THE IRISH SOFTWARE RESEARCH CENTRE

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Coláiste na hOllscoile Corcaigh, Éire
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Enabling Autonomous Systems to Adapt to Novel Faults

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❑ Problem Statement:

Autonomous systems (AS) such as cars, UAVs and satellites currently have no mechanism to deal with novel faults where no pre-defined control exists. Controllers for optimal control in known system modes exist. However since the number of faults to consider in an AS is virtually endless it is impossible to pre-define a controller for every fault at design time.

This research aims to explore new control mechanisms for AS to be able to maintain control under unexpected fault conditions which is a critical ability for the continuous progression of autonomous vehicle.

We focus on autonomous vehicle trajectory optimization as our application domain.

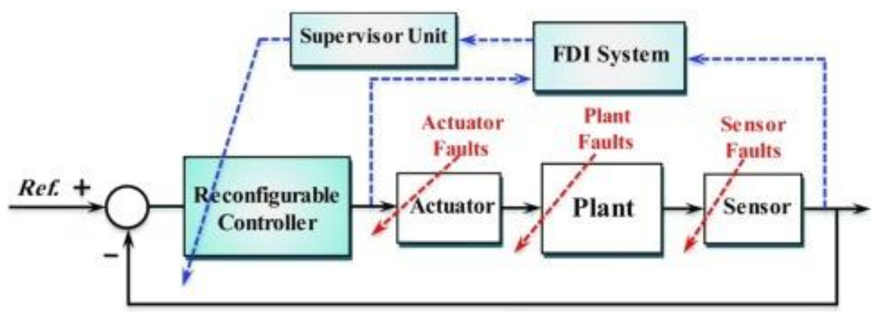

Fig1 Left: Fictional Rendering of a flying vehicle

Right: Fault tolerant control under faults.

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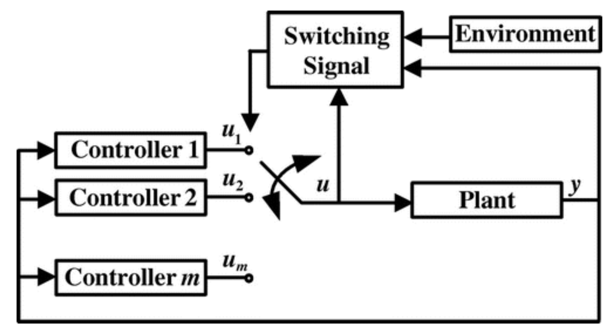
❑ Approach

Currently state-of-the-art research in Fault Tolerant Control (FTC) mainly relies on control switching with pre-defined controllers.

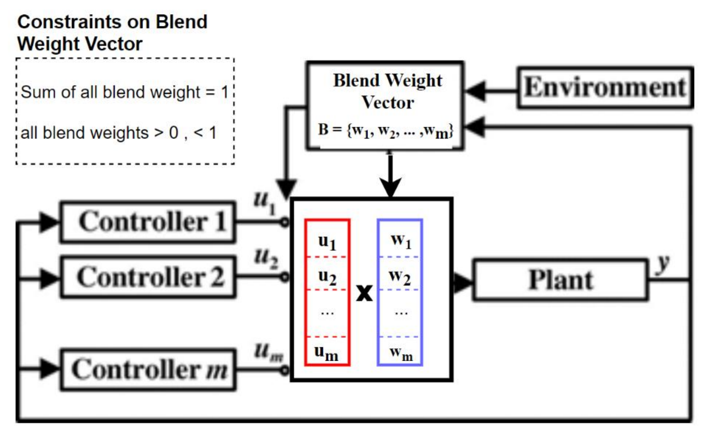
<u>Control Switching</u>:



- Control Signal *U* decides which controller is active
- Limited to pre-defined controllers, no control under novel system disturbance.

We are exploring Blended Control, which combines the output of all pre-defined controllers proportionally to synthesise a new controller online.

Blended Control:



- We take the weighted sum of all controllers multiplied by their weight.
- Changing weights allows for generation of new controllers for novel disturbances
- Blended Control has not been widely studied.

