# Annexure3b- Complete filing

**TITLE:** **Hybrid Model for Real-Time Gesture Understanding**

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1. **Project Overview**
2. The AI-Powered Deadlock Detection Simulator is a software tool designed to model and analyze resource allocation scenarios in operating systems, specifically focusing on detecting and resolving deadlocks. Deadlocks are a critical issue in systems where multiple processes compete for limited resources, potentially leading to a standstill where no process can proceed. This project aims to provide a user-friendly graphical interface to simulate resource allocation graphs (RAGs), detect deadlocks using an AI-driven algorithm, and offer actionable resolution strategies. Built using Python, the simulator leverages the Tkinter library for its GUI and implements a modified banker’s algorithm to identify deadlocks. The tool is intended for educational purposes, helping students and professionals understand deadlock concepts, and for system designers to test resource allocation strategies.
3. The simulator allows users to create processes and resources, define relationships (requests and allocations), visualize the system state, and analyze potential deadlocks. It also includes features like undo/redo functionality, state saving/loading, and a resolution guide to assist users in breaking deadlock cycles. The project integrates AI by using heuristic-based analysis to suggest optimal resolution steps, making it a valuable tool for both learning and practical applications.

**2. Module-Wise Breakdown**

The project is divided into several modules, each handling a specific aspect of the simulator. Below is a detailed breakdown:

**2.1 Resource Allocation Graph (RAG) Module**

This module forms the core of the system, managing the data structure that represents processes, resources, and their relationships. It includes:

* **Process Management**: Handles the creation and tracking of processes with unique identifiers (e.g., P1, P2).
* **Resource Management**: Manages resources, their total instances, and available instances.
* **Edge Management**: Tracks requests (process to resource) and allocations (resource to process) using a dictionary-based structure.
* **Deadlock Detection**: Implements a modified banker’s algorithm to detect deadlocks by simulating resource allocation and checking for safe states.

**2.2 Graphical User Interface (GUI) Module**

The GUI module provides an interactive interface for users to visualize and manipulate the RAG. Key components include:

* **Canvas**: Displays processes as circles and resources as rectangles, with edges representing requests and allocations.
* **Control Panel**: Includes buttons and input fields to add nodes, create edges, and run simulations.
* **Status Bar**: Shows real-time updates on the system state, such as the number of processes, resources, and edges.

**2.3 Deadlock Detection and Resolution Module**

This module uses AI-driven techniques to detect deadlocks and suggest resolutions:

* **Detection**: Analyzes the RAG to identify cycles that indicate a deadlock, using a simulation-based approach.
* **Resolution Guide**: Provides step-by-step instructions to resolve deadlocks, such as releasing resources from specific processes.
* **AI Integration**: Employs heuristics to prioritize resolution steps, such as identifying the process holding the most critical resources.

**2.4 State Management Module**

This module ensures the system state can be saved, loaded, and manipulated:

* **Undo/Redo**: Tracks user actions (e.g., adding nodes, creating edges) and allows reversing or reapplying them.
* **State Export/Import**: Saves the RAG state as a JSON file and loads it back for future use.

**2.5 Utility Module**

Handles miscellaneous functionalities:

* **Node Positioning**: Automatically positions nodes on the canvas for better visualization.
* **Error Handling**: Displays user-friendly error messages for invalid actions (e.g., adding duplicate processes).

**3. Functionalities**

The simulator offers the following key functionalities:

1. **Process and Resource Creation**: Users can add processes and resources with customizable instances for resources.
2. **Edge Creation**: Supports request edges (process to resource) and allocation edges (resource to process), with adjustable counts.
3. **Visualization**: Displays the RAG on a canvas, with processes as blue circles, resources as green rectangles, and edges as arrows (red for requests, black for allocations).
4. **Deadlock Detection**: Runs an AI-driven algorithm to detect deadlocks and highlights affected processes and resources.
5. **Resolution Guidance**: Provides a detailed guide to resolve deadlocks, including suggestions for resource release.
6. **State Persistence**: Allows saving the current state to a JSON file and loading it later.
7. **Undo/Redo**: Enables users to revert or reapply actions, enhancing usability.
8. **Help System**: Offers a help dialog with instructions and shortcuts for ease of use.

**4. Technology Used**

**Programming Languages:**

* Python: Chosen for its simplicity, readability, and extensive library support. Python is used for both the backend logic and the GUI.

