



LIDLAW UNDERGRADUATE LEADERSHIP AND RESEARCH PROGRAMME
APPLICATION – 2023 COHORT

Name	<i>Advik Bahadur</i>
Programme	<i>Engineering</i>
Year of Study	<i>2nd Year</i>
Research Project Title	<i>Investigation of the effectiveness of introducing a few adaptive controllable nodes in complex systems to increase autonomy and synchronisation.</i>
Proposed Supervisor(s)	<i>Dr Harun Šiljak, Department of Electronics and Electrical Engineering.</i>

Before completing this submission, you should review the [Laidlaw Programme Application Guide](#) sections and “Leadership-in-action experience proposal (Summer 2)”

Research Project Proposal (750-1000 words max.)

See Self-defined research project proposal (Summer 1) in the guidance for more information

Introduction

The ability to adapt to adversities, challenges, and environmental conditions is the core principle upon which humanity and the rest of the biological world have developed and grown. It allows us to reconfigure ourselves over time depending on the changes around us, allowing us to be adaptive machines. This idea of adaption is the foundation of multiple modern Artificial Intelligence and control systems. It allows a unit to dynamically change and develop to counteract any imbalances in the system to bring it to equilibrium.

Given the sudden rise in demands in the industry, concerning energy, transportation, water supply, waste management and such complex systems, there is a great need to develop control systems that can be easily mapped over current networks or ones that can be integrated into upcoming technologies, that can quickly and smoothly account for any volatility or disruptions, while also maintaining autonomy.

Taking inspiration from Corso, Gambuzza et al’s *Synchronizing Network Systems in the Presence of Limited Resources via Edge Snapping* [1], For this research project, I would like to experiment with introducing an adaptive controllable network on top of multiple Barabási–Albert networks, using the popular edge snapping method, that would essentially “rewire” the network in case of faults



or disruptions. What I would do differently to the paper mentioned above is consider the constraints and lack of resources by experimenting with only a certain number of controllable nodes in the network in contrast to having all nodes in the network be adaptive, and exploring the probability of still being able to achieve synchronisation in the network given these conditions. An example of possible implementations of this could be a possible minor upgrade to the power grid, that would introduce these adaptive and controllable nodes to only certain parts of the whole circuit while still being able to achieve a level of synchronisation and control on it. These “smart” nodes could be placed near wind farms and/or near other low-power generators, to introduce autonomy in the grid and still insure balance, synchronisation and overall stability in the network. Such an upgrade would be quite possible in the current network without a larger investment. This concept also has possible implementations in fields like security and telecommunications.

Project Methodology & Timeline

To develop such adaptive networks I plan to make use of weighted graphs. Such graphs are composed of nodes; and links that connect them. The weights associated with each link can be dynamically modified, relying upon certain differential dependencies. To compose the data set of my research I plan to use the Barabási-Albert model that can generate multiple random scale-free networks. This will allow a good variation in the types of networks generated while accounting for complexity. Since this research would focus on the limited amount of controllable nodes in the network, the models generated would also define the number and location of the nodes in the network that would be controllable, which can be varied easily.

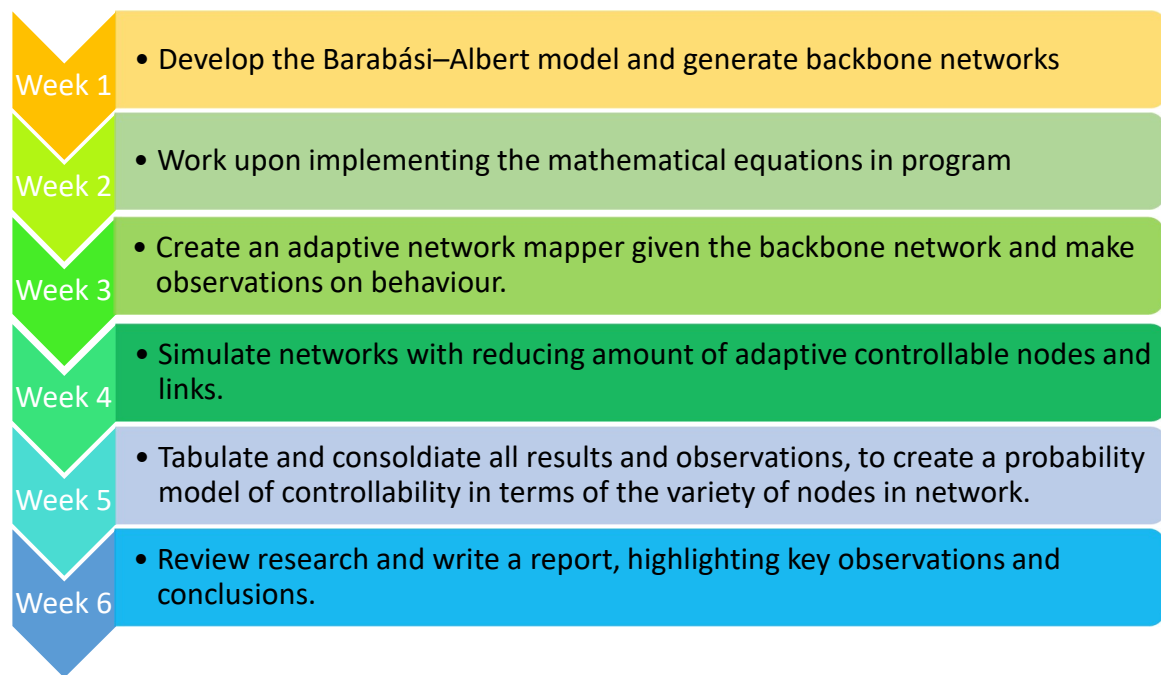
Adapting from the techniques used in *Synchronizing Network Systems in the Presence of Limited Resources via Edge Snapping* [1], I intend to use edge snapping to serve as the control mechanism of our system. This technique effectively switches on/off a certain link depending upon the magnitude of error between coupled nodes, allowing the network to adapt and recorrect until it reaches a state of stability or equilibria.

