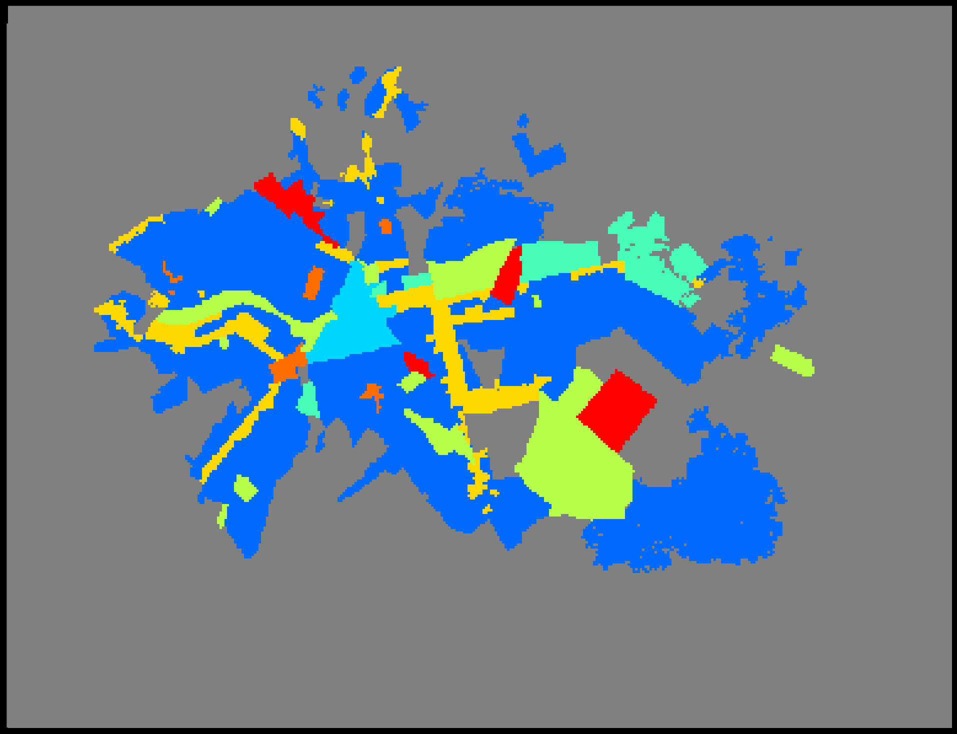

1985

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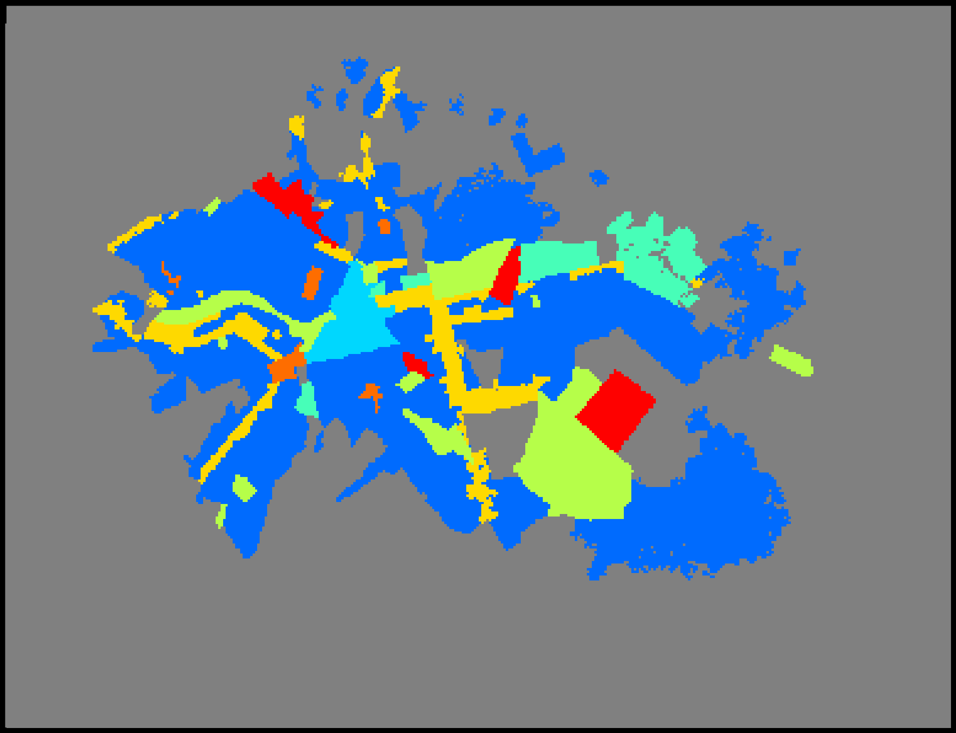

1986

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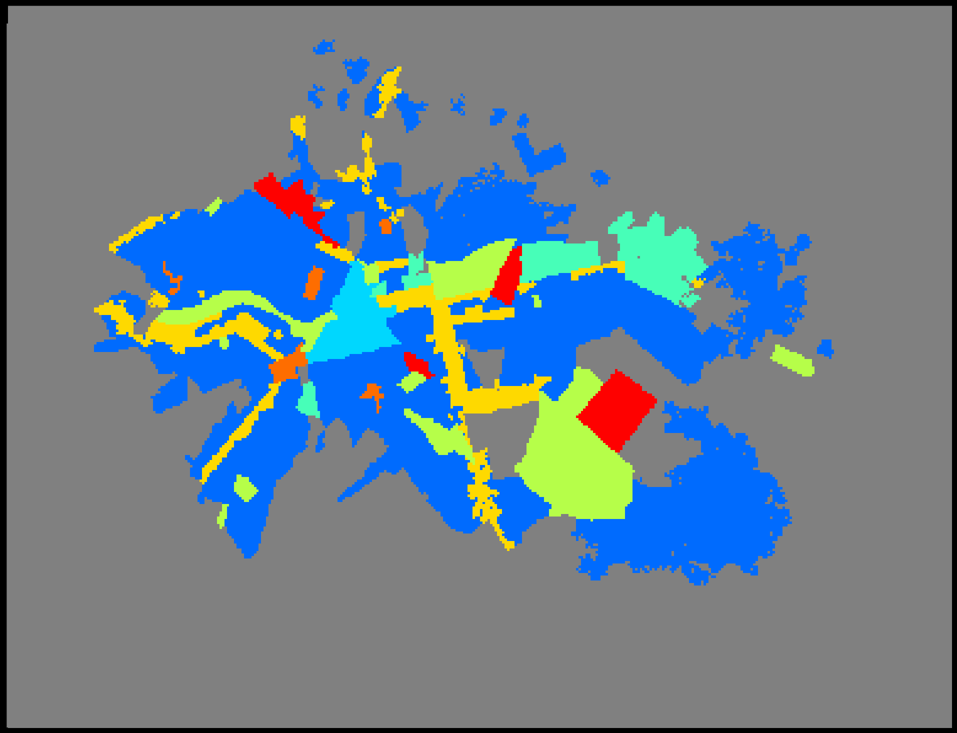