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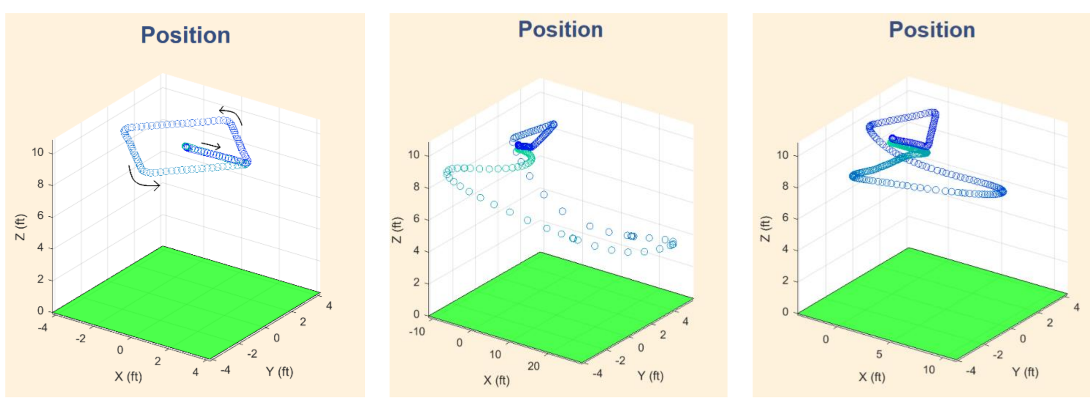
❑ Methodology

We focus on Trajectory Optimisation under Novel Disturbances on a Quadcopter and Car trajectory following simulation.

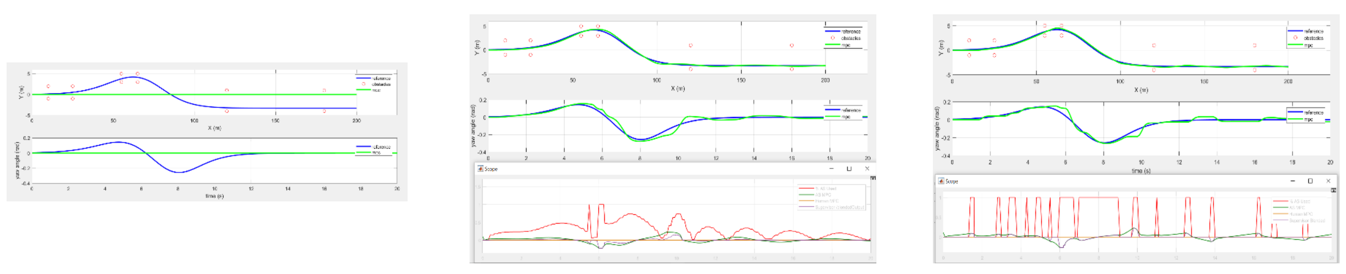
<u>Randomized Quadcopter Control under Novel Disturbances</u>



We utilize randomized algorithms to generate new blended controllers online to improve trajectory optimization under novel disturbances such as abrupt rotor faults.

Quadcopter: Left: Reference Trajectory , Middle: 9% Rotor Fault *Controller Switching* Trajectory , Right: 9% Rotor Fault *Randomized Blending* Trajectory

<u>Collaborative Human / Autonomous System Blended Control (Car)</u>



Car: Left: Reference Trajectory, Middle: Collaborative Blended Control , Right: Switching Control

We explore collaborative trajectory optimization for Human and Autonomous Car. We model a novel disturbance as the Human becoming unresponsive and explore the effects on a double lane change manoeuvre of a car steering simulation for :

a) Proportionally Blended Control based on deviation error.

b) Switched Control based on deviation error.

Both were able to avoid the obstacles and main trajectory when the Human became unresponsive but the Blended Control signal provided smoother control.

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❑ Results to date / Future Work

To date we have successfully applied Randomized Algorithms and a Reinforcement Learning (RL) Framework on a Quadcopter and Car Trajectory Following task MATLAB simulation.

<u>Randomized Algorithms: *Publication in progress*</u>

1. *We propose a randomized blending framework able to provide FTC during novel fault conditions.*
2. *We empirically demonstrated the effectiveness of this framework compared to an optimal reference controller constrained by FDI delays on a quadcopter and car steering simulation.*

<u>Collaborative Control: *Proceedings of ECC18, Cyprus.*</u>

1. *We investigate several collaborative control strategies for Trajectory Optimization where one controller experiences disturbances.*
2. *We empirically compared these architectures on a Car steering simulation.*

<u>Learning: *Proceedings of AICS18 , Dublin.*</u>

1. *We propose an online Reinforcement Learning Framework for blended control under novel disturbances.*
2. *After 200 online learning iterations we were able to reduce the deviation error on a quadcopter by 63-75% compared to traditional control switching.*

Future Work includes the application of searching for the optimal blend weight vector. A collaboration with the Cognitive Robotics Lab and MAVLab in TU Delft , Netherlands for real system experimentation is being finalised.

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