Creating DNA from Scratch for DNA-based data storage

SDDEC23-05

Evan Walters, Colin Frank, Astha Upadhyay, Rachel San Agustin, Caden Wortman, Anna Hackbarth

Client & Advisor: Professor Meng Lu

Problem

DNA sequencing is well-developed, but DNA synthesis is expensive and difficult to access in small quantities. This project has a wide range of potential applications in fields such as data storage, biotechnology, medicine, and genomics.

Solution

To facilitate small scale synthesis, we will use custom built software in tandem with integrated hardware and a modular flow device to create DNA fabrication technology. This will be used to make DNA strands for testing and research purposes.

Intended Users & Uses

Users: Academic Institutions, Research Labs, Pharmaceutical, Biomanufacturing, Agriculture, Bioenergy, and DNA data storage
Uses: Research and development of DNA sequencing

Testing & Integration

GUI:

- Form 1 and 2:
  - Tested during development, excluding external software.
  - Near completion in the project's infancy, GUI operated as a PowerShell script, emphasizing user input over logic.
- Form 3:
  - Tested in stages.
  - Initially used a timer for pulsing effect.
  - Changed to 'for' loop due to threading problems

Hardware:

- Photoresist Development
  - Tested the precision of the UV Projector by exposing undeveloped photoresist
    - Used various projected times and measured the result
    - Found how precise our projector was and how long the exposure time should be
      - To find the precision we used the 1951 USAF resolution test chart

Microfluidics:

- Performed basic testing functions including setting pressure, valve switching, and cycle tests.
- Integrating functions into GUI to streamline the user experience.

Technical Challenges & Details

GUI Software:

- Written in C# using Visual Studio
- Target Framework: .NET Core 3.1
- Notable Included Libraries: Threading.Tasks, Forms.VisualStyles.VisualStyleElements, fgt_sdk

Hardware & Projector:

- Began using an LCD Board, but excess heat caused issues with the reaction. Tried a TI Projector with a modified UV LED, but experienced overheating issues.
- Currently using a prebuilt UV Projector from SICUBE and extending the lens to get the precision we need.

Microfluidics:

- Software Development kit provided by Fluigent, written in Visual Studio using C#
- A valve-switching mechanism, air pressure control, and multiple nucleotide solutions.

Resources

- https://wyss.harvard.edu/technology/dna-data-storage/
  - Harvard DNA Data Storage technology proposal
- https://en.wikipedia.org/wiki/1951_USAF_resolution_test_chart
  - A standardized chart used for optical resolution testing
- Consultations with the ETG for program access and for hardware modifications
- https://www.nti.org/wp-content/uploads/2023/05/NTIBIO_Benchtop-DNA-Report_FINAL.pdf
  - Washington D.C. think tank encouraging DNA sequencing technologies research

Design Requirements

Functional:

- Software:
  - User-Friendly Interface:
  - Intuitive front-end allowing customizable user inputs
  - Communicates with hardware and fluid control
- Image Generation:
  - The back-end processes the DNA string, creating an 'image' on the projector
  - Flip every other nucleotide string to ensure complementary strand

Nonfunctional:

- Software:
  - Graphical User Interface (GUI):
    - Recommended array size
    - Capable of conversion to a .exe file for convenient execution.
- Image Generation:
  - Small size constraint to fit into the physical housing of the unit.

Operating Environment:

- Standard controlled lab environments with temperatures ranging between 55° F and 85° F, level operating surface with no outdoor exposure.

Standards:

- Guidelines for Life Cycle Management - 24748-1-2018
- Test Processes - 29119-2-2021
- Systems and Software Integration - P24748-6
- Systems and Software Engineering – Life Cycle Management Pt: 1
- Systems and Software Engineering – Software Testing Pt: 2,
- Systems and Software Engineering – Life Cycle Management Pt: 6