**Libraries and Tools:**

* Tkinter: A standard Python library for creating the graphical user interface. It provides widgets like buttons, canvases, and dialogs.
* ttk (Tkinter Themed Widgets): Enhances the GUI with modern, platform-native styling.
* json: Used for serializing and deserializing the RAG state to/from JSON format for saving and loading.
* collections.defaultdict: Simplifies the management of request and allocation edges by providing default values.
* sys, math: Utility libraries for system-level operations and mathematical calculations.

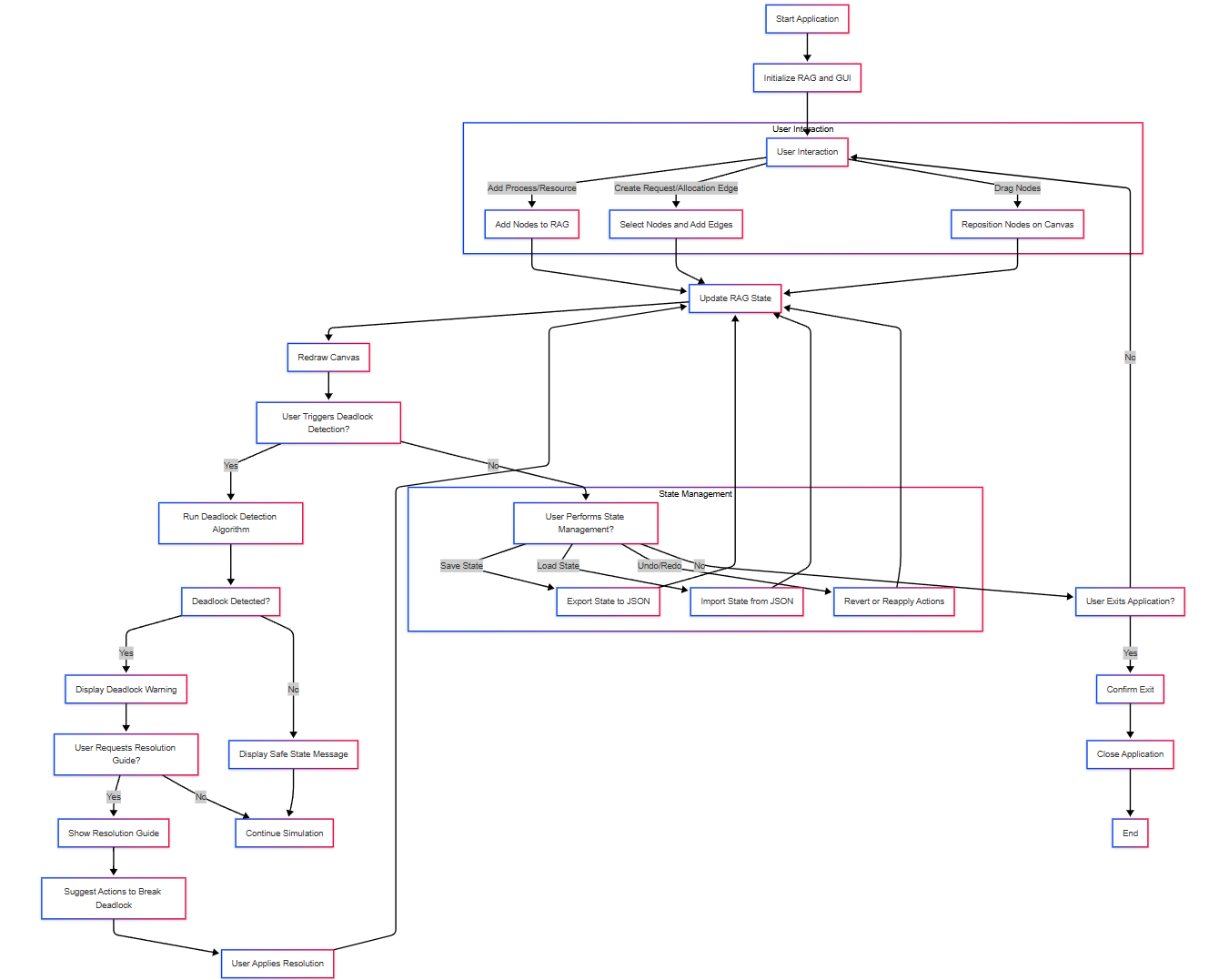
**Other Tools:**

* GitHub: Used for version control and collaboration, hosting the project repository.
* Visual Studio Code: The primary IDE for coding, debugging, and testing the application.

