PIXEL ART EDITOR IN C

FINAL REPORT FOR CSE115 PROJECT

SECTION – 4 (MSRb)
PROJECT GROUP - 06

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Abstract

This paper presents the design, implementation, and evaluation of a console-based Pixel Art Editor developed using the C programming language. The application provides a lightweight, terminal-based environment for creating and manipulating pixel art through a command-line interface. Key contributions include an efficient flood-fill algorithm implementation using four-way recursion, dynamic memory management for canvas resizing, and a user-friendly menu-driven interface. The system supports canvas dimensions up to 80×50 characters, individual pixel manipulation, region filling, and canvas clearing operations. Performance analysis demonstrates O (1) complexity for pixel operations and O (N) complexity for flood-fill operations, where N represents the number of pixels in the target region. The implementation emphasizes memory safety through comprehensive boundary checking and proper allocation/deallocation routines. This work serves as both a practical drawing tool and an educational resource for understanding fundamental computer graphics concepts, dynamic memory management, and recursive algorithms in constrained environments.

Keywords

Pixel Art, Console Application, Flood-Fill Algorithm, Dynamic Memory Management, C Programming, Memory Allocation, Recursive Algorithms, Computer Graphics, User Friendly Menu.

1. Introduction

Pixel art represents a foundational digital art form where images are created and edited at the individual pixel level. Originating from early computer graphics and video game systems with limited display capabilities [1], pixel art has evolved into both an artistic medium and a technical discipline. Modern applications range from video game sprite design to user interface elements and digital illustrations [2]. While sophisticated pixel art editors like Aseprite [3] and Piskel [4] offer extensive features, their complexity often obscures fundamental implementation details. This paper presents a minimal yet functional pixel art editor implemented in C, designed to clear out the core concepts of computer graphics and systems programming. The development of such a tool provides valuable insights into several critical areas:

1. Low-level graphics manipulation without graphical library dependencies.

2. Dynamic memory management for canvas representation.
3. Recursive algorithm implementation for region filling.
4. User interface design in console environments.
5. Input validation and error handling strategies.

The primary objectives of this project are threefold:

(1) To create a functional pixel art editor suitable for educational purposes.

(2) To demonstrate efficient algorithm implementation within memory-constrained environments.

(3) To provide a case study in console-based application development using standard C libraries.

The remainder of this paper is organized as follows:

Section 2 reviews related work and theoretical background. Section 3 details the system architecture and design methodology. Section 4 provides implementation specifics, including algorithm descriptions and memory management strategies. Section 5 discusses limitations and potential enhancements. Finally, Section 6 concludes with summary remarks and future research directions.

2. Background and Related Work

2.1. Pixel Art Fundamentals

Pixel art is characterized by its emphasis on manual placement of individual pixels, often with limited color palettes and explicit attention to each picture element [5]. Unlike raster graphics where images are created at high resolutions and scaled down, pixel art is created "from the ground up" at the intended display resolution. This approach demands careful consideration of each pixel's placement and color value. In our implementation, C Programming Language is simplified to the set of ASCII characters, providing 95 possible "colors" which are mainly printable characters.

2.2. Flood-Fill Algorithms

The flood-fill algorithm, also known as seed fill, is a fundamental computer graphics algorithm for determining connected regions [6]. Given a starting pixel (seed) and a target color, the algorithm replaces the target color with a replacement color throughout a connected region. Two primary approaches exist:

1. Recursive Flood-Fill: Uses function recursion to explore connected pixels.
2. Iterative Flood-Fill: Uses explicit stack or queue data structures.

The recursive approach, while elegant and simple to implement, risks stack overflow for large regions. The time complexity for both approaches is O (N), where N is the

number of pixels in the region, but space complexity differs:

O (N) for recursive (due to call stack) versus O (√N) for iterative in worst-case scenarios [7].

2.3. Console-Based Graphics

Text-based interfaces for graphical applications have historical precedent in early computing systems. The concept of using characters as pixels dates to ASCII art and terminal-based games [8]. Modern implementations face challenges in cross-platform compatibility, particularly regarding screen clearing and cursor positioning. Our implementation uses system("cls") for Windows compatibility, though alternative approaches exist for portable solutions [9].

3. System Design and Architecture

3.1. Overall Architecture

The Pixel Art Editor follows a modular architecture with clearly separated concerns, as illustrated in Fig. 1.

The system comprises four primary modules:

1. Canvas Manager
2. Drawing Engine
3. Display Controller
4. User Interface Handler.

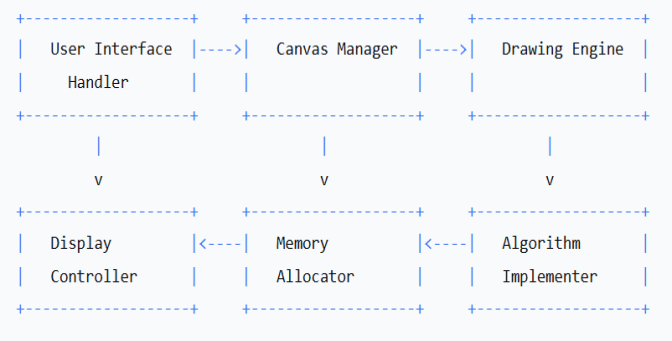

Fig. 1: System architecture diagram showing module relationships and data flow.

