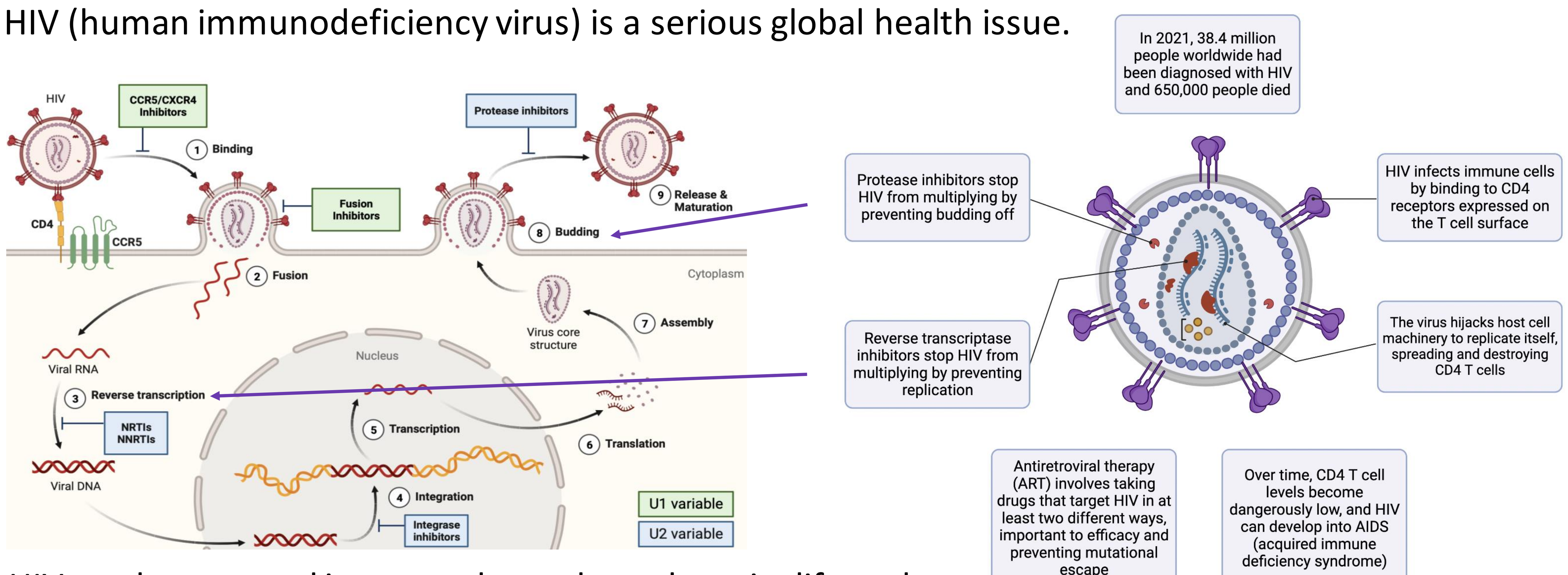
RETROFIT
ReinforcemEnT leaRning algOrithm For HIV Treatment

Background

HIV (human immunodeficiency virus) is a serious global health issue.



HIV can be targeted in many places throughout its life cycle.

Aims

- Leverage reinforcement learning to tackle the complex issue of HIV treatment planning
- Train a Q-learning algorithm to model to optimize treatment efficacy value to increase CD4 cell counts
- Show how the algorithm could be extended to predict optimal HIV treatment for a certain patient

Results

Empirically derived optimal solutions using Q-learning:

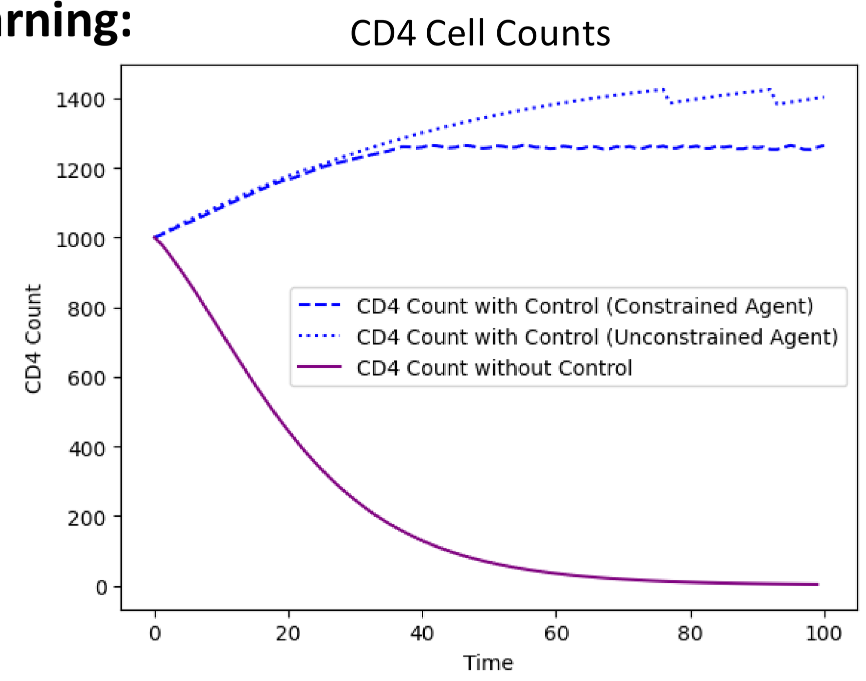


Figure 1: CD4 cell count against time with control (blue) and without control (purple)

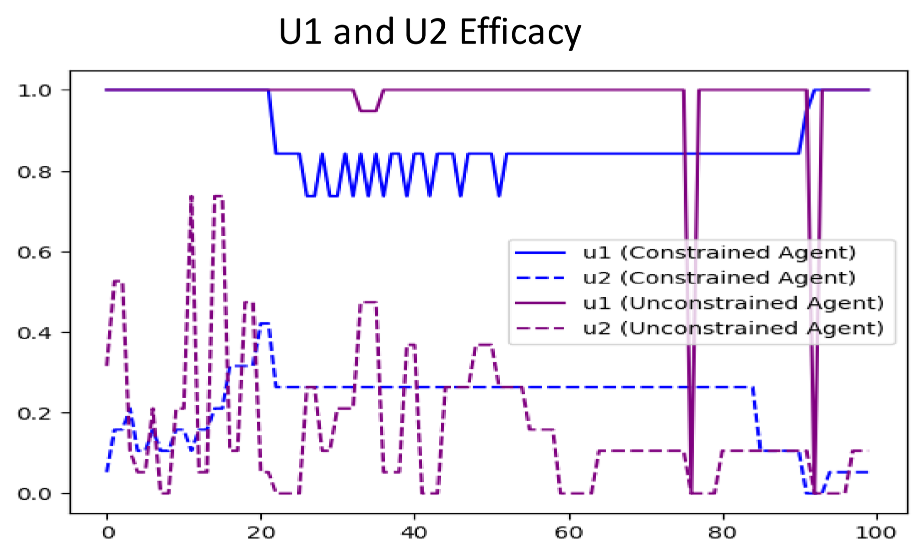


Figure 2: Comparing the U1 and U2 efficacies with a constrained and unconstrained agent.

- **U1** – the efficacy of drug therapy in blocking the infection of new cells (ex. protease inhibitors). This prevents the CD4 cells becoming infected by HIV.
- **U2** – the efficacy of drug therapy by inhibiting the production of virus (ex. reverse transcriptase inhibitors). Prevents the HIV replicating inside the CD4 cells, which leads to the death of the CD4 cell.
- **CD4 cell count** – the number of healthy immune cells found in a patient, normally >500 cells/μL, indicates HIV progression and severity
- **Constrained vs unconstrained agent** – The constrained agent is restricted to making smaller changes in the levels of U1 and U2, whereas the unconstrained agent can make arbitrary changes to the values of U1 and U2