**5. Flow Diagram**

The flow of the simulator can be described as follows:

1. **Initialization**: The application starts, initializing the RAG and GUI.
2. **User Interaction**:
   * Add processes/resources via the control panel.
   * Create request/allocation edges by selecting nodes and specifying counts.
   * Drag nodes to reposition them on the canvas.
3. **State Update**: The RAG updates its internal state (processes, resources, edges) and redraws the canvas.
4. **Deadlock Detection**:
   * User triggers the detection process.
   * The system runs the banker’s algorithm to check for deadlocks.
   * Results are displayed via a message box, and the status bar is updated.
5. **Resolution**:
   * If a deadlock is detected, the user can view the resolution guide.
   * The guide suggests actions like releasing resources to break the deadlock.
6. **State Management**:
   * Users can save/load the state or undo/redo actions as needed.
7. **Exit**: The application closes after user confirmation.



**6. Revision Tracking on GitHub**

* **Repository Name:**

**AI-Deadlock-Simulator**

* **GitHub Link:**

**[**[**https://github.com/username/AI-Deadlock-Simulator**](https://github.com/username/AI-Deadlock-Simulator)**]**

**(Note: The above is a placeholder. You would replace it with the actual repository link.)**

**The project is hosted on GitHub, where all changes are tracked. Key commits include:**

* **Initial setup of the project structure and basic RAG implementation.**
* **Addition of the GUI using Tkinter.**
* **Implementation of the deadlock detection algorithm.**
* **Integration of undo/redo and state persistence features.**
* **Final testing and bug fixes.**

**7. Conclusion and Future Scope**

**T**he AI-Powered Deadlock Detection Simulator successfully achieves its goal of providing an interactive tool for understanding and resolving deadlocks in resource allocation systems. The integration of AI-driven heuristics for deadlock resolution adds significant value, making the tool both educational and practical. The GUI is intuitive, and features like undo/redo and state persistence enhance user experience.

**Future Scope:**

1. Advanced AI Features: Incorporate machine learning to predict potential deadlocks before they occur based on historical data.
2. Multi-Threading Support: Simulate real-world scenarios with concurrent processes.
3. Cross-Platform Compatibility: Package the application for Windows, macOS, and Linux using tools like PyInstaller.
4. Web-Based Version: Develop a web version using frameworks like Flask or Django for broader accessibility.
5. Enhanced Visualization: Add animations to show the deadlock detection process step-by-step.

**8. References**

 Silberschatz, A., Galvin, P. B., & Gagne, G. (2018). *Operating System Concepts*. Wiley.

 Python Software Foundation. (n.d.). *Python Documentation*. Retrieved from <https://docs.python.org/3/>

 Tkinter Documentation. (n.d.). Retrieved from <https://docs.python.org/3/library/tkinter.html>

 Tanenbaum, A. S., & Bos, H. (2014). *Modern Operating Systems*. Pearson.

**9.Appendix**

**A. AI-Generated Project Elaboration/Breakdown Report**

The AI-Powered Deadlock Detection Simulator is a tool designed to simulate resource allocation scenarios in operating systems, focusing on deadlock detection and resolution. It uses a resource allocation graph (RAG) to model processes, resources, and their relationships. The project is divided into modules for RAG management, GUI, deadlock detection/resolution, state management, and utilities. The GUI, built with Tkinter, allows users to visualize the RAG, add nodes/edges, and detect deadlocks. The deadlock detection algorithm, inspired by the banker’s algorithm, identifies unsafe states, while AI-driven heuristics suggest resolution steps. Features like undo/redo and state persistence enhance usability.

**B. Problem Statement**

In operating systems, deadlocks occur when multiple processes hold resources and wait for others, creating a cycle that prevents progress. Understanding and resolving deadlocks is crucial for system design and education. However, manually analyzing resource allocation scenarios is complex and error-prone. The goal of this project is to develop an AI-powered simulator that models resource allocation, detects deadlocks, and provides resolution guidance, making the process accessible and educational.

