Weather Feature Extraction on the Academic Cloud for Drone Route Planning

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• Next Generation Weather Radars (NEXRAD)
  • High power, long range
  • Limited ability to observe the lower part of the atmosphere because of the Earth's curvature

• CASA
  • Network of short range Doppler radars
  • Fast updating, near to the ground observations
  • Overlapping coverage provides multiple views of weather feature
Drone Guidance Application

- Unmanned aviation systems (UAS) is a rapidly growing industry
- Small aircraft are sensitive to weather and CASA seeks to provide customized information to minimize weather risk
- Compute and network intensive workflows associated with processing CASA radar data and forecast models at various timescales
- Uses the academic cloud, ExoGENI and Chameleon, for data processing and dynamically created private layer 2 networks
- Implement network-aware workflow scheduling, predictions and ensemble mechanisms using the Pegasus Workflow Management System (WMS)
CASA Wind Contouring Data Processing Workflow

• Ingests compressed data from 7 radars
• Combine into grid of maximum observed wind speed
• Generate combined radar image
• Compute wind contours with velocity thresholds
• Send alerts based on user locations
CASA Hail Data Processing Workflow

- Ingest compressed data from 4 CASA radars
- Collect Nexrad single radar data
- Hail event identification
- Combine hail data from multiple radars
- Compute hail contouring
- Generate combined radar image
• Layer 2 AL2S network linked to a dedicated portal server
• Shared NFS storage node acting as a network bridge and container/data repository
• Pegasus submit node orchestrating workflows and serving as HT Condor master
• HT Condor worker node pool
Drone Route Planning Web Application

• Select Start and End Point
• Assign a vehicle type with weather parameters
• Assign some risk parameters
• Pass submitted flight to a flight database
• Generate routing request
• Return routed flight, or advisory that the flight is not advisable

"properties":{
"eventName":"VA NORTH TEXAS AT DALLAS TO
PALO PINTO GENERAL HOSPITAL_2020-09-08T19:19:22Z",
"startTime":"2020-09-08T19:19:22Z",
"endTime":"2020-09-08T20:53:57Z",
"products":[
{"hazard":"HAIL_CASA","parameters": [{"distance":0,"distanceUnits":"kilometers"}],
{"hazard":"RAIN_RATE_CASA","parameters": [{"thresholdUnits":"inph","distance":3,"distanceUnits":"kilometers","threshold":1,"valueField":"RainfallRateLevel"}],
{"hazard":"STORM_CASA_10","parameters": [{"thresholdUnits":"dBZ","distance":0,"distanceUnits":"kilometers","threshold":30,"valueField":"ReflectivityLevel"}],
{"hazard":"FORECAST_CASA_30","parameters": [{"thresholdUnits":"dBZ","distance":0,"distanceUnits":"kilometers","threshold":30,"valueField":"ReflectivityLevel"}],
{"hazard":"WINDS_CASA","parameters": [{"thresholdUnits":"mph","distance":2,"distanceUnits":"kilometers","threshold":25,"valueField":"mag"}]}]}}
CASA Flight Routing Architecture

- Flight Generation Web App
- Flight DB
- RabbitMQ
- Mobius/Pegasus Command and Control
- Flight Simulation

Weather Workflows with Virtual SDX:
- Hall
- Rain
- Wind

- 100mbps
- 250mbps
- 500mbps

- Custom Obstacle Query
- Custom Obstacle Data

- Monitoring
- Worker Task Assignment

- Sensor and Model Data

- Latest Flight Data
- Latest Flight Query
- Latest Flight Paths

Routing Request
Simulation Request
Flight Registration

Flight Routing Process

- Latest weather polygons are queried from the obstacle database.
- Safety/Uncertainty buffers are added on a per feature basis, and then polygons are merged and regenerared into master obstacle course, including static areas.
- A graph is created using convex hull points of the master obstacle course.
- Modified A* algorithm used to generate the shortest path from the resultant graph.
- Results are posted back into the flight database, along with new end time estimate, distance, and cost.
- Flights are advanced along their routed paths in realistic ways based on flight speeds.

- Routing occurs on an ongoing basis as the weather observations and forecasts evolve over time.

- Forecasts are unpredictable and prone to error! Estimates are constantly evolving.

- Even if operations generally rely on longer term forecast for strategic decisions, they will still have to consider developing, perhaps unexpected weather at flight time and be able to navigate.
Pro: Seamlessly distributes processing on an arbitrary pool of worker nodes

Con: Planning and orchestration can take a long time

Options:
- Bundle fast workflows together
- Favor longer running workflows
- Use Pegasus to assign message queue based listeners that handle the jobs, rather than assigning the jobs directly
- Use Pegasus for jobs with lower timeliness requirements
Pegasus/Condor uses Current and Ongoing

- **Current use:**
  - Pegasus jobs contain the super set of all product contour levels for all ongoing flights at all times

- **In Development:**
  - Use Pegasus to analyze ensemble model suites, for which the processes are duplicated for each member, with dependent jobs for overall uncertainty analysis once all the individual runs have been processed
  
- Jobs to route all flights as a fleet, and ensure that paths do not intersect in space and time
Requests/suggestions:

REST API for remote job submission

Lightweight options for faster jobs (no checkpointing/reduced metrics/faster planning(?))

Contingency job planning in workflows

Deeper integration with Mobius for resource procurement
Thank You!