Centre for Digital Built Britain

Aerial Swarm Robotics for Active Inspection of Bridges

Benefits to society, digital, construction, complex integrated systems, data and information

"Taking the robots from research labs to a challenging real world is an important step to achieving the Centre's mission to deliver a digital built Britain"

– Dr Shan Luo, Director of the smARTLab, University of Liverpool

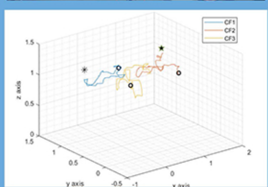
Summary

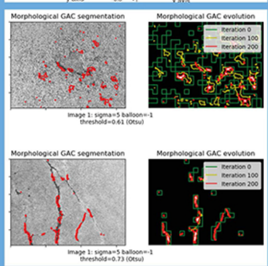
This project proposes a solution to the problem of maintaining the infrastructure of bridges and other structures. Bridges can have hazardous environments that are hard for humans to reach, making the labour intensive inspection and maintenance process ineffective. However, this task may have the potential to be done by autonomous systems. In this project we aim to create a coordinated aerial swarm system to inspect the cracks in the bridge structures, improving the monitoring coverage and efficiency. With strict constraints of the environments and mutual interference, the development of such multi-UAV system for bridge inspection is challenging. We have achieved the following objectives of the project: Agile coordination and collision avoidance for aerial swarms (WP1); Image based bridge defect detection and assessment (WP2); System integration and validation (WP3).

Key Findings

1. Our proposed FFPSO algorithm can reduce the number of collisions to zero effectively. As shown in theTable here, PSO has a much larger number of crashes than any other algorithm given that it has no collision avoidance mechanism. Both PSO-CA and FFPSO-GRAV never result in any crashes whereas FFPSO-LIN only results in very few on average.

Number of Drones	Algorithm: PSO	PSO-CA	FFPSO-LIN	FFPSO-GRAV
2	1.704	0	2.274	0
3	62.476	0	0.05	0
4	134.758	0	0.044	0
5	198.004	0	0.018	0
6	256.418	0	0.028	0
7	258.894	0	0.024	0
8	224.106	0	0.022	0
9	244.658	0	0.012	0
10	234.614	0	0.038	0





2. Real drone test. The experiments in the real environment were performed using the FFPSOLIN algorithm on a swarm of 3 Crazyflie 2.0s shown to the right. As illustrated to the right, experiments show that the FFPSO works effectively on a real MAV swarm.
3. Crack detection. Both of the improved initial sets in all CNNs show good accuracy to find the edges of the cracks shown in the images here. Dilation of the images helps to connect regions that are part of a continuous crack but harshly hinders the progress of the Active Contours (ACs) since there is a limited amount of iterations we can do quickly. The AC results ultimately depend on the accuracy of the CNN, if it is not accurate then neither will the ACs.

4. Real bridge inspection. These images show snapshots of the footage taken from a Parrot Bebop 2, showing a real bridge and its structure.

Impact and Value

1. The project aims to develop an autonomous system using digital technologies (robotics, AI and data analysis) for monitoring the health of bridges and other structures, which contributes to guarantee the safety and well-being of the people of Britain.
2. It has explored the implications of a digital built Britain for mobility and transport. The project creates a bridge inspection system that ensures the safety and structural integrity of bridges. It contributes to avoiding personnel and economic losses due to collapses of bridges lack of inspection and monitoring.
3. It has explored the exploitation of existing or emerging tools, technologies and techniques and their role in delivering a digital built Britain;
4. It has explored ways to leverage data and information to deliver a digital built Britain.
5. It has explored the commercial challenges and opportunities of a digital built Britain.

Long-term Vision

Taking the findings in this project, we are confident to see in the future that autonomous systems can be deployed to survey, detect and repair defects in the city infrastructures. It will monitor the structural integrity of bridges and flag any potential issues, helping to avoid the tragedies like the Morandi bridge collapse. In addition, it will take the human inspectors from the hazardous inspection and maintenance environments.

Next Steps/Further Work

1. Decentralised FFPSO. In future work, the FFPSO algorithm will be converted into a fully decentralised algorithm in which the global best can be propagated to all individuals of the swarm without the use of a central server.
2. Fully autonomous aerial swarm for bridge inspection. A fully autonomous system that consists of a swarm of aerial robots equipped with embedded systems and sensors will be developed to inspect the bridge actively
3. Contact based bridge inspection robot swarm. In addition to the visual inspection, contact based (with tactile sensors) robotic inspection system will be developed to monitor the city infrastructures in further details (a larger grant will be submitted to the EPSRC or Innovate UK).

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