1987

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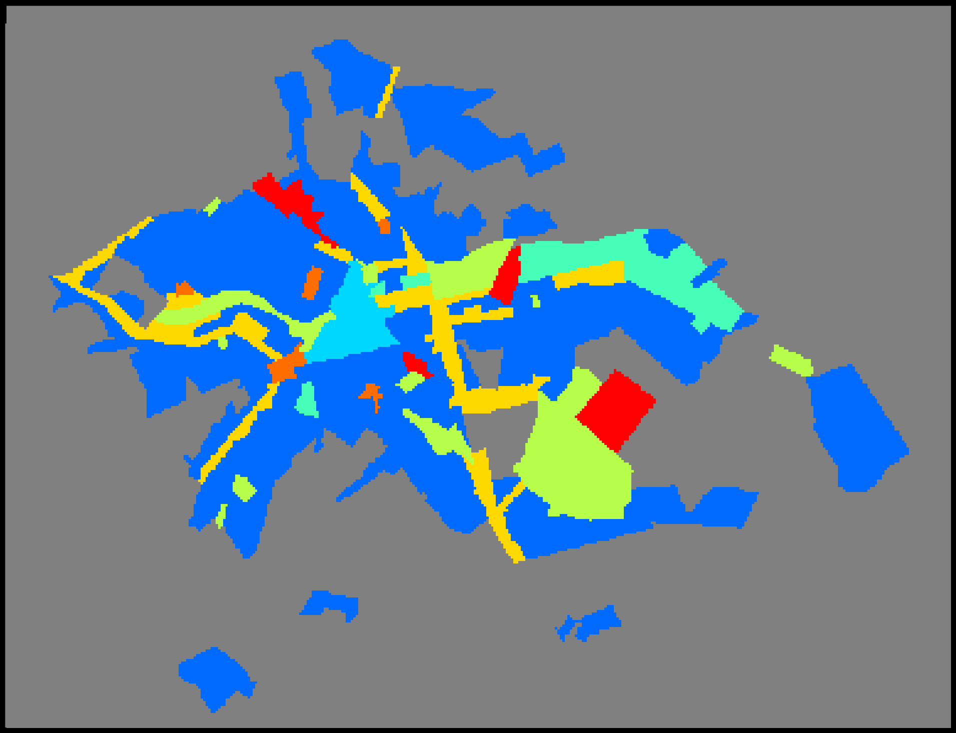

1988

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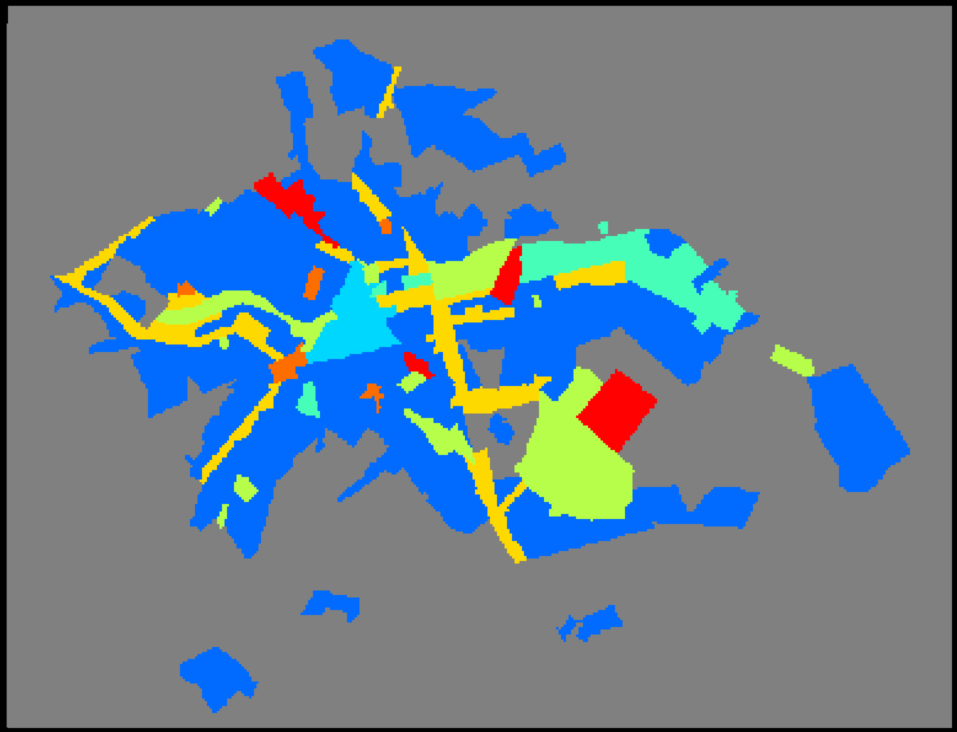

1989

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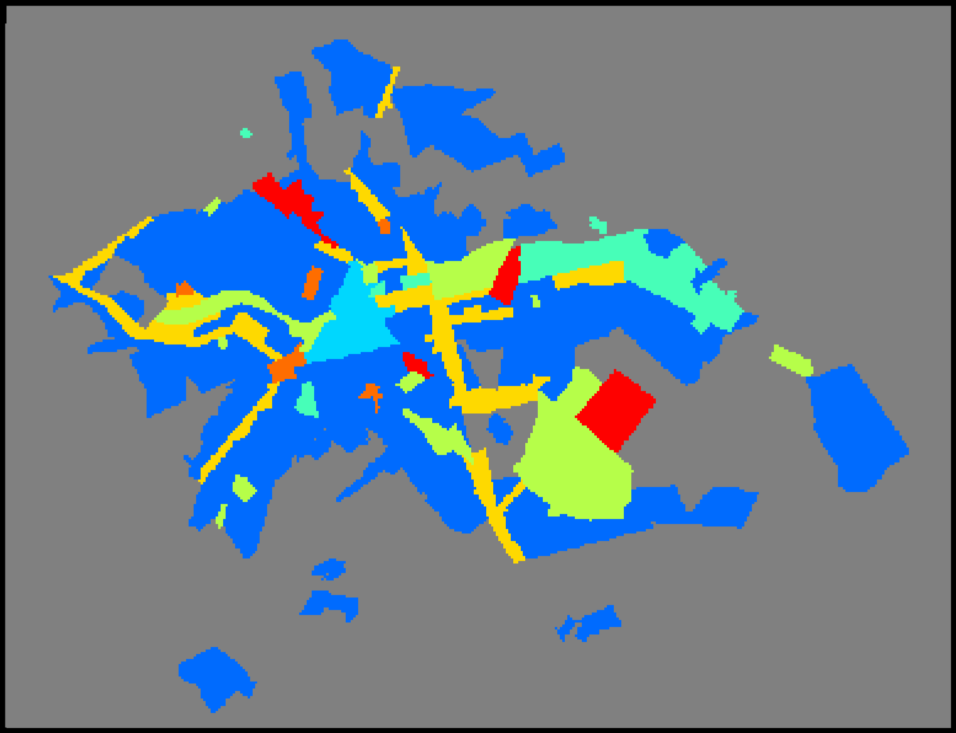