Theoretically derived results from [5]

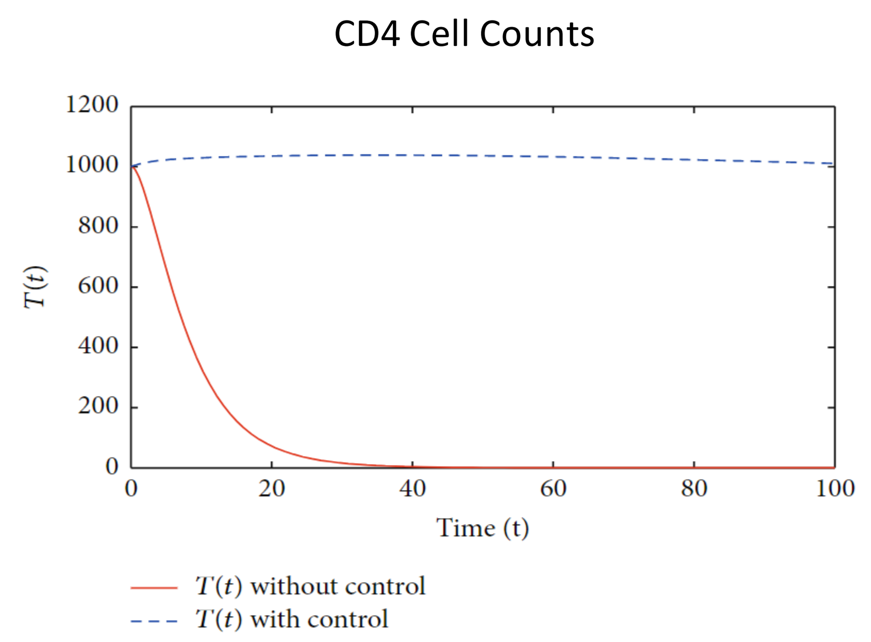


Figure 4: CD4 cell count with (blue) and without control (orange)