**C. Solution/Code**

Below is the complete code for the AI powered deadlock detection project

import tkinter as tk

from tkinter import ttk, messagebox, filedialog

from collections import defaultdict

import sys

import math

import json

class ResourceAllocationGraph:

    def \_\_init\_\_(self):

*self*.processes = set()

*self*.resources = {}

*self*.allocations = defaultdict(int)

*self*.requests = defaultdict(int)

*self*.next\_process\_id = 1

*self*.next\_resource\_id = 1

    def get\_auto\_process\_name(self):

        while f"P{*self*.next\_process\_id}" in *self*.processes:

*self*.next\_process\_id += 1

        return f"P{*self*.next\_process\_id}"

    def get\_auto\_resource\_name(self):

        while f"R{*self*.next\_resource\_id}" in *self*.resources:

*self*.next\_resource\_id += 1

        return f"R{*self*.next\_resource\_id}"

    def add\_process(self, process\_id=None):

        if not process\_id:

            process\_id = *self*.get\_auto\_process\_name()

        if process\_id in *self*.processes:

            raise ValueError(f"Process {process\_id} already exists")

*self*.processes.add(process\_id)

        return process\_id

    def add\_resource(self, resource\_id=None, instances=1):

        if not resource\_id:

            resource\_id = *self*.get\_auto\_resource\_name()

        if resource\_id in *self*.resources:

            raise ValueError(f"Resource {resource\_id} already exists")

*self*.resources[resource\_id] = {'total': instances, 'available': instances}

        return resource\_id

    def add\_request(self, process, resource, count=1):

        if process not in *self*.processes or resource not in *self*.resources:

            raise ValueError("Invalid process or resource")

*self*.requests[(process, resource)] += count

    def add\_allocation(self, process, resource, count=1):

        if process not in *self*.processes or resource not in *self*.resources:

            raise ValueError("Invalid process or resource")

        if count > *self*.resources[resource]['available']:

            raise ValueError(f"Not enough instances available")

*self*.allocations[(process, resource)] += count

*self*.resources[resource]['available'] -= count

    def remove\_allocation(self, process, resource, count=1):

        if (process, resource) in *self*.allocations:

*self*.allocations[(process, resource)] -= count

*self*.resources[resource]['available'] += count

            if *self*.allocations[(process, resource)] <= 0:

                del *self*.allocations[(process, resource)]

    def detect\_deadlock(self):

        work = {r: info['available'] for r, info in *self*.resources.items()}

        allocation = defaultdict(lambda: defaultdict(int))

        request = defaultdict(lambda: defaultdict(int))

        for (p, r), cnt in *self*.allocations.items():

            allocation[p][r] = cnt

        for (p, r), cnt in *self*.requests.items():

            request[p][r] = cnt

        finish = {p: False for p in *self*.processes}

        involved\_resources = defaultdict(set)

        while True:

            found = False

            for p in *self*.processes:

                if not finish[p] and all(request[p][r] <= work[r] for r in *self*.resources):

                    for r in *self*.resources:

                        work[r] += allocation[p][r]

                    finish[p] = True

                    found = True

            if not found:

                break

        deadlocked = [p for p, done in finish.items() if not done]

        if deadlocked:

            for p in deadlocked:

                for r in request[p]:

                    if request[p][r] > work[r]:

                        involved\_resources[p].add(r)

        return len(deadlocked) > 0, deadlocked, involved\_resources

    def get\_deadlock\_resolution\_guide(self, deadlocked, involved\_resources):

        if not deadlocked:

            return "No deadlock detected. The system is in a safe state."

        guide = "Deadlock Resolution Guide:\n\n"

        guide += f"Deadlocked Processes: {', '.join(deadlocked)}\n"

        guide += "Involved Resources and Requests:\n"

        for p in deadlocked:

            requests = [f"{r} ({*self*.requests[(p, r)]} requested)" for r in involved\_resources[p]]

            allocations = [f"{r} ({*self*.allocations[(p, r)]} allocated)" for r in *self*.resources if (p, r) in *self*.allocations]

            guide += f"- {p}: Requests: {', '.join(requests) if requests else 'None'}, Allocations: {', '.join(allocations) if allocations else 'None'}\n"

        guide += "\nHow to Resolve:\n"

        guide += "1. Identify a process holding resources that others need.\n"

        guide += f"   - Suggestion: Release allocations from {deadlocked[0]}.\n"

        guide += "2. Release enough resources to break the cycle:\n"

        for r in involved\_resources[deadlocked[0]]:

            if (deadlocked[0], r) in *self*.allocations:

                count = *self*.allocations[(deadlocked[0], r)]

                guide += f"   - Release {count} instance(s) of {r} from {deadlocked[0]} manually.\n"

        guide += "3. Adjust requests or add resources as needed.\n"

        return guide

    def export\_state(self):

        return json.dumps({

            "processes": list(*self*.processes),

            "resources": *self*.resources,

            "allocations": dict(*self*.allocations),

            "requests": dict(*self*.requests)