1990

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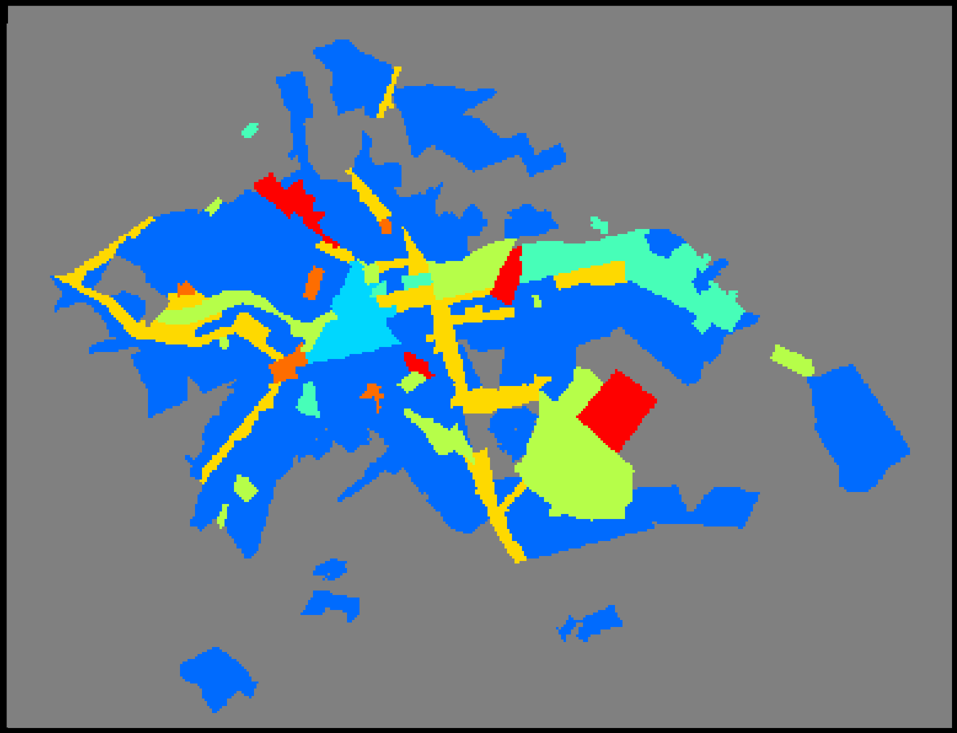

1991

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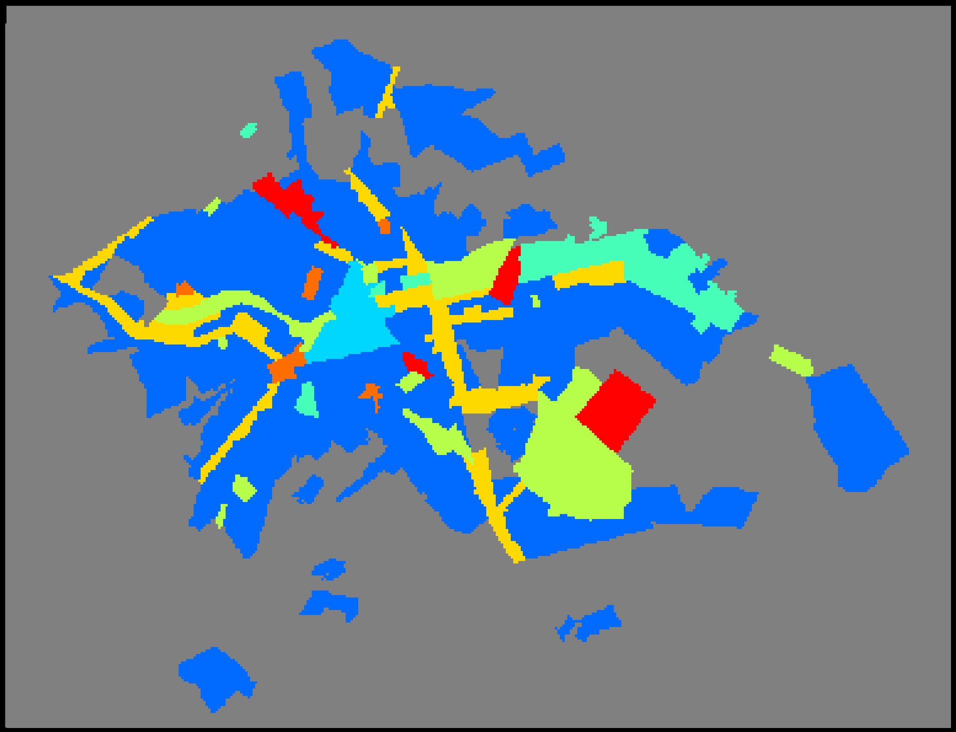

