Modelica Library for Balloon Assisted Unmanned Aerial Vehicle

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Agenda

1. Introduction to Balloon Assisted Unmanned Aerial Vehicle (BUAV)
2. Components of BUAV
3. Integration Systems
4. Simulation Case Study
5. Next Steps
Today’s clearcut approach – damages ground
Increased demands on future forestry

- Improved economics
  - Big forestry machines are expensive and have to run 24h
- Environmental and climate demands on less fossil fuel usage (avoid diesel)
- Handle challenges:
  - Increased climate change
  - Avoid damage on land and water
  - Risk of forest fire
- Possibilities for efficient forestry without clearcut areas
  - For example, close to cities
- Increased efficiency
  - In productive forests in areas which are difficult to access
- More environmentally friendly and robust forestry – pick only selected trees, allow a mix of different trees
An autonomous ground independent lifting system

- **Aerostat**: Balances the system weight without load.
- **Multicopter**: Provides lift power without load. Maneuvering and control.
- **Energy package (batteries, also hydrogen in balloon)**
- **Storage of energy**
- **Grapple and sensors for localizing tree trunk**

Patent application has been made for this system.
Transportation of timber

- Timber
- Branches
- Whole tree
Early Prototype Demo Flight by GI LIFT AB
Outside Linköping December 2019
Introduction to Balloon Assisted Unmanned Aerial Vehicle Model (BUAV)
Introduction

- Balloon assisted UAV (Unmanned Aerial vehicle) is an integrated device having a hydrogen/helium balloon attached to a multicopter.
- BUAV can be used to transport heavy objects, high altitude surveillance, provide extended flight time for UAV and so on.
- Multibody BUAVSystems library has been developed in Modelica/ OpenModelica.
- This library can be used for:
  - Stability Analysis of the UAV and Control System Design
  - Stability Analysis of the Payload including oscillationa
  - Path Planning- Time, Power and Energy
  - Load Analysis
Components of BUAV Systems
**Library Architecture**

**AerostatSystem** simulates the drag and lift dynamics of a balloon filled with a buoyant gas.

**UAVSystem** model captures the force and torque exerted on the USV for a given input profile.

**PayloadSystem** model captures the dynamics of a hanging payload in motion.
Library Architecture

- **LinearMotion3D** takes velocities in 3 dimensions and generates the combined force input.
- **PathPlanner** and **PathData** provide the velocity profile inputs based on user waypoint selection.
- **Configuration** model takes all parametric inputs for the system like UAV, payload mass, Balloon dimensions, payload cable length etc.

OpenModelica Library- Extending the MultiBody Library
Example Models

**IntegratedSystem** example model calculates the total force and torque exerted on the uav and the payload oscillation for a predefined path input.

**StateEstimation** example model is an integrated system of balloon, UAV and the payload which *stimulates how the system moves* for a given set of UAV propeller inputs.
IntegratedSystem
Architecture of IntegratedSystem

1. User
   - User Input - Parameters (text file)
   - User Input - Waypoints (csv file)

2. Path Generator
3. Text File for Path
4. Path Planner
5. Configurations
6. IntegratedSystem
   - Aerostat System
   - UAV System
   - Payload System

7. 3D Motion
8. Visualisation

Legend:
- External resources
- Modelica models
- Python script
- Output
Workflow of Integrated System

Parameters.txt
- maxHorizontalVelocity=10
- maxVerticalVelocity=1
- horDelay=2
- verDelay=2
- windVelocity=4
- windDirection=0
- uavMass=55
- payloadMassOnward=50
- deadWeight=6
- dragCoefficientSphere=0.47
- gasDensity=0.08988
- payloadRadius=0.2
- payloadLength=0.5
- dragCoefficientCylinder=0
- cableLength=1
- aerostatMass=70
- aerostatRadius=2.7
- airDensity=1.23

Waypoints.csv
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Plots of Integrated System

Coordinate Plot

Force Plot

Payload Oscillation Plot

Energy Plot
Simulation Case Studies
BUAV vs UAV Simulation

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<tr>
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<th>Value</th>
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<td>UAV Mass</td>
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<tr>
<td>Payload Mass</td>
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<td>kg</td>
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<tr>
<td>Maximum lift velocity</td>
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<td>m/s</td>
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<tr>
<td>Maximum horizontal velocity</td>
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<td>m/s</td>
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<tr>
<td>Balloon mass with harness</td>
<td>76.6</td>
<td>kg</td>
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<tr>
<td>Balloon radius</td>
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<tr>
<td>Balloon drag coefficient</td>
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<table>
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Waypoints

Parameters
BUAV vs UAV Simulation

- **70% reduction in power consumption**

- **46% reduction in Max Thrust required by UAV**
Next Steps

- Control System Design
- Flight Controller
- Payload Controller
- Path Optimization
- Interactive Simulation

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Thank You