Internships in DNA Computing and DNA nanotechnology

Team: TAPDANCE: Theory And Practice of DNA Computing Engines

Where: Hamilton Institute and Department of Computer Science,
Maynooth University, Ireland

Maynooth University
National University of Ireland Maynooth

Hamilton Institute

Team Website: https://dna.hamilton.ie/

Supervisor: Prof Damien Woods, https://dna.hamilton.ie/woods/

Contact: damien.woods@mu.ie

What we do: We carry out fundamental research on DNA/molecular computers. We work on:

- computational **theory** of molecular models of computation;
- **software** for design of DNA, and
- **experimental implementation** in the wet-lab using DNA.

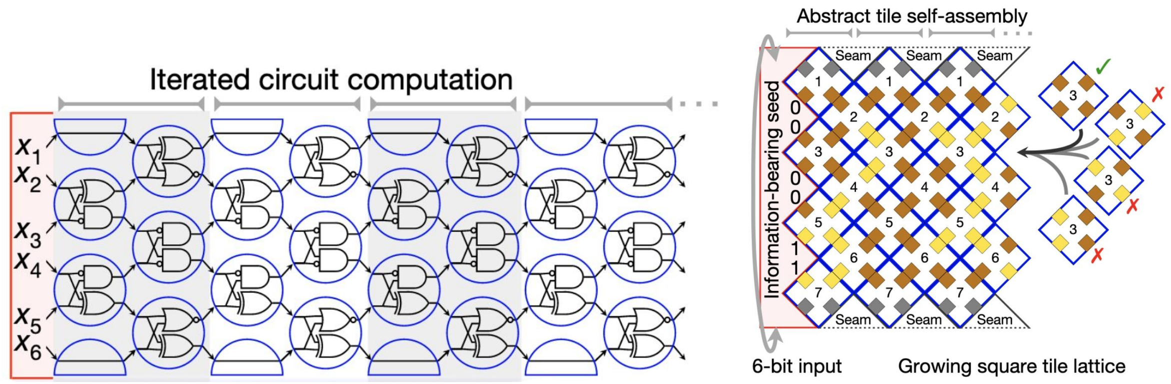
Our team is multidisciplinary: we prove theorems about models of computation, we make designs using in-house software and on the whiteboards, and we implement our molecular computer designs using artificially-synthesised DNA molecules. Crucially, a smart, hardworking student can develop their own model of computation and implement it all in one project. Some of our project lead to publications.

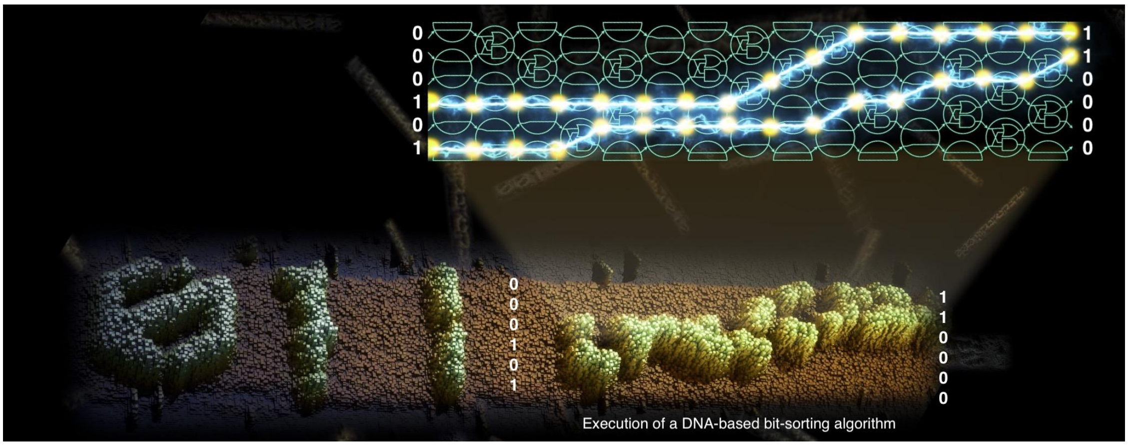
Looking for: Internship students in Computer Science, Physics, Chemistry, Bioengineering, and related domains with an interest in computer-science theory (mathematics), programming, and experimental implementation.

When: Flexible starting date

Example projects: see pages 2 & 3 for two example projects. But projects can be designed and tailored to meet the interests of the student.

Project 1: Building a molecular computer via self-assembly





Woods, Doty, Myhrvold, Hui, Zhou, Yin, Winfree, Diverse and robust molecular algorithms using reprogrammable DNA self-assembly, *Nature* 2019
Video presentation: https://dna.hamilton.ie/assets/dw/Woods-dna26.mp4