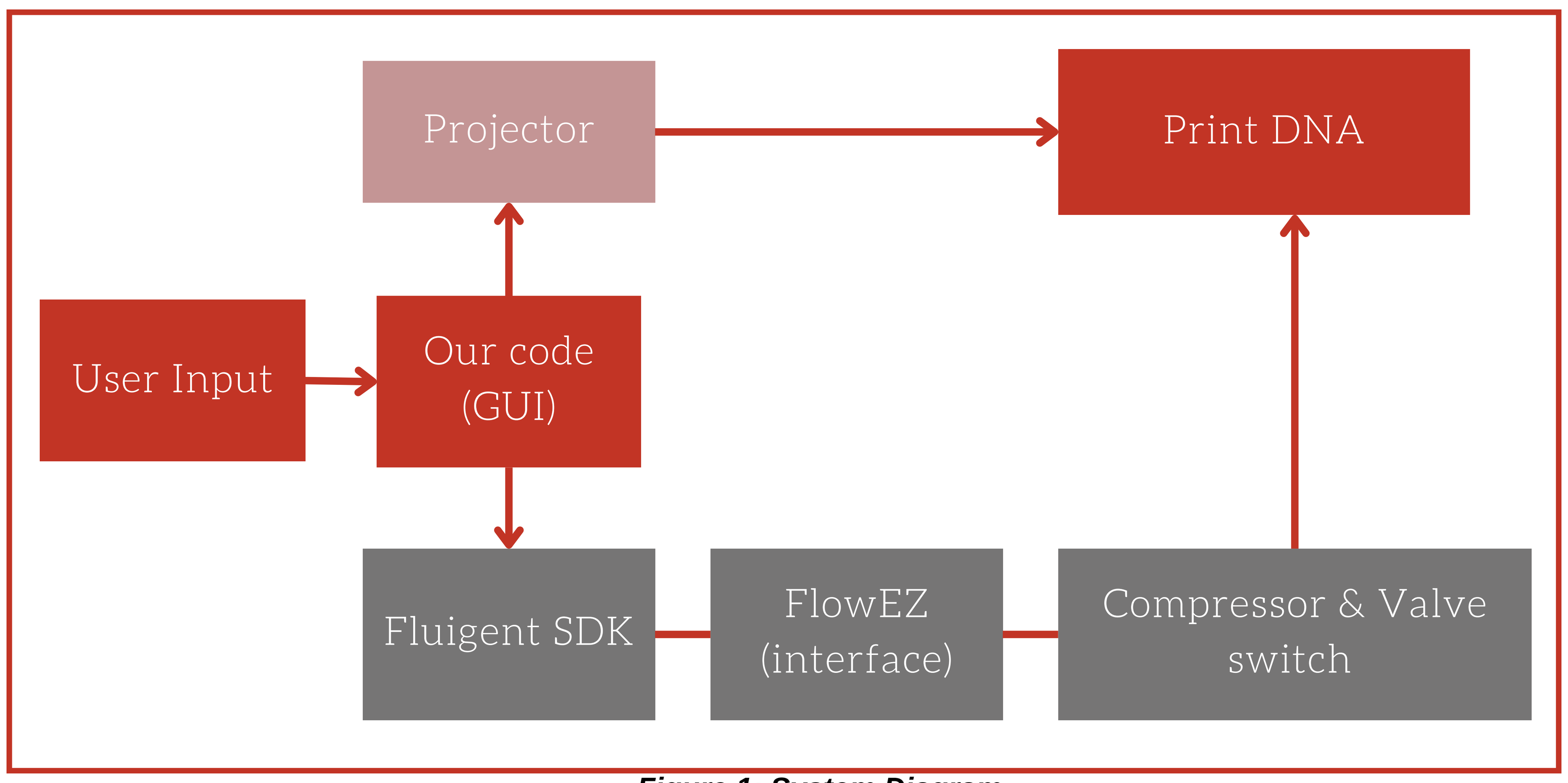

Figure 1: System Diagram

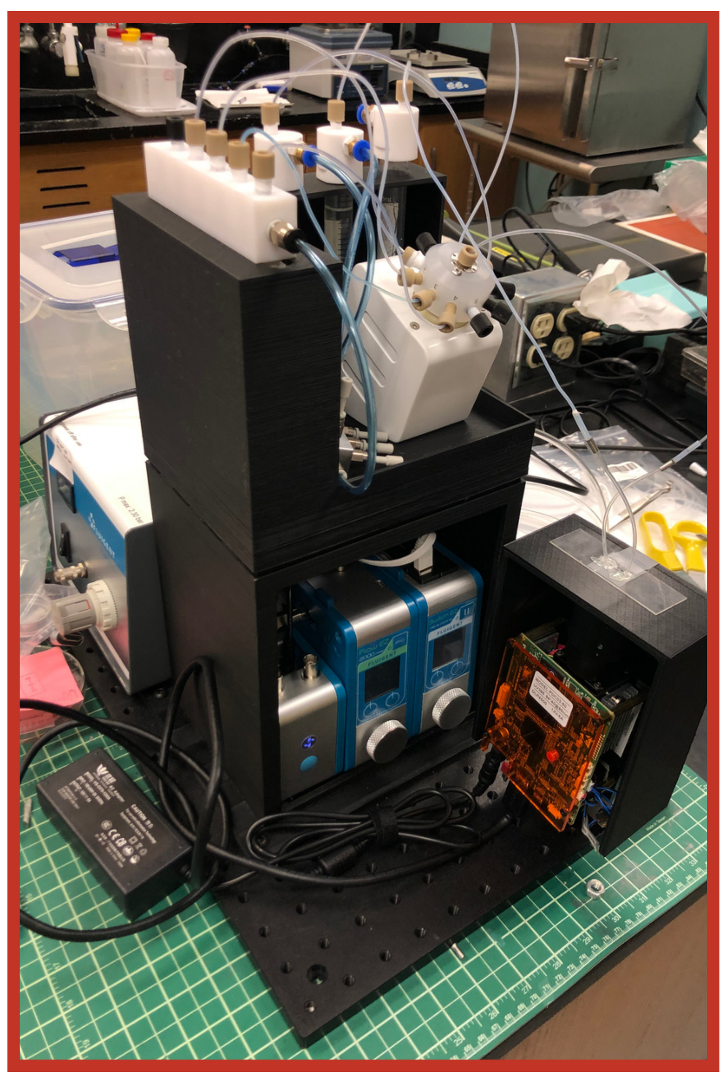