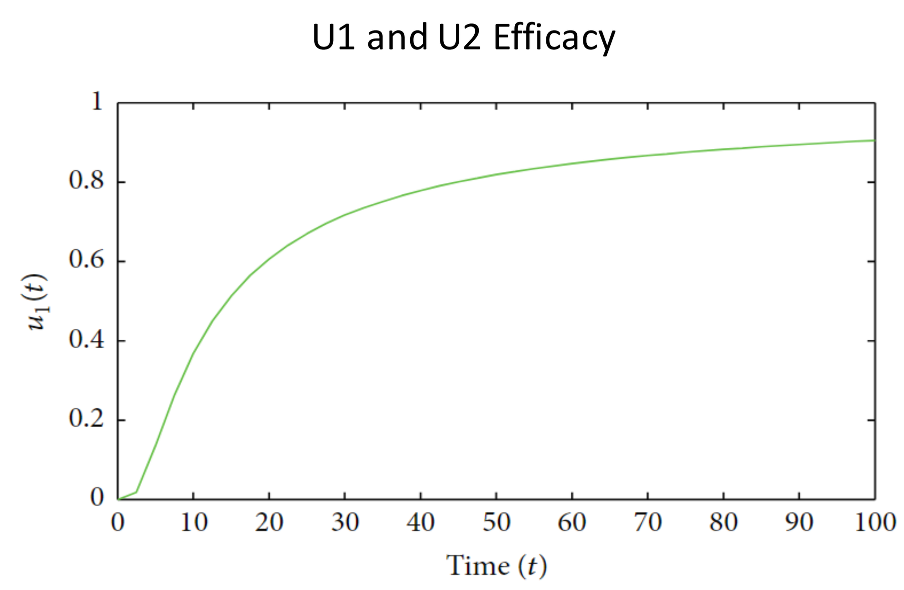


Figure 5: Optimal value of U1 against time

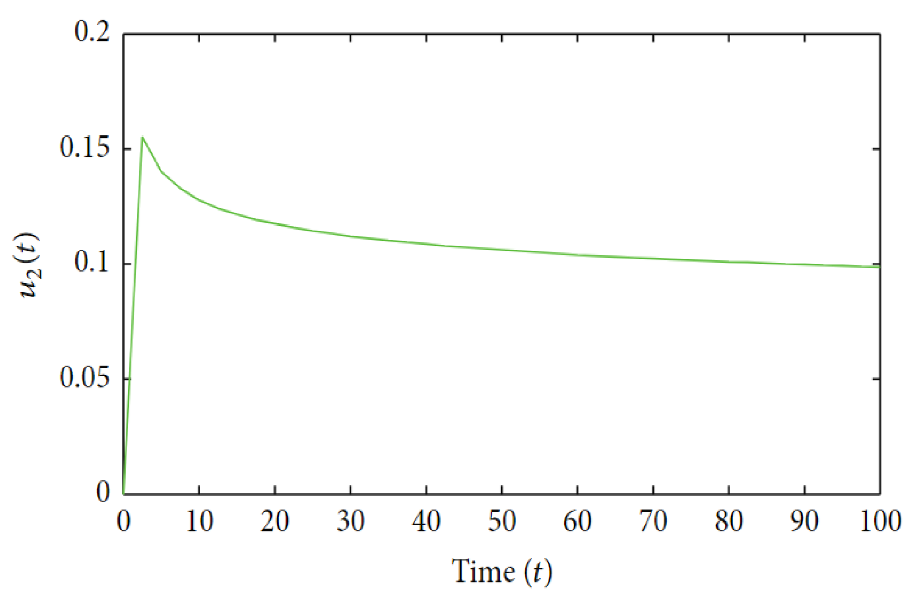


Figure 6: Optimal value of U2 against time

Methods

Three differential equations describing how the concentrations of uninfected CD4 (T), infected CD4 (V), and free HIV (I) evolve with time:

$$(1)\quad \frac{dT}{dt}=rT\left(1-\frac{T}{T_{max}}\right)-\frac{(1-u_1)\beta VT}{1+\alpha V}$$

$$(2)\quad \frac{dV}{dt}=(1-u_2)N\mu I-\gamma V \qquad (3)\quad \frac{dI}{dt}=\frac{(1-u_1)\beta VT}{1+\alpha V}-\mu I$$

Q-Learning:

1. Initialise table of values for state, action pairs
2. Agent performs an action
3. Environment is updated
4. Reward calculated
5. Value of the state, action pair is updated

Conclusions

- Successfully trained RL agent to increase CD4 count of a patient infected with HIV
- Found levels of U1 and U2 suggested by agent resemble those found through theoretical methods
- Developed a framework for the optimization of HIV treatment plans over more complex constraints

Next Steps

- Evaluate the performance of the agent against patient profiles and medical data
- Develop the agent to give it the capacity to generate optimal treatment plans
- Make the model more patient-specific by incorporating the treatments that have unique advantages and disadvantages (e.g. Pregnancy, mental health struggles, treatment resistance)
- Generalise the technique to develop treatment plans for other illnesses