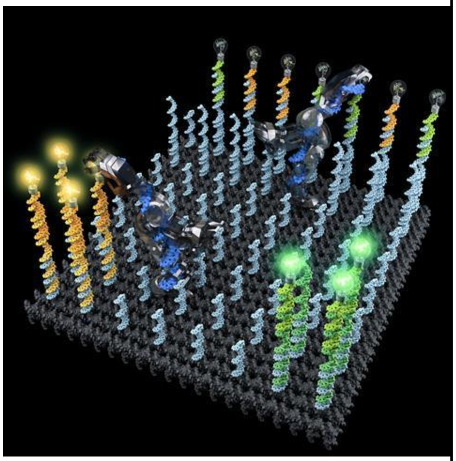
The aim of this project is to build a molecular computer that works on the principle of self-assembly. The student will use tools and techniques from the Woods/TAPDANCE group, and the project mixes design and wet-lab implementation. Building computers, that use principles **other** than electricity following through silicon circuits, is a challenging and intellectual fruitful long-term goal. Building upon the computer-science theory of Algorithmic Self-Assembly [1,2], systems computing using self-assembly of DNA tiles have been realised. Those include a DNA-based binary counter [3] (DNA tiles stick together to count in binary!), and more recently a system that implemented 21 algorithms with low-error rate [4]. In this project, you will be using Algorithmic Self-Assembly in order to design and implement a device capable of running computations, such as arithmetic or Boolean circuit logic. The main focus of the project will be experimental rather than theoretical with the goal to construct such a computational device in the wetlab. The project is self-contained meaning you can learn the lab techniques in the first few days/weeks. You will have the opportunity to work with world leaders in the field.

References

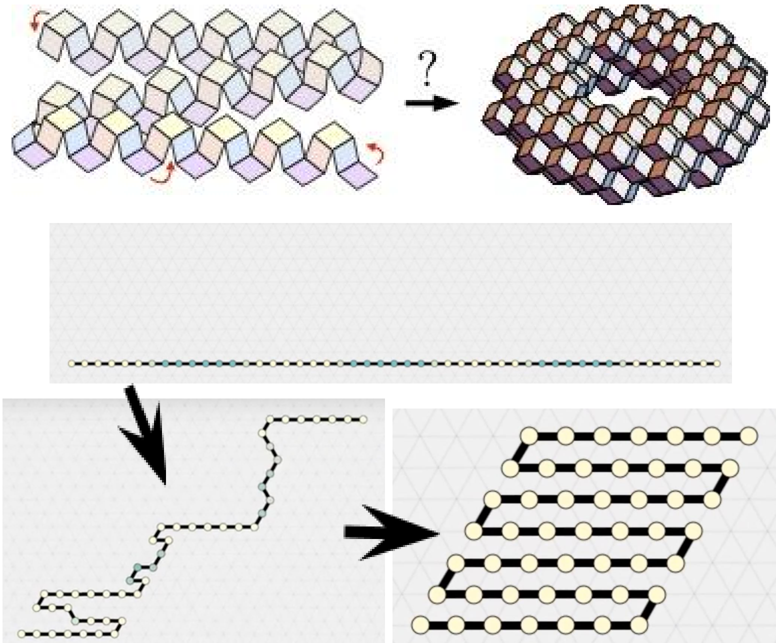
[1] D Doty. Theory of algorithmic self-assembly, Communications of the ACM, 2012.
[2] D Woods. Intrinsic universality and the computational power of self-assembly, Philosophical transactions of the royal society, 2015.
[3] CG Evans. Crystals that count! Physical principles and experimental investigations of DNA tile self-assembly, PhD thesis, 2014.
[4] D Woods*, D Doty*, C Myhrvold, J Hui, F Zhou, P Yin, E Winfree. Diverse and robust molecular algorithms using reprogrammable DNA self-assembly. Nature 567, 366–372 (2019). *=joint first

Project 2: Molecular Robotics

Building programmable molecular robots out of DNA!



Thubagere, Li, Johnson, Chen, Doroudi, Lim Lee, Izatt, Wittman, Srinivas, Woods, Winfree, Qian Science. 2017



Kostitsyna, Wood, Woods. Turning Machines: a simple algorithmic model for molecular robotics. Natural Computing, 2022 https://arxiv.org/abs/2009.00755

Blog post: https://dna.hamilton.ie/2020-09-16-turning-machines.html

Control of a molecular robot able to realise tasks at the nanometer scale has been a long term goal in the field of DNA nanotechnology. To date the programmability of molecular robots has been limited, and we don't understand their algorithmic capabilities. In our group, we've researched the theory of such systems and now we are aiming to implement them in the wet-lab!

In this project, you will be using DNA origami [1] or DNA tiles [2], to design and implement a theoretical model we call Turning Machines [3]. The main focus of the project will be experimental and/or theoretical with the goal to construct such molecular robots [4] in the wetlab, and/or reason mathematically about their capabilities. As with all projects in our group, little background is required and you will learn the basics in the first days and weeks. The project is self-contained meaning you can learn the lab techniques in the first few days/weeks.

References

[1] Rothemund, P. Folding DNA to create nanoscale shapes and patterns. Nature 440, 297–302 (2006).

[2] D Woods*, D Doty*, C Myhrvold, J Hui, F Zhou, P Yin, E Winfree. Diverse and robust molecular algorithms using reprogrammable DNA self-assembly. Nature 567, 366–372 (2019). *=joint first

[4] Kostitsyna, Wood, Woods. Turning Machines: a simple algorithmic model for molecular robotics. Natural Computing, 2022. Conference version appeared at DNA26, 2020.

[3] Thubagere AJ, Li W, Johnson RF, Chen Z, Doroudi S, Lee YL, Izatt G, Wittman S, Srinivas N, Woods D, Winfree E, Qian L. A cargo-sorting DNA robot. Science. 2017.