        }, indent=4)

    def import\_state(self, state\_json):

        state = json.loads(state\_json)

*self*.processes = set(state["processes"])

*self*.resources = state["resources"]

*self*.allocations = defaultdict(int, state["allocations"])

*self*.requests = defaultdict(int, state["requests"])

class RAGSimulator(tk.Tk):

    def \_\_init\_\_(self):

        super().\_\_init\_\_()

*self*.title("Resource Allocation Graph Simulator")

*self*.geometry("1280x720")

*self*.rag = ResourceAllocationGraph()

*self*.selected\_nodes = []

*self*.edge\_mode = None

*self*.node\_positions = {}

*self*.dragging = None

*self*.undo\_stack = []

*self*.redo\_stack = []

*# UI Constants*

*self*.PROCESS\_COLOR = "#4FC3F7"

*self*.RESOURCE\_COLOR = "#81C784"

*self*.PROCESS\_RADIUS = 30

*self*.RESOURCE\_SIZE = 70

*self*.LEFT\_MARGIN = 150

*self*.RIGHT\_MARGIN = 1100

*# Styling*

*self*.style = ttk.Style()

*self*.style.theme\_use('clam')

*self*.style.configure("TButton", padding=5, font=('Helvetica', 10))

*self*.style.configure("TLabel", font=('Helvetica', 11))

*self*.style.configure("Header.TLabel", font=('Helvetica', 14, 'bold'))

*self*.style.configure("Status.TLabel", font=('Helvetica', 9), background='#e0e0e0')

*self*.setup\_ui()

*self*.setup\_menu()

*self*.protocol("WM\_DELETE\_WINDOW", *self*.on\_close)

    def setup\_menu(self):

        menubar = tk.Menu(*self*)

        file\_menu = tk.Menu(menubar, tearoff=0)

        file\_menu.add\_command(label="New Graph", command=*self*.reset\_graph, accelerator="Ctrl+N")

        file\_menu.add\_command(label="Save State", command=*self*.export\_state)

        file\_menu.add\_command(label="Load State", command=*self*.import\_state)

        file\_menu.add\_separator()

        file\_menu.add\_command(label="Exit", command=*self*.on\_close)

        menubar.add\_cascade(label="File", menu=file\_menu)

        edit\_menu = tk.Menu(menubar, tearoff=0)

        edit\_menu.add\_command(label="Undo", command=*self*.undo, accelerator="Ctrl+Z")

        edit\_menu.add\_command(label="Redo", command=*self*.redo, accelerator="Ctrl+Y")

        menubar.add\_cascade(label="Edit", menu=edit\_menu)

        menubar.add\_command(label="Help", command=*self*.show\_help)

*self*.config(menu=menubar)

    def setup\_ui(self):

        main\_frame = ttk.Frame(*self*, padding=10)

        main\_frame.pack(fill=tk.BOTH, expand=True)

        control\_pane = ttk.PanedWindow(main\_frame, orient=tk.VERTICAL)

        control\_pane.pack(side=tk.LEFT, fill=tk.Y, padx=(0, 10))

        node\_frame = ttk.LabelFrame(control\_pane, text="Add Nodes", padding=8)

        control\_pane.add(node\_frame, weight=1)

        ttk.Button(node\_frame, text="New Process", command=*self*.add\_process).pack(fill=tk.X, pady=2)

        ttk.Button(node\_frame, text="New Resource", command=*self*.add\_resource).pack(fill=tk.X, pady=2)

*self*.instances\_var = tk.IntVar(value=1)

        ttk.Label(node\_frame, text="Resource Instances:").pack(pady=(5, 2))

        ttk.Spinbox(node\_frame, from\_=1, to=10, textvariable=*self*.instances\_var,

                   width=5).pack()

        edge\_frame = ttk.LabelFrame(control\_pane, text="Edges", padding=8)

        control\_pane.add(edge\_frame, weight=1)