1992

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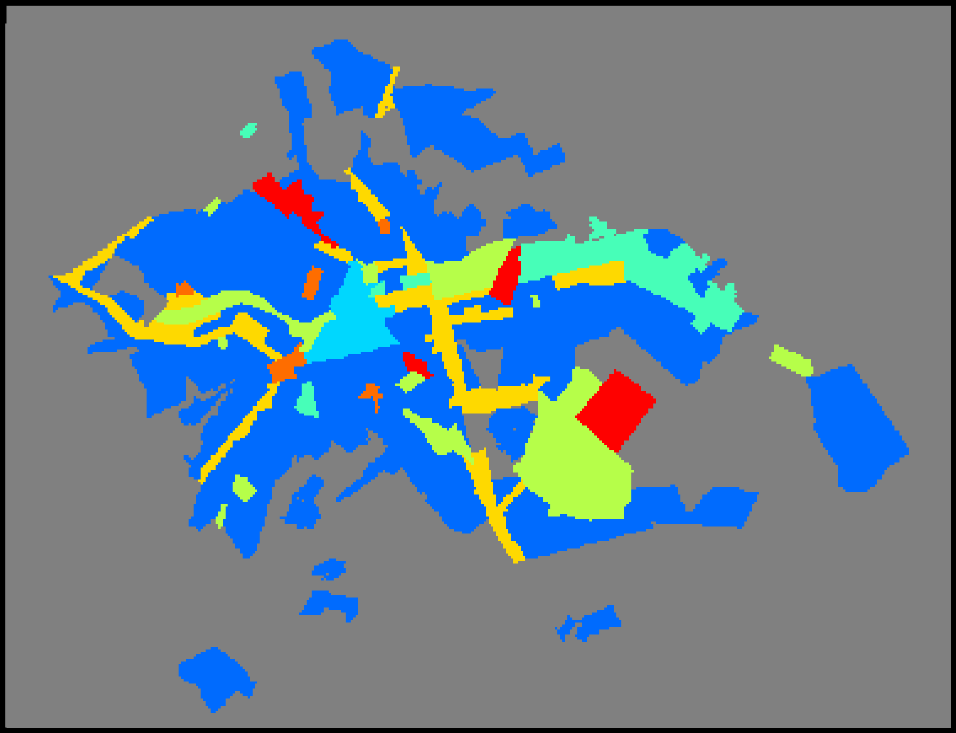

1993

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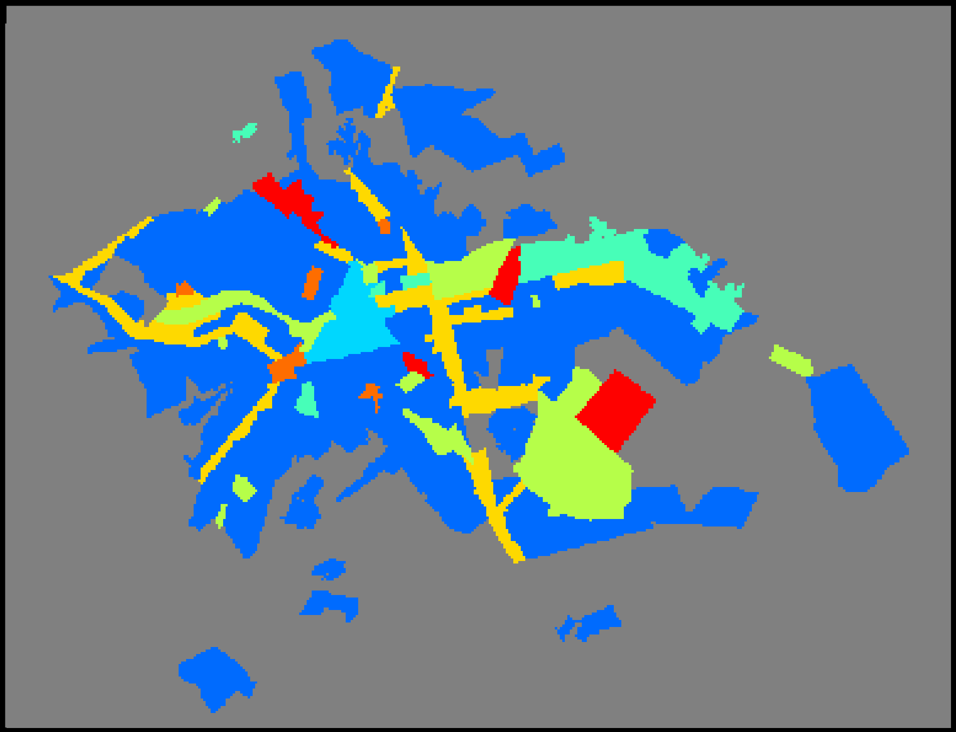

1994

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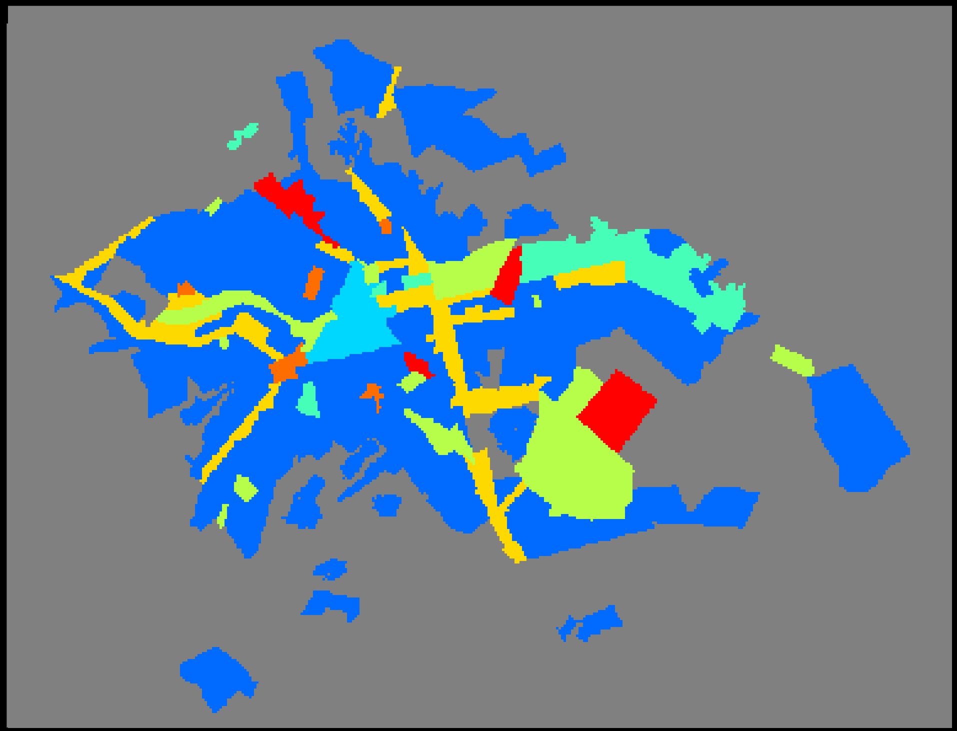