Figure 2: Flow Control & Projector

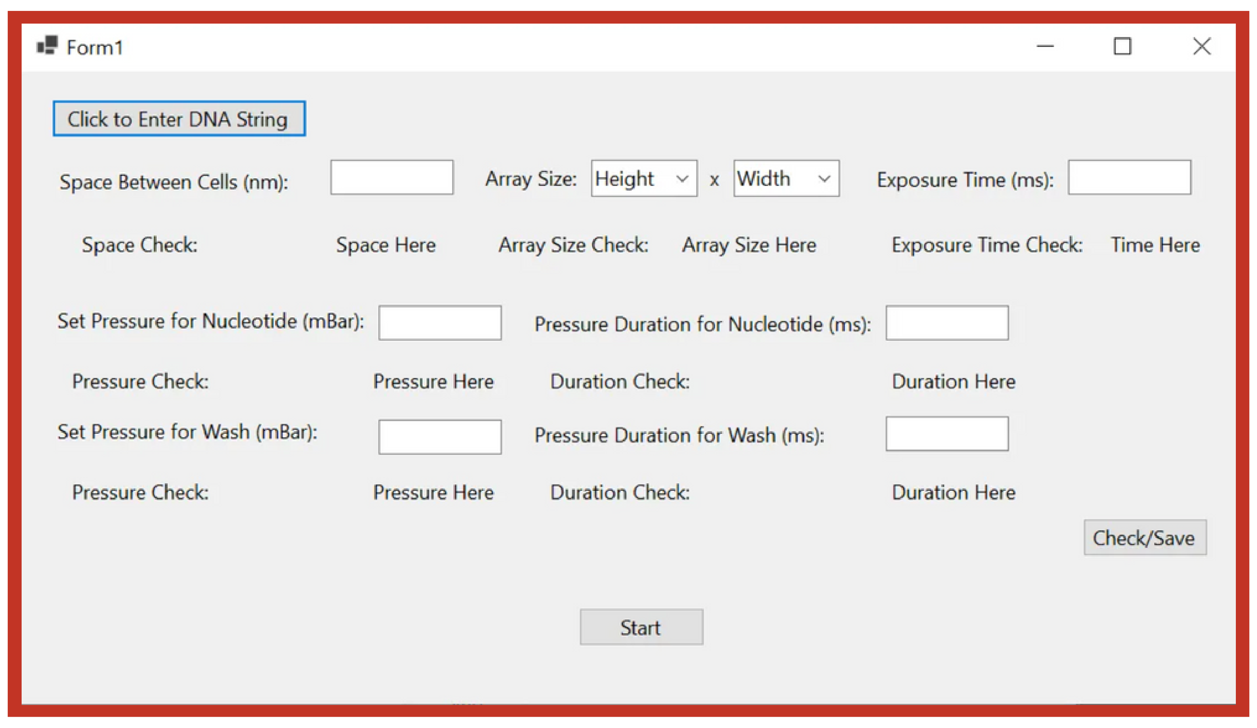

Figure 3: GUI User Interface

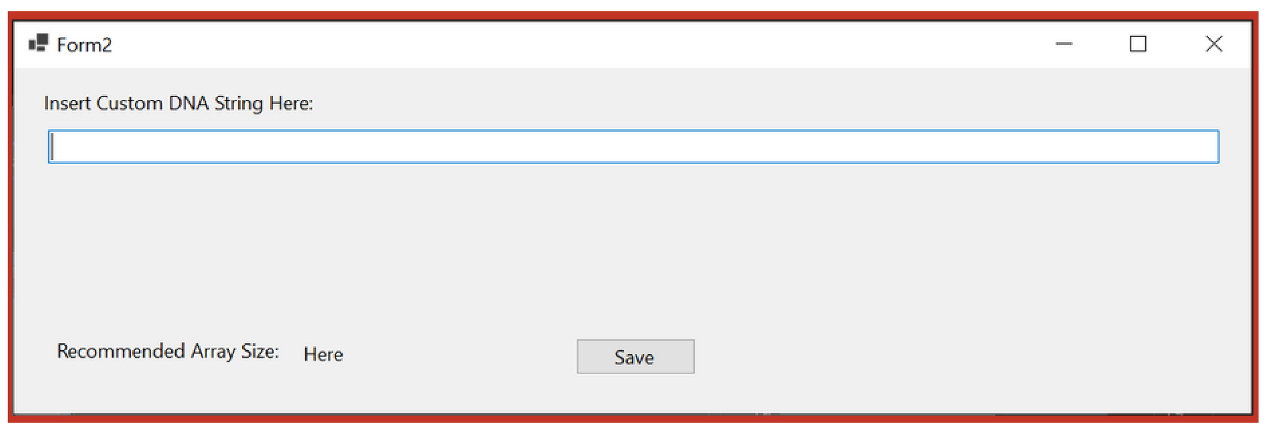

