Locked In: Development of an autonomous goal-based route planner for drone missions

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Motivation

Lockheed Martin CDL Systems (LMCDL) is advancing Unmanned Aerial Vehicle (UAV) mission planning through the development of cutting-edge ground control software. The SAFE project introduced a plugin for autonomous route mapping but encountered obstacles in achieving optimization and dynamic hazard navigation.

Building on this foundation, the subsequent Locked In project seeks to enhance the plugin by integrating dynamic route recalculation, elevating fuel efficiency through refined optimization algorithms, and ensuring a consistent, stable user experience. The goal is to deliver an advanced autonomous drone navigation system designed to avoid emerging obstacles while simultaneously reducing flight expenses.

Problem Statement

UAVs are increasingly used for their cost savings and lower manpower requirements. LMCDL has led in creating software for their control, but operators still need to constantly manage the UAV, diverting attention from other tasks.

The SAFE project automated route planning in 2019 but lacked full optimization and dynamic data handling. Specifically, the original algorithm cannot avoid dynamic obstacles, either being an updated obstacle in the map, or an external third-party vehicle in flight.

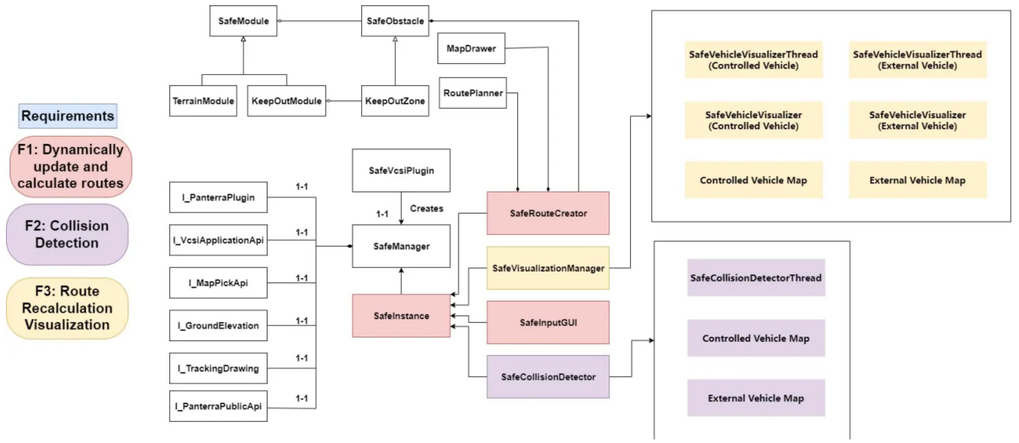
The new Locked-In project builds on this, enhancing the VCSi plugin with better navigation, reliability, and efficiency in mission planning. The updated plugin is expected to have functionalities such as multi-thread handling & route planning, dynamic route recalculation to avoid emerging obstacles, third-party vehicle visualizations, etc.

Algorithm

- A* is a widely-used pathfinding algorithm known for its efficiency and optimality.
- It operates on a weighted graph, where nodes represent locations, and edges represent connections between them.
- A* uses a heuristic function to guide its search, balancing the cost of reaching a node from the start with the estimated cost to reach the goal from that node.
- By intelligently exploring the graph, A* efficiently finds the shortest path from a start node to a goal node.
- Our program uses this algorithm to map an initial route for Lockheed's drones, avoiding static obstacles as well as rerouting sections of the route whenever new dynamic obstacles such as 3rd party vehicles are set to collide with our drone.

A* Algorithm Pseudo-Code

```
procedure
    create OPEN                                  # set of nodes to be evaluated
    create CLOSED                                # set of nodes already evaluated
    add first node to OPEN
    repeat
        current = node in OPEN with min f_cost   # distance from start + to end
        remove current from OPEN
        add current to CLOSED
        if current is target node then
            return                               # path found
        end if
        for each neighbor of current do
            if neighbor != traversable or neighbor is in CLOSED then
                continue to next neighbor
            end if
            if new path to neighbor is shorter or neighbor is not in OPEN then
                calculate and set neighbor's f_cost
                set neighbor's parent to current
                if neighbor is not in OPEN then
                    add neighbor to OPEN
                end if
            end if
    until OPEN is empty
end procedure
```



Key Software Components

SafeCollisionDetector: Collision Detection Management
Utilizes simulated real-time location data from third-party vehicles and obstacles.

SafeVehicleVisualizer & SafeVehicleVisualizerThread: Path Visualization
Dynamic visualization of third-party vehicles & obstacles.

SafeRoutePlanner & SafeRouteCreator: Algorithm and Route Calculation
Multi-thread optimized algorithm for route calculation with real-time data inputs.

Results

1. **Dynamic Route Recalculation**: Plugin can now accommodate for simulated live incoming data on hazards and recalculate route as needed.
2. **Visualization of Dynamic Route Recalculation**: Plugin will show a visualization in VCSi of the vehicle in control flying a simulated route and avoiding simulated incoming hazards in real time.
3. **Handle Vehicle of Different Sizes**: Now can adjust the size of the keep out zone to handle different vehicle sizes.
4. **Visualization of Algorithm**: Pathfinding algorithm is now visualized via red cubes to show the operator potential paths explored for troubleshooting purposes.
5. **Parallelize Plugin**: Have plugin run on its own thread so that it does not clog up VCSi.