1995

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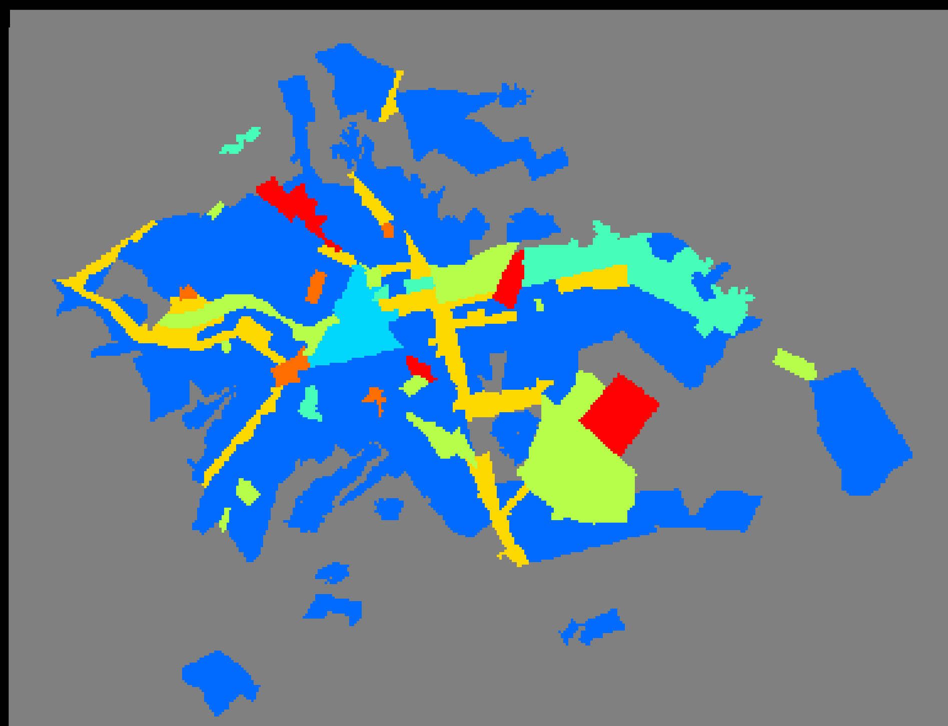

1996

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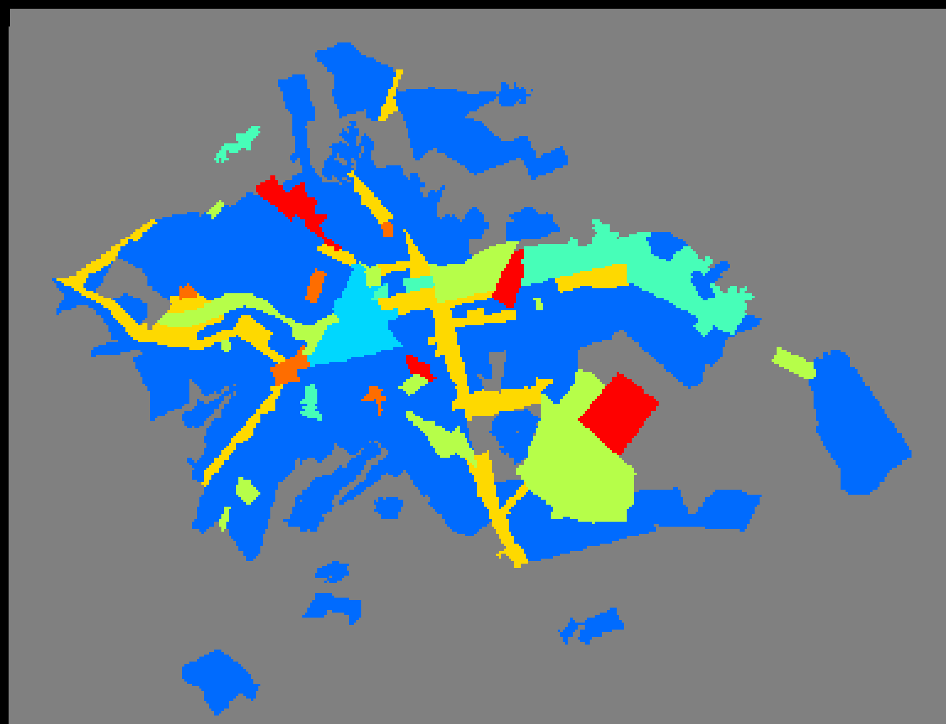

1997

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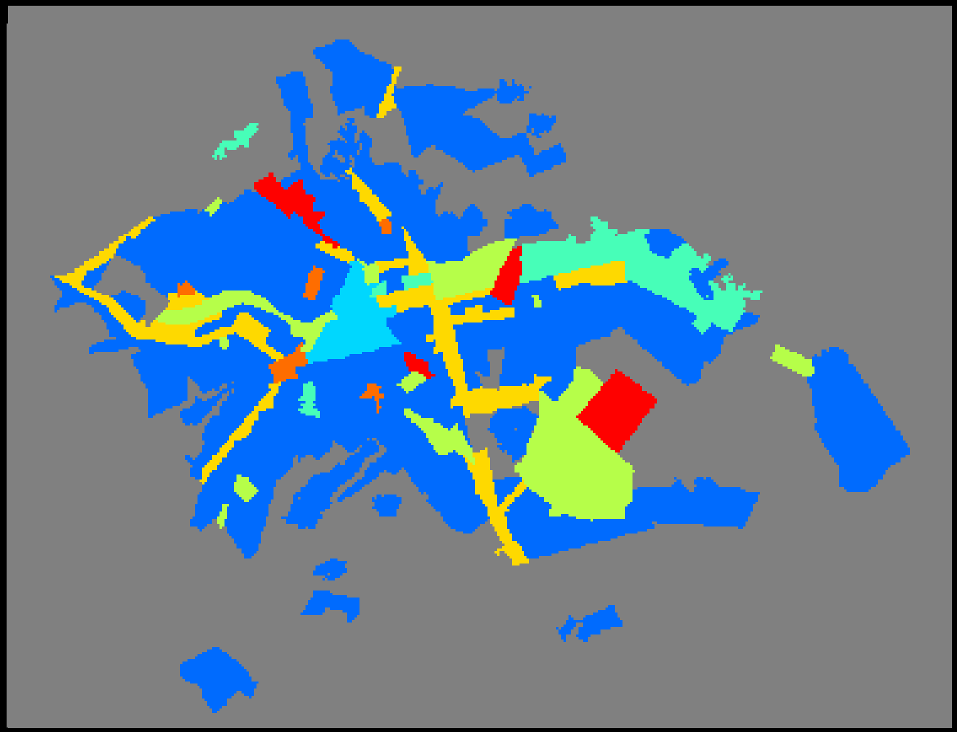

