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Agent-Based Epidemic Model with Optimization of Interventions

🧠 What It Is:

A system that simulates the spread of a disease (like COVID-19 or flu) through a population of agents (people), and **uses optimization algorithms** to find the best intervention strategy—e.g., when to close schools, limit travel, or deploy vaccines—to **minimize infections and economic cost**.

🏗️ Components Breakdown

1. Agent-Based Simulation Engine

Each person is modeled as an "agent" with:

- State: Susceptible, Infected, Recovered (SIR) or SEIR (E = Exposed)
- Location: home, school, workplace
- Behavior: movement, interactions

Simulates the stochastic spread of disease over time and space.

Toolkits:

- Mesa (Python agent-based framework)
- NetworkX for social graphs
- Matplotlib or Plotly for live plots

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2. Intervention Policy Layer

Interventions may include:

- Lockdowns (school/business closures)
- Mask mandates
- Travel restrictions
- Vaccination scheduling
- Public awareness campaigns

Each intervention has:

- A **cost** (economic, political, social)
- A **delay** or ramp-up time
- An **effectiveness**

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3. Optimization Engine

Use optimization to **choose which interventions to apply, and when**, to achieve goals like:

- Minimizing total infections
- Keeping R_0 (reproduction number) below a target
- Minimizing cost under a constraint

Techniques:

- **Mixed Integer Programming** (with OR-Tools, Gurobi, or Pyomo)
- **Genetic Algorithms** (for nonlinear or discrete decision spaces)
- **Simulated Annealing** or other metaheuristics

🔁 Example Loop

1. Run the simulator forward in time with given interventions.
2. Evaluate the outcome (e.g., infections, cost).
3. The optimizer tweaks intervention schedule to improve results.

4. Repeat (possibly with parallel scenarios or stochastic variation).

📊 Example Outputs

- Time-series plots: infection curve with/without interventions
- Cost vs. Infection heatmaps
- Maps of infection hotspots
- Intervention schedules (calendar format)

🧪 Potential Scenarios to Simulate

- What if we delay school closures by 2 weeks?
- How many people must be vaccinated to avoid another wave?
- What's the tradeoff between economic loss and infection rate?

🚀 Why It Stands Out

- Combines **simulation**, **optimization**, **data science**, and **public health modeling**
- Real-world relevance (everyone understands COVID-style policy tension)
- Highly customizable (add mobility networks, contact tracing, super-spreader events, etc.)
- Perfect for demos: visually rich, story-driven, and impactful

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🧱 Tech Stack Suggestion

Component	Tools
Agent simulation	Python + Mesa
Optimization	OR-Tools / Pyomo / DEAP (GA)
Visualization	Plotly / Dash / Streamlit
Optional web app	Flask + React, or just Streamlit

Data storage	Pandas / JSON / SQLite

💡 Bonus Features (if time allows)

- Add **vaccination hesitancy** modeling (psychological agents)
- Use **real-world mobility data** (e.g., from OpenStreetMap)
- Add an **interactive UI** where users test policies manually
- Export policies and outcomes to a report or PDF

📚 What You'll Learn and Show Off

- Agent-based modeling (used in epidemiology, traffic, urban planning)
- Mathematical modeling of interventions as constraints
- MIP/heuristic optimization over noisy, dynamic systems
- Trade-off analysis in policy design
- Effective data visualization

🎯 Use Case in Interviews / Career Fair

> "I built a simulation that models disease spread in a synthetic population, and an optimizer that determines the most cost-effective intervention strategy. It's a tool for answering 'What if?' questions in public health and logistics."

If you want, I can help you **scope this into milestones**, draft a **README layout**, or design a **publication-style report** so it doubles as a portfolio and academic piece.

Would you like help getting started with a scaffolded plan for it?