Figure 4: GUI Form 2

Figure 5: GUI Form 3

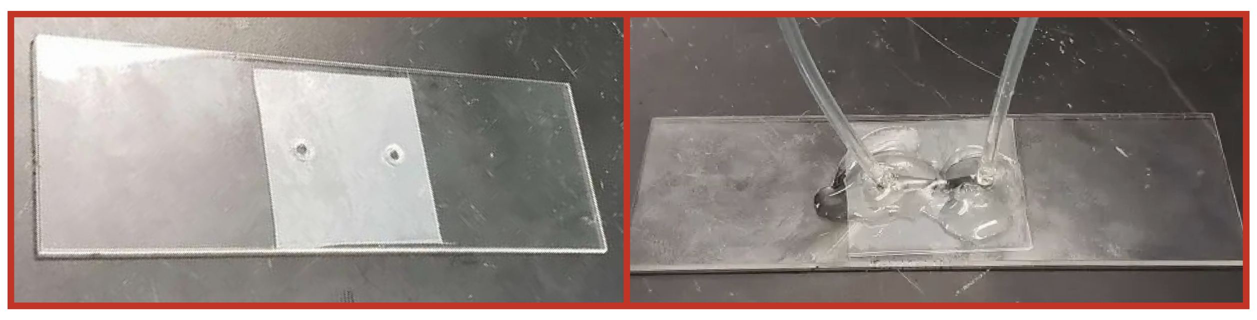

Figure 6: Flow Cell in Construction