1998

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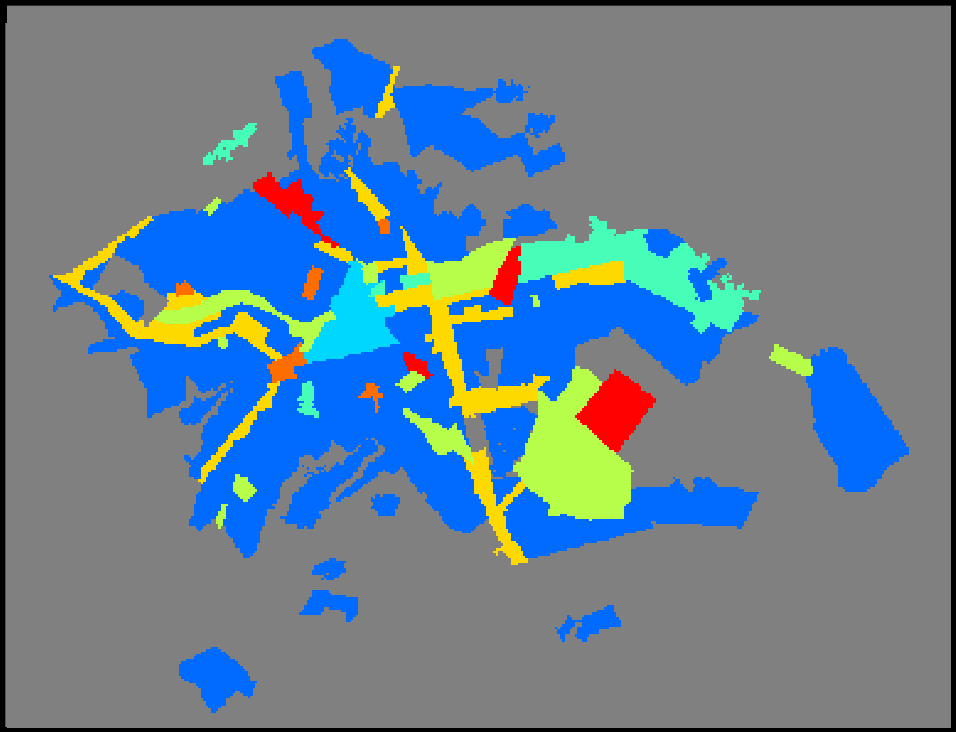

1999

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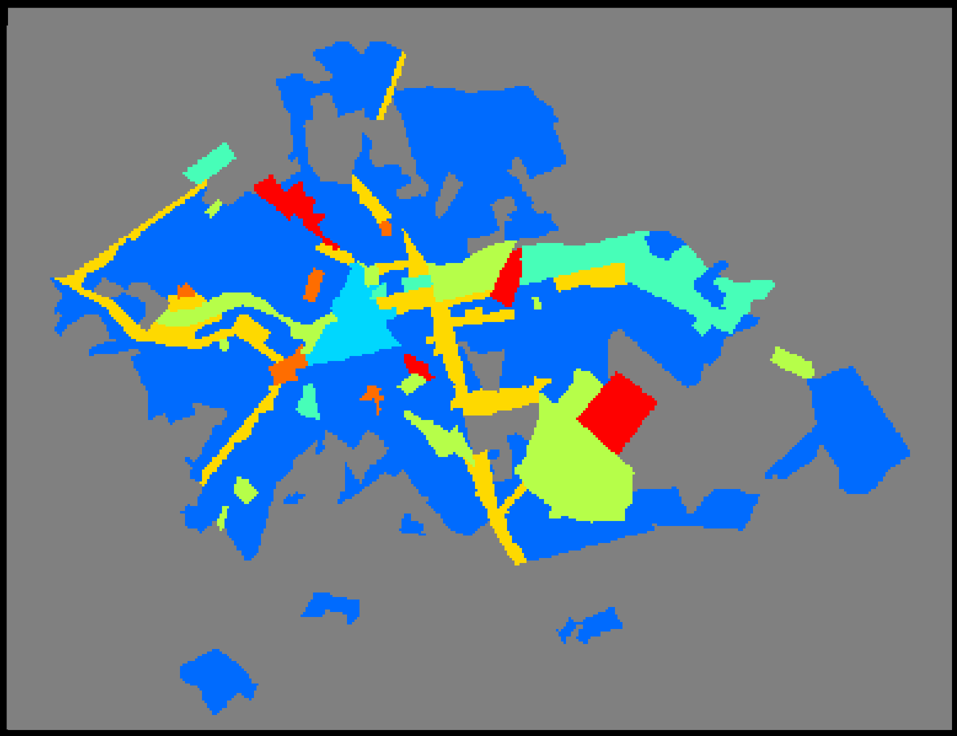


2000

MARKOV CHAIN

$$K_{t-1} \longrightarrow K_t$$

$$K_t = \begin{bmatrix} P_{rr} & P_{rc} & P_{ri} \\ P_{cr} & P_{cc} & P_{ci} \\ P_{ir} & P_{ic} & P_{ii} \end{bmatrix} K_{t-1} \qquad K = \begin{bmatrix} c \\ r \\ i \end{bmatrix}$$