*self*.count\_var = tk.IntVar(value=1)

        ttk.Label(edge\_frame, text="Edge Count:").pack(pady=(0, 2))

        ttk.Spinbox(edge\_frame, from\_=1, to=5, textvariable=*self*.count\_var,

                   width=5).pack(pady=2)

        ttk.Button(edge\_frame, text="Request Edge",

                  command=lambda: *self*.set\_edge\_mode("request")).pack(fill=tk.X, pady=2)

        ttk.Button(edge\_frame, text="Allocation Edge",

                  command=lambda: *self*.set\_edge\_mode("allocation")).pack(fill=tk.X, pady=2)

        ttk.Button(edge\_frame, text="Clear Selection",

                  command=*self*.clear\_selection).pack(fill=tk.X, pady=2)

        sim\_frame = ttk.LabelFrame(control\_pane, text="Simulation", padding=8)

        control\_pane.add(sim\_frame, weight=1)

        ttk.Button(sim\_frame, text="Check Deadlock",

                  command=*self*.detect\_deadlock).pack(fill=tk.X, pady=2)

        ttk.Button(sim\_frame, text="Resolution Guide",

                  command=*self*.show\_resolution\_guide).pack(fill=tk.X, pady=2)

*self*.canvas = tk.Canvas(main\_frame, bg='white', highlightthickness=0)

*self*.canvas.pack(side=tk.RIGHT, fill=tk.BOTH, expand=True)

*self*.canvas.bind("<Button-1>", *self*.on\_click)

*self*.canvas.bind("<B1-Motion>", *self*.on\_drag)

*self*.canvas.bind("<ButtonRelease-1>", *self*.on\_release)

*self*.status = ttk.Label(main\_frame, text="Ready", style="Status.TLabel",

                              relief=tk.SUNKEN, anchor='w', padding=4)

*self*.status.pack(side=tk.BOTTOM, fill=tk.X)

*self*.bind\_all("<Control-z>", lambda e: *self*.undo())

*self*.bind\_all("<Control-y>", lambda e: *self*.redo())

*self*.bind\_all("<Control-n>", lambda e: *self*.reset\_graph())

    def show\_help(self):

        messagebox.showinfo("Help",

            "Resource Allocation Graph Simulator\n\n"

            "Shortcuts:\n"

            "Ctrl+Z: Undo\n"

            "Ctrl+Y: Redo\n"

            "Ctrl+N: New Graph\n\n"

            "Usage:\n"

            "1. Add processes and resources\n"

            "2. Select two nodes to create edges\n"

            "3. Request: Process → Resource (red)\n"

            "4. Allocation: Resource → Process (black)\n"

            "5. Drag nodes to reposition\n"

            "6. Check deadlocks and use 'Resolution Guide' for manual resolution tips")

    def export\_state(self):

        file\_path = filedialog.asksaveasfilename(defaultextension=".json",

                                               filetypes=[("JSON files", "\*.json")])

        if file\_path:

            with open(file\_path, 'w') as f:

                f.write(*self*.rag.export\_state())

*self*.status.config(text="State saved")

    def import\_state(self):

        file\_path = filedialog.askopenfilename(filetypes=[("JSON files", "\*.json")])

        if file\_path:

            with open(file\_path, 'r') as f:

*self*.push\_undo\_action('import', *self*.rag.export\_state())

*self*.rag.import\_state(f.read())

*self*.reposition\_nodes()

*self*.update\_display()

*self*.status.config(text="State loaded")

    def set\_edge\_mode(self, mode):

*self*.edge\_mode = mode

*self*.selected\_nodes = []

*self*.status.config(text=f"Select nodes for {mode} edge")

    def update\_display(self):

*self*.canvas.delete("all")

*self*.draw\_edges()

*self*.draw\_nodes()

*self*.draw\_selection()

*self*.status.config(text=f"P: {len(*self*.rag.processes)} | R: {len(*self*.rag.resources)} | "

                              f"Edges: {len(*self*.rag.allocations) + len(*self*.rag.requests)}")

    def draw\_edges(self):

        for (p, r), count in *self*.rag.requests.items():

            if count > 0 and p in *self*.node\_positions and r in *self*.node\_positions:

*self*.draw\_edge(p, r, "request", count)

        for (p, r), count in *self*.rag.allocations.items():

            if count > 0 and p in *self*.node\_positions and r in *self*.node\_positions:

*self*.draw\_edge(r, p, "allocation", count)

    def draw\_edge(self, from\_node, to\_node, edge\_type, count):

        x1, y1 = *self*.node\_positions[from\_node]

        x2, y2 = *self*.node\_positions[to\_node]

        color = '#EF5350' if edge\_type == "request" else '#424242'

        arrow = tk.FIRST if edge\_type == "request" else tk.LAST

        mid\_x, mid\_y = (x1 + x2) / 2, (y1 + y2) / 2

*self*.canvas.create\_line(x1, y1, x2, y2, fill=color, width=2, arrow=arrow)