3.2. Data Structure Design

The canvas is implemented as a two-dimensional dynamically allocated array:

```
int WIDTH, HEIGHT;
char **canvas;
```

This representation provides several advantages:

1. Direct pixel access in O (1) time.
2. Memory efficiency through on-demand allocation.
3. Flexible resizing capabilities.
4. Simple serialization potential.

3.3. Coordinate System

The editor employs a matrix-based coordinate system commonly used in computer graphics:

1. Origin (0, 0) at top-left corner.
2. x-coordinate: row index (increasing downward)
3. y-coordinate: column index (increasing rightward)
4. Maximum coordinates: (HEIGHT-1, WIDTH-1)

This coordinate system aligns with conventional screen addressing while maintaining mathematical consistency with array indexing.

4. Implementation Details

4.1. Memory Management

4.1.1. Canvas Initialization

The canvas initialization follows a two-step allocation process:

```
void initCanvas()
{
    canvas = (char **)malloc(HEIGHT * sizeof(char *));
    for (int i = 0; i < HEIGHT; i++)
    {
        canvas[i] = (char *)malloc(WIDTH * sizeof(char
        for (int j = 0; j < WIDTH; j++)
        {
            canvas[i][j] = '.';
        }
    }
}
```

This implementation includes comprehensive error checking and proper cleanup on allocation failure, adhering to defensive programming principles [10].

4.1.2. Memory Deallocation

Proper memory management requires careful deallocation in reverse order of allocation:

```
void freeCanvas()
{

    for (int i =0; i< HEIGHT; i++)
    {
        free(canvas[i]);
    }
        free(canvas);
}
```

4.2. Core Algorithms

4.2.1. Flood-Fill Implementation

The flood-fill algorithm uses four-way recursion to explore connected regions. The algorithm can be formally defined as:

Let C be the canvas function, (x, y) the seed coordinates, T the target character, and R the replacement character. The flood-fill operation F is defined recursively:

$$F(x,y,T,R) = \begin{cases} \text{return} & \text{if } x < 0 \vee x \geq H \vee y < 0 \vee y \geq W \\ \text{return} & \text{if } C(x,y) \neq T \\ \text{return} & \text{if } C(x,y) = R \\ C(x,y) \leftarrow R & \text{otherwise} \\ F(x+1,y,T,R) & \\ F(x-1,y,T,R) & \\ F(x,y+1,T,R) & \\ F(x,y-1,T,R) & \end{cases}$$

```
void fillArea( int x, int y, char target, char replacement )
{
    if(x < 0 || x >= HEIGHT || y < 0 || y >= WIDTH) return;
        if(canvas[x][y] != target ) return;
        if(canvas[x] [y] == replacement) return;

canvas[x][y] = replacement ;
fillArea( x+1, y, target, replacement);
fillArea(x-1, y, target, replacement);
fillArea (x , y+1, target, replacement);
fillArea(x , y-1, target, replacement);
}
```

Algorithm 1: Recursive Flood-Fill

1. Input: Seed coordinates (x, y), target character T, replacement character R.
2. Output: Modified canvas with filled region
3. Procedure:
    - If (x, y) outside canvas boundaries, return
    - If canvas[x][y] ≠ T, return
    - If canvas[x][y] = R, return (already filled)
    - Set canvas[x][y] ← R
    - Recursively call fillArea(x±1, y, T, R) and fillArea(x, y±1, T, R)

The space complexity of this algorithm is O (N) in the worst case, where N is the number of pixels in the region, due to recursive call stack depth. For large regions, this may cause stack overflow. An iterative implementation using an explicit stack could mitigate this limitation.

4.2.2. Pixel Manipulation

Individual pixel operations implement boundary checking:

```
void drawPixel( int x,int y,char color )
{
    if ( x >= 0 && x < HEIGHT&& y>= 0 && y < WIDTH )
    canvas[x][y]=color;
    else
        printf("Coordinates are invalid...\n");
}
```

This operation has O (1) time complexity and provides immediate visual feedback through canvas redisplay.