Markov Chain: Defines percentages for each land use in future times

LINEAR REGRESSION MODELS

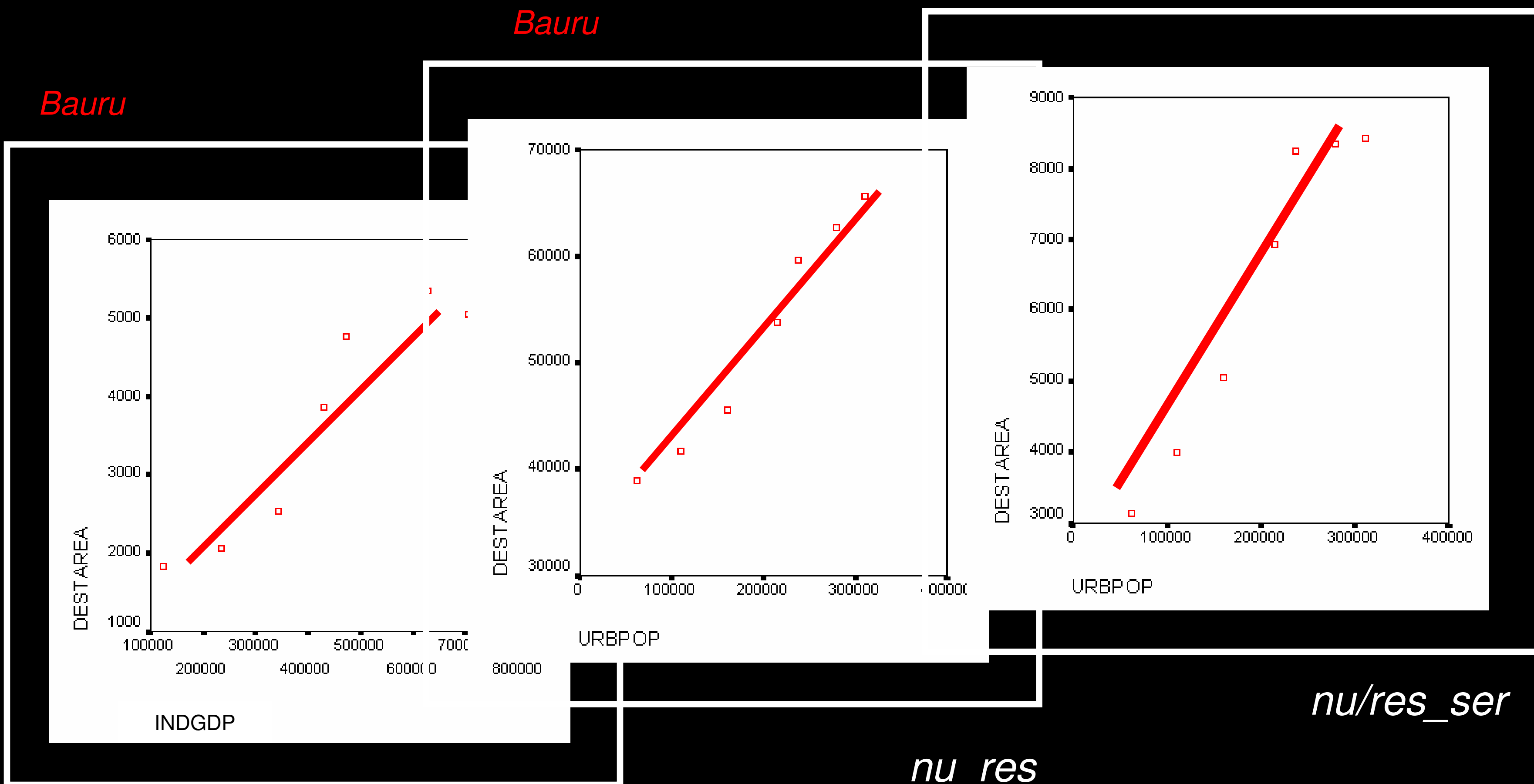
Y = Economic or Demographic Data

X = Land Use Area

Bauru

Bauru

Bauru



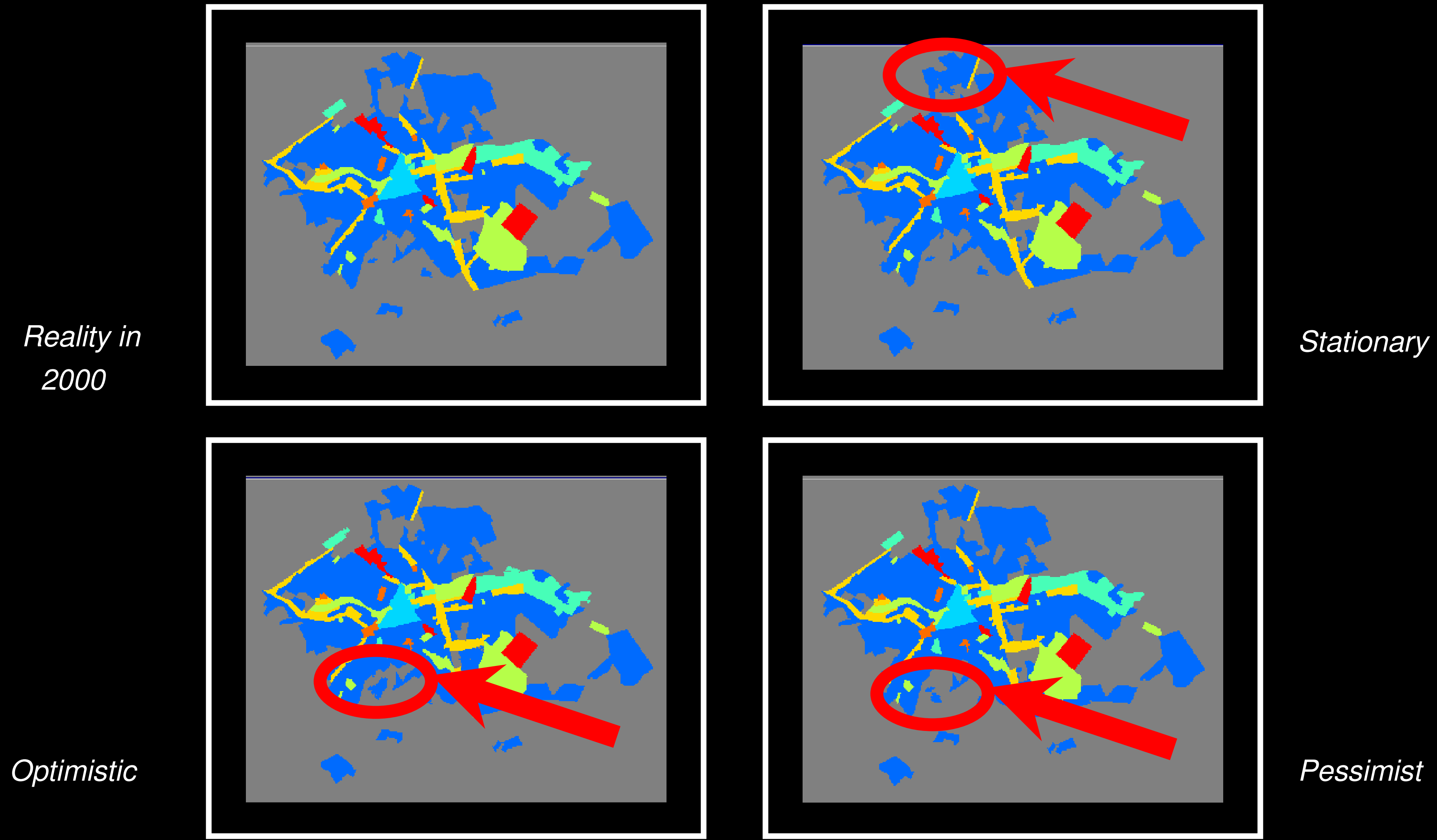
nu_ind

nu_res

nu/res_ser

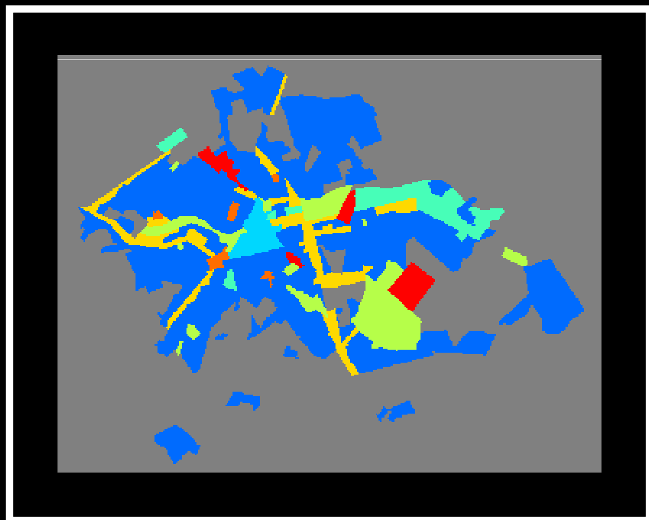
Univariate Models for Optimistic and Pessimist Scenarios