Using the equations used in the paper and considering the constraints, and requirements defined above, the controllability of the network can be modelled and simulated using MATLAB and other widely available Python libraries. Such highly advanced platforms should substantially expedite this entire process and hence should allow all computations and simulations to be completed within 6 weeks while also allowing for a proper tabulation of the results and even perhaps some further considerations.



From all of this, I hope to make useful observations and implement my findings as variables in my models to achieve a more efficient result and conclusion.

To keep track of the progress of my research in the 6 Weeks, I hope to operate on basis of smaller deadlines I would achieve at the end of each week, which will link together my research while allowing me to complete this project on time. This would mean that I will be working on each of the tasks highlighted in the timeline below throughout the 6-weeks, but the tasks completion date would be fixed.



Intended Outcomes

- Create a data set large enough that it can account for the complexity in most systems.
- Develop a probability model that can be useful to define the controllability and adaptiveness of a network given the number of adaptive nodes.
- Develop my observations into useful theory and conclusions for complex systems that can be useful considerations for such implementations in the industry.

Planning for pre-approval requirements (if relevant e.g. ethics approval, Garda vetting)

-Not required-

Planning for expected additional project costs (if relevant e.g. lab expenses, subscriptions, software, project-related travel)



Since this project can be undertaken without the use of any lab equipment, only computing power might be required, which can easily be provided by the university PCs. Hence there is no real cost associated with doing this research.

Are there any other relevant details to your proposal e.g., interdisciplinary collaborations, potential for international travel, or links to existing projects or organisations?

-NA-

Leadership-in-Action experience proposal (500 words max.)

See *Leadership in Action Proposal (Summer 2)* in the guidance for more information

LiA Category Insert x as appropriate	Category A: Central Laidlaw Foundation Project	
	Category B: Leadership Placement	X
	Category C: In-field application of research	

For my Leadership-in-Action experience, I would like to work with the engineers working on project CAELUS, a joint project by AGS airports and NHS Scotland to develop what is going to be the UK's first medical delivery drone service. It is appalling that every year lives are lost due to the lack of medication or extended delivery times. It is vital to have medication delivered promptly when it is needed. The contribution I would want to make to this project would be to develop a path-generating model for such autonomous drones, given the noise emissions of the machines and the legislation coming into effect to restrict this.

Recently, legislation passed by the EU, which was retained in the UK, provides a framework of regulations for Unmanned Aerial Vehicles (UAFs), and it outlines the method to determine the noise emissions following the ISO 3744:2010 standards. Hence with such UAFs producing above 80 Db's [2] of noise when in motion, paths need to be generated to accommodate for this. Another legislation passed requires states to publish strategic noise maps every five years [3]. As highlighted in Noise mitigation of UAV operations through a Complex Networks approach [4], an approach to have the least amount of disruption in cities by these noise levels is to have the UAFs travel through regions with already high noise emissions. These regions are commonly found at and around high-traffic roads and motorways. Given the common take-off and landing locations of the drones, agent-based modelling could be used to demonstrate the paths the drone would take to avoid high amounts of disruptions in the noise levels. By running this model for multiple drones, multiple locations of relevance and for a large amount of "ticks", the unit of time in agent-



based models, essentially a map of an air network can be established which will have the least amount of noise impact to the region.

From this a navigation algorithm will be developed which will calculate the fastest route to the drone's destination, using the air map and paths created. This method will hence provide a path to the destination that will impact the least amount of residential areas, parks and businesses and quickly deliver its vital and critical cargo to its destination. This technology will also allow a drone to be recovered easily in case the drone fails mid-flight, as its path will be known to the operators, even when its location is not.

Are there any other relevant details to your proposal e.g., interdisciplinary collaborations, potential for international travel, or links to existing projects or organisations, plans to apply to a Study Abroad / Erasmus opportunity?

- As mentioned above I plan to collaborate with AGS Airports and NHS Scotland on their work on project CAELUS.
- I do not have any plans currently to pursue Erasmus/ Study Abroad

References

- 1) Corso A, Gambuzza LV, De Lellis P, Frasca M. Synchronizing network systems in the presence of limited resources via edge snapping. *Chaos [Internet]*. 2023 Jan [cited 2023 Feb 12];33(1):013123. Available from <https://aip.scitation.org/doi/10.1063/5.0093560>
- 2) Christiansen F, Rojano-Doñate L, Madsen PT, Bejder L. Noise levels of multi-rotor unmanned aerial vehicles with implications for potential underwater impacts on marine mammals. *Frontiers in Marine Science [Internet]*. 2016 [cited 2023 Feb 12];3. Available from: <https://www.frontiersin.org/articles/10.3389/fmars.2016.00277>
- 3) Agency EP. Noise guidelines [Internet]. [cited 2023 Feb 12]. Available from: [https://www.epa.ie/our-services/monitoring--assessment/noise/noise-guidelines/#:~:text=The%20Environmental%20Noise%20Directive%20\(EN,of%20exposure%20to%20environmental%20noise.](https://www.epa.ie/our-services/monitoring--assessment/noise/noise-guidelines/#:~:text=The%20Environmental%20Noise%20Directive%20(EN,of%20exposure%20to%20environmental%20noise.)
- 4) Šiljak, Harun & Einicke, Karina & Kennedy, John & Byrne, Stephen. (2022). Noise mitigation of UAV operations through a Complex Networks approach.