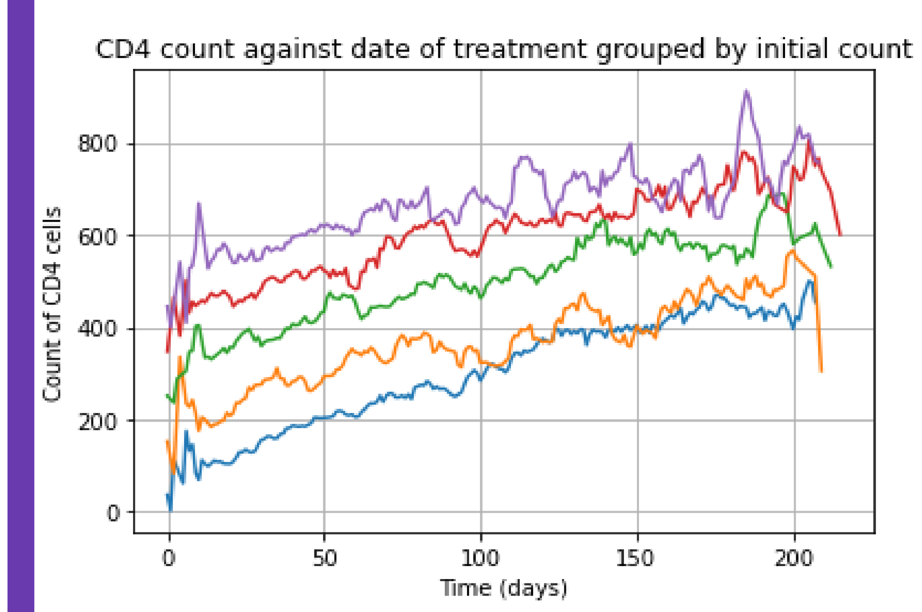


Figure 7: CD4 cell count against date of treatment, where patients are grouped by initial count in steps of 100

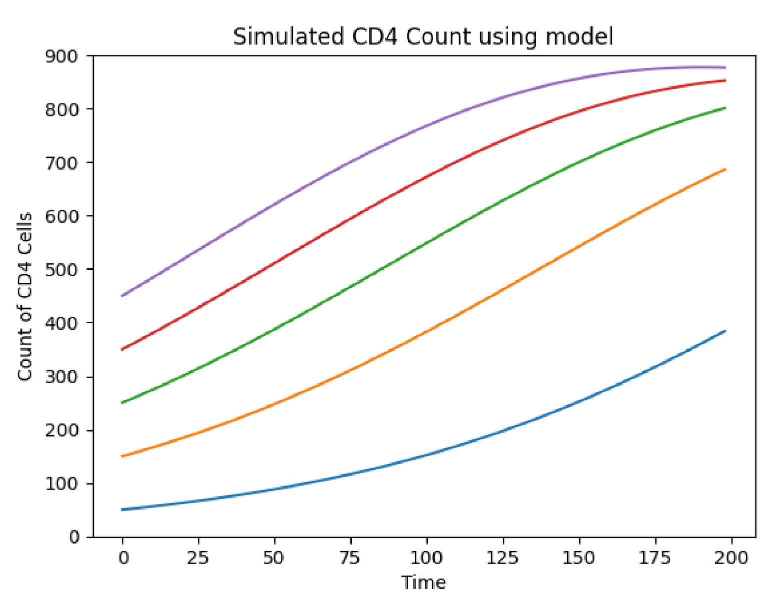


Figure 8: Simulated plot of CD4 cell count against date of treatment for the 5 groups, using our trained model

Evaluation & Comparison

- Data grouped by patients' initial CD4 count in steps of 100 (ranging from 0 to 500)
- The results from our model greatly resemble the trend in the actual data!
- Success in obtaining the correct parameters

References

[1] Gandhi, R.T. et al. (2020) 'Long-term Outcomes in a Large Randomized Trial of HIV-1 Salvage Therapy: 96-Week Results of AIDS Clinical Trials Group A5241 (OPTIONS)', The Journal of Infectious Diseases, 221(9), pp. 1407–1415.
[2] Gibas, K.M. et al. (2022) 'Two-drug regimens for HIV treatment', The Lancet HIV, 9(12), pp. e868–e883. Available at: https://doi.org/10.1016/S2352-3018(22)00249-1.
[3] HIV and AIDS Epidemic Global Statistics (no date) HIV.gov. Available at: https://www.hiv.gov/hiv-basics/overview/data-and-trends/global-statistics
[4] Ogunlaran, O.M. and Oukouomi Noutchie, S.C. (2016) 'Mathematical Model for an Effective Management of HIV Infection', BioMed Research International, 2016, p. e4217548. Available at: https://doi.org/10.1155/2016/4217548.

Interdisciplinary Research Computing Course – Group project poster
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