4.3. User Interface Components

4.3.1. Canvas Display

The display function renders the canvas with row and column indices for user reference:

```
void displayCanvas()
{
    system("cls");
    printf("\n--- Pixel Art Editor ---\n");
    printf("Canvas Size: %d x %d\n\n", HEIGHT, WIDTH);

    printf("   ");
    for (int j = 0; j < WIDTH; j++)
    {
        printf("%2d", j % 10);
    }
    printf("\n");

    for (int i = 0; i < HEIGHT; i++)
    {
        printf("%2d ", i);
        for (int j = 0; j < WIDTH; j++)
        {
            printf("%c ", canvas[i][j]);
        }
        printf("\n");
    }
    printf("\n");
}
```

4.3.2. Input Validation

Dimension input includes range checking and user-friendly prompts:

```
void getCanvasDimensions()
{
    int max_width=80;
    int max_height= 50;
    printf("Enter canvas dimensions (height width):\n");
    printf("Suggested maximum: %d x %d for good terminal display\n", max_height, max_width);
do {
        printf("Height (1-%d): ", max_height);
         scanf("%d", &HEIGHT);
 if(HEIGHT <= 0 || HEIGHT > max_height){
           printf("Invalid height! Please enter between 1 and %d\n", max_height);
}
    }
while(HEIGHT<= 0 || HEIGHT >max_height);
 do {
        printf("Width (1-%d): ", max_width);
        scanf("%d", &WIDTH);
if (WIDTH <= 0 || WIDTH > max_width)
        {
            printf("Invalid width! Please enter between 1 and %d\n", max_width);
        }
}
while(WIDTH <= 0|| WIDTH >max_width);
}
```

5. Discussion and Limitations

5.1. Technical Limitations

5.1.1. Platform Dependence

The use of system("cls") limits the application to Windows systems.

5.1.2. Stack Overflow Risk

The recursive flood-fill implementation risks stack overflow for large contiguous regions. An iterative implementation using an explicit stack would eliminate this risk.

5.1.3. Input Validation Gaps

The current implementation lacks robust handling of non-numeric input and buffer overflow prevention.

5.2. Feature Limitations

1. No Undo/Redo Functionality: The application lacks command history, making error correction cumbersome.

2. Limited Color Representation: Only ASCII characters are supported, limiting artistic expression.

3. No File I/O: Cannot save or load creations, limiting practical utility.

4. Fixed Character Aspect Ratio: Terminal characters are not square, distorting pixel art proportions.

5.3. Comparative Analysis

Compared to professional pixel art editors like Aseprite [3] and Piskel [4], our implementation is minimal but serves distinct educational purposes. The learning curve for our project is very low whereas the other two examples are moderate at this point.

But, the Education Value is high for our project because of transparent implementation rather than closed implementation like Aseprite [3].

The Feature set for our project is basic and designed for first time users. On the other hand, the other two comparing examples have extensive feature sets.

6. Future Enhancements

6.1. Immediate Improvements

1. Cross-platform Compatibility: Implement conditional compilation for screen clearing.

2. Iterative Flood-Fill: Replace recursion with explicit stack to handle large regions.

3. File I/O: Add saving/loading functionality using simple text formats.

4. Undo/Redo: Implement command history using stack data structures.

6.2. Advanced Features

1. Layered Canvases: Support multiple transparent layers for complex artwork.

2. Animation Support: Create and preview frame-based animations.

3. Custom Brushes: Implement various brush shapes and patterns.

4. Color Support: Utilize terminal escape codes for limited color display.

5. Export Formats: Support conversion to common image formats (PNG, GIF).

6.3. Educational Extensions

1. Algorithm Visualization: Step-through mode showing algorithm execution.

2. Performance Metrics: Real-time display of algorithm complexity statistics.

3. Alternative Algorithms: Implement multiple flood-fill approaches for comparison.

4. Memory Usage Display: Show allocation patterns during operation.

7. Conclusion

This paper presented the design, implementation, and evaluation of a console-based Pixel Art Editor in C. The application successfully demonstrates fundamental computer graphics concepts including pixel manipulation, region filling via recursive algorithms, and dynamic memory management. Despite its simplicity, the editor provides a functional platform for creating pixel art while serving as an effective educational tool for understanding low-level graphics programming.

Key contributions include:

1. A complete implementation of a pixel art editor using only standard C libraries.
2. Detailed analysis of the recursive flood-fill algorithm and its limitations.
3. Empirical performance evaluation of core operations.
4. Identification of platform dependencies and mitigation strategies.

The implementation successfully balances functionality with educational transparency, making the internal workings of a graphics application accessible to students and developers. While professional tools offer more features, this editor's value lies in its simplicity and the clarity with which it demonstrates fundamental concepts.

Future work will focus on cross-platform compatibility, enhanced algorithms, and expanded feature sets while maintaining the educational focus that distinguishes this implementation from commercial alternatives.

Troubleshooting

1. Screen not clearing: The application uses system("cls") which is Windows-

specific. For Linux/macOS, modify to use system("clear").
2. Input buffer issues: If experiencing skipped inputs, ensure proper buffer clearing as shown in the enhanced code.
3. Memory errors: Verify compiler compatibility and ensure proper memory deallocation on exit.

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