*self*.canvas.create\_text(mid\_x, mid\_y - 10, text=str(count), fill=color,

                              font=('Helvetica', 10, 'bold'))

    def draw\_nodes(self):

        for p in *self*.rag.processes:

            if p in *self*.node\_positions:

                x, y = *self*.node\_positions[p]

*self*.canvas.create\_oval(x-*self*.PROCESS\_RADIUS, y-*self*.PROCESS\_RADIUS,

                                      x+*self*.PROCESS\_RADIUS, y+*self*.PROCESS\_RADIUS,

                                      fill=*self*.PROCESS\_COLOR, outline='#0277BD', width=2,

                                      tags=('node', p))

*self*.canvas.create\_text(x, y, text=p, font=('Helvetica', 12, 'bold'), tags=('text', p))

        for r in *self*.rag.resources:

            if r in *self*.node\_positions:

                x, y = *self*.node\_positions[r]

                avail = *self*.rag.resources[r]['available']

                fill = *self*.RESOURCE\_COLOR if avail > 0 else '#EF9A9A'

*self*.canvas.create\_rectangle(x-*self*.RESOURCE\_SIZE/2, y-*self*.RESOURCE\_SIZE/2,

                                           x+*self*.RESOURCE\_SIZE/2, y+*self*.RESOURCE\_SIZE/2,

                                           fill=fill, outline='#2E7D32', width=2, tags=('node', r))

*self*.canvas.create\_text(x, y-10, text=r, font=('Helvetica', 12, 'bold'))

*self*.canvas.create\_text(x, y+10, text=f"{avail}/{*self*.rag.resources[r]['total']}",

                                      font=('Helvetica', 10))

    def draw\_selection(self):

        for node in *self*.selected\_nodes:

            x, y = *self*.node\_positions[node]

            size = *self*.PROCESS\_RADIUS if node in *self*.rag.processes else *self*.RESOURCE\_SIZE/2

*self*.canvas.create\_oval(x-size-5, y-size-5, x+size+5, y+size+5,

                                  outline='#FFB300', width=2, dash=(4, 2))

    def on\_click(self, event):

        item = *self*.canvas.find\_closest(event.x, event.y)

        tags = *self*.canvas.gettags(item)

        if 'node' in tags or 'text' in tags:

            node = tags[1]

            if *self*.edge\_mode:

                if node not in *self*.selected\_nodes:

*self*.selected\_nodes.append(node)

                    if len(*self*.selected\_nodes) == 2:

*self*.create\_edge()

            else:

*self*.dragging = node

*self*.drag\_offset = (event.x - *self*.node\_positions[node][0],

                                  event.y - *self*.node\_positions[node][1])

*self*.update\_display()

    def on\_drag(self, event):

        if *self*.dragging:

*self*.node\_positions[*self*.dragging] = (event.x - *self*.drag\_offset[0],

                                                event.y - *self*.drag\_offset[1])

*self*.update\_display()

    def on\_release(self, event):

*self*.dragging = None

    def create\_edge(self):

        try:

            if len(*self*.selected\_nodes) != 2:

                return

            n1, n2 = *self*.selected\_nodes

            count = *self*.count\_var.get()

            if *self*.edge\_mode == "request" and n1 in *self*.rag.processes and n2 in *self*.rag.resources:

*self*.rag.add\_request(n1, n2, count)

*self*.push\_undo\_action('request', n1, n2, count)

            elif *self*.edge\_mode == "allocation" and n1 in *self*.rag.resources and n2 in *self*.rag.processes:

*self*.rag.add\_allocation(n2, n1, count)

*self*.push\_undo\_action('allocation', n2, n1, count)

            else:

                raise ValueError("Invalid edge direction")

*self*.clear\_selection()

*self*.update\_display()

        except ValueError as e:

            messagebox.showerror("Error", str(e))

*self*.clear\_selection()

    def push\_undo\_action(self, action\_type, node1=None, node2=None, count=0, state=None):

*self*.undo\_stack.append({

            'type': action\_type, 'node1': node1, 'node2': node2,

            'count': count, 'state': state, 'positions': *self*.node\_positions.copy()

        })

*self*.redo\_stack.clear()

    def undo(self):

        if not *self*.undo\_stack:

            return

        action = *self*.undo\_stack.pop()

        if action['type'] == 'request':

*self*.rag.requests[(action['node1'], action['node2'])] -= action['count']

            if *self*.rag.requests[(action['node1'], action['node2'])] <= 0:

                del *self*.rag.requests[(action['node1'], action['node2'])]

        elif action['type'] == 'allocation':