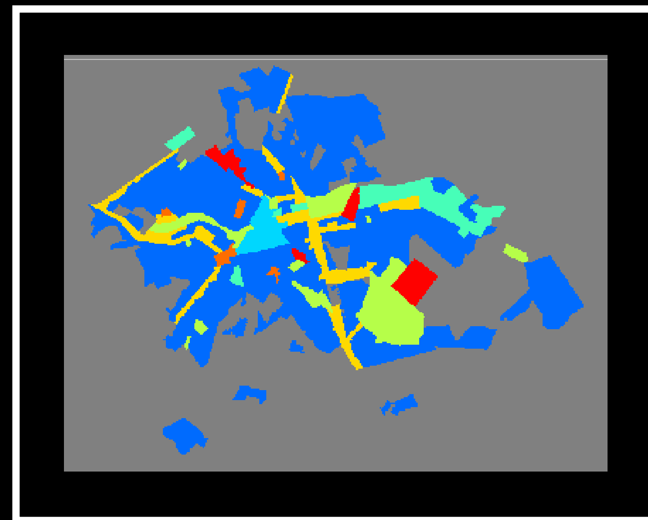
SHORT-TERM FORECAST SCENARIOS - 2004



MEDIUM-TERM FORECAST SCENARIOS - 2007

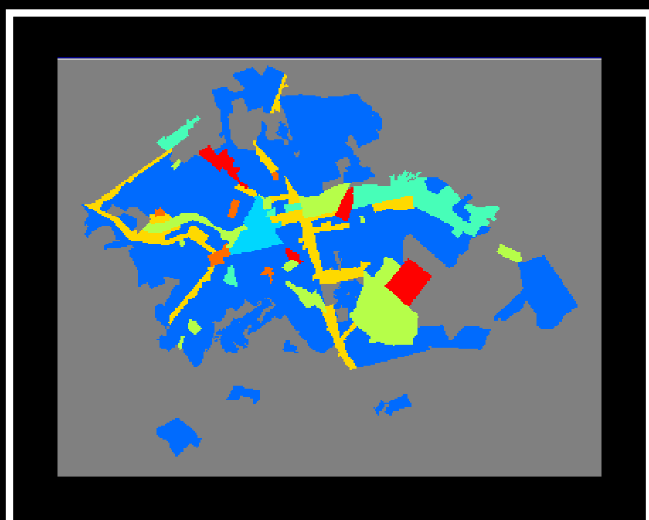
Reality in 2000

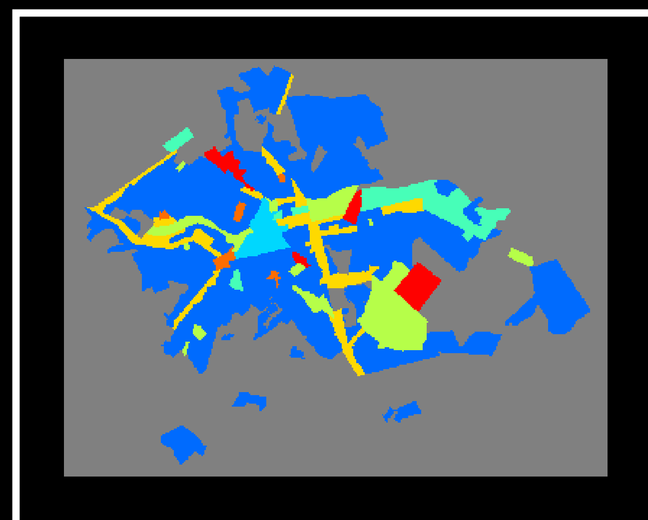




Stationary

Optimistic





Pessimist

LIMITATIONS IN MODELLING

- *urban models still work upon basis of generalization procedures and cannot cope with detailed land use information;*

- *they depend on regular and reliable (coherent with reality) land use data, and local governments do not frequently issue land use maps;*

- *they depend on land use as well as technical and social infrastructure data throughout long time series, what is not always available in developing countries cities, especially in older decades.*

ADVANTAGES & ADVANCES IN MODELLING

- *improvements in the computational processing capacity in recent times have rendered possible the adoption of finer spatial resolutions as well as larger study areas;*

- *incorporation of new methods for the weighting of variables (neural networks, multicriteria evaluation, decision tree, etc.), of new techniques for automatic calibration (genetic algorithms) and for automatic distances assessment in the variables maps;*

- *urban models provide a sinoptic overview of land use change trends throughout time;*

- *the behavior of social actors and stakeholders in the urban environment is revealed by means of the implicit findings extracted from the variables driving land use change.*

CONCLUDING COMMENTS

- *weights of evidence and logistic regression provide similar outputs, but preference should be given to the WE, for its transparency and operational simplicity;*
- *non-urban areas to residential use: the most challenging category for modelling, due to the fact that their boundaries are highly unstable factors and their occurrence is imprecise (landlords´ and enterpreneurs´ decisions);*
- *"expander" disregards cells probabilities values in its propagation;*
- *possibility of defining sizes/variances separately for each algorithm;*
- *possibility of inserting fractal parameters in the transition algorithms;*

CONCLUDING COMMENTS

- *in the yearly simulation outputs, the input variables should be yearly updated as well whenever possible;*
- *the stationary scenarios overestimate current trends of land use change, since they have been parameterized upon basis of urban growth rates experienced in the late 1980s and 1990s;*
- *optimistic and pessimist scenarios based on linear regression models ought to employ time series analysis for the independent variables estimation;*
- *the acknowledged urban growth steady decline (Prud´Homme, 1989) will lead to a shift of concern in urban CA modeling, which will tend to focus on more subtle transformations, like density increases and vertical growth.*

FINAL CONSIDERATIONS

Applicability of Land Use Dynamics Models:

- Local and Regional Planning Authorities: identify urban expansion vectors and their vocations; order and redirect urban growth.
- Sublocal Public Administrators: establish goals for investiments in technical and social infrastructure.
- Private Decision-Makers: provision of subsidies for the definition of priorities as to where and how intense to invest.
- Organised Civil Society: support to social movements demanding for social equipments or technical infrastructure implementation.

Thank you!

IAI INSTITUTE
MEXICO, 2004

IAI INSTITUTE ON URBANIZATION AND GLOBAL ENVIRONMENTAL CHANGE IN LATIN AMERICA

HANDS ON URBAN MODELLING

Cláudia Maria de Almeida

09/2004