*self*.rag.remove\_allocation(action['node2'], action['node1'], action['count'])

        elif action['type'] == 'add\_process':

*self*.rag.processes.remove(action['node1'])

            del *self*.node\_positions[action['node1']]

        elif action['type'] == 'add\_resource':

            del *self*.rag.resources[action['node1']]

            del *self*.node\_positions[action['node1']]

        elif action['type'] == 'import':

*self*.rag.import\_state(action['state'])

*self*.node\_positions = action['positions']

*self*.redo\_stack.append(action)

*self*.update\_display()

    def redo(self):

        if not *self*.redo\_stack:

            return

        action = *self*.redo\_stack.pop()

        if action['type'] == 'request':

*self*.rag.add\_request(action['node1'], action['node2'], action['count'])

        elif action['type'] == 'allocation':

*self*.rag.add\_allocation(action['node2'], action['node1'], action['count'])

        elif action['type'] == 'add\_process':

*self*.rag.add\_process(action['node1'])

*self*.node\_positions[action['node1']] = action['positions'][action['node1']]

        elif action['type'] == 'add\_resource':

*self*.rag.add\_resource(action['node1'], action['count'])

*self*.node\_positions[action['node1']] = action['positions'][action['node1']]

        elif action['type'] == 'import':

            curr\_state = *self*.rag.export\_state()

*self*.rag.import\_state(action['state'])

            action['state'] = curr\_state

*self*.undo\_stack.append(action)

*self*.update\_display()

    def add\_process(self):

        try:

            p\_id = *self*.rag.add\_process()

*self*.node\_positions[p\_id] = (*self*.LEFT\_MARGIN, len(*self*.rag.processes) \* 100)

*self*.push\_undo\_action('add\_process', p\_id)

*self*.update\_display()

        except ValueError as e:

            messagebox.showerror("Error", str(e))

    def add\_resource(self):

        try:

            r\_id = *self*.rag.add\_resource(instances=*self*.instances\_var.get())

*self*.node\_positions[r\_id] = (*self*.RIGHT\_MARGIN, len(*self*.rag.resources) \* 100)

*self*.push\_undo\_action('add\_resource', r\_id, count=*self*.instances\_var.get())

*self*.update\_display()

        except ValueError as e:

            messagebox.showerror("Error", str(e))

    def clear\_selection(self):

*self*.selected\_nodes = []

*self*.edge\_mode = None

*self*.update\_display()

    def detect\_deadlock(self):

        has\_deadlock, processes, involved\_resources = *self*.rag.detect\_deadlock()

        if has\_deadlock:

            messagebox.showwarning("Deadlock", f"Deadlocked: {', '.join(processes)}\n"

                                             f"Involved Resources: {dict(involved\_resources)}")

*self*.status.config(text="Deadlock detected!")

        else:

            messagebox.showinfo("Safe", "No deadlock detected")

*self*.status.config(text="System safe")

        return has\_deadlock, processes, involved\_resources

    def show\_resolution\_guide(self):

        has\_deadlock, processes, involved\_resources = *self*.rag.detect\_deadlock()

        guide = *self*.rag.get\_deadlock\_resolution\_guide(processes, involved\_resources)

        if has\_deadlock:

            messagebox.showinfo("Deadlock Resolution Guide", guide)

        else:

            messagebox.showinfo("No Deadlock", guide)

    def reset\_graph(self):

        if messagebox.askyesno("Reset", "Clear all data?"):

*self*.push\_undo\_action('import', *self*.rag.export\_state())

*self*.rag = ResourceAllocationGraph()

*self*.node\_positions = {}

*self*.clear\_selection()

*self*.redo\_stack.clear()

*self*.update\_display()

*self*.status.config(text="Graph reset")

    def reposition\_nodes(self):

*self*.node\_positions.clear()

        for i, p in enumerate(*self*.rag.processes):

*self*.node\_positions[p] = (*self*.LEFT\_MARGIN, (i + 1) \* 100)

        for i, r in enumerate(*self*.rag.resources):

*self*.node\_positions[r] = (*self*.RIGHT\_MARGIN, (i + 1) \* 100)

    def on\_close(self):

        if messagebox.askokcancel("Quit", "Exit application?"):

*self*.destroy()

if \_\_name\_\_ == "\_\_main\_\_":

    app = RAGSimulator()

    app.mainloop()