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Optimising testing and antiretroviral therapy for prevention and control of HIV/AIDS transmission dynamics in Indonesia

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INTRODUCTION & AIM

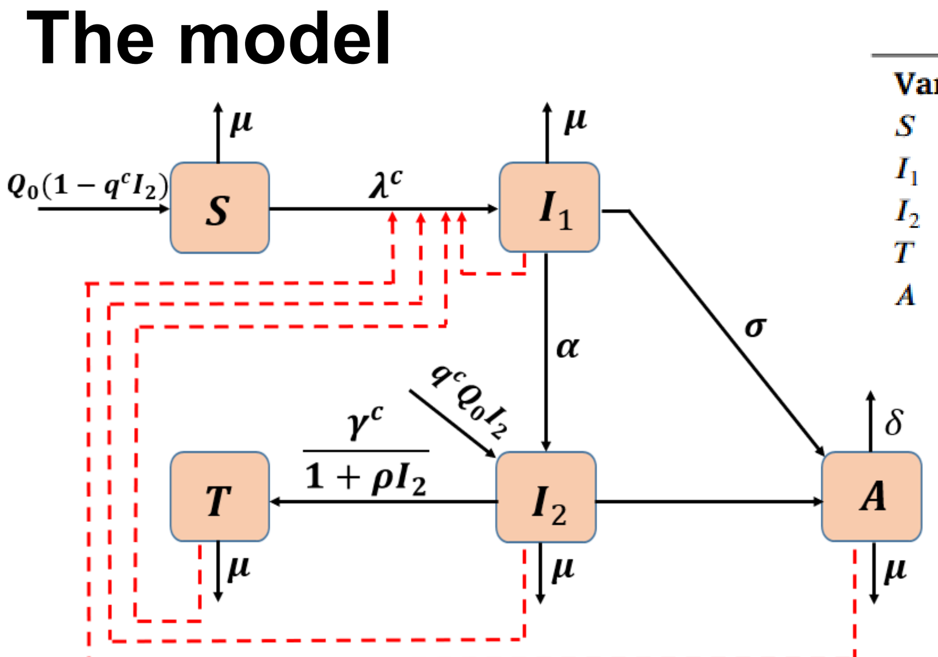
- Human immunodeficiency virus (HIV) is an RNA virus that attacks lymphocyte cells in the body [1].
- The virus is responsible for HIV infection [2].
- HIV can progress to the most severe stage, acquired immunodeficiency syndrome (AIDS), if treatment is not received [2].
- Globally, 39.9 million people were living with HIV in 2023, with 630,000 AIDS-related deaths [1].
- There are three routes of HIV transmission – sexual contact with HIV-infected persons, exchange of body fluids or tissues from HIV-infected persons, and mother to child transmission [1].
- HIV is not curable, although the use of antiretroviral therapy (ART) can halt the virus from progressing from one stage to the next [2].
- HIV-infected nursing mother have below 1% chance of transmitting HIV via breast milk if they routinely take ART [2].

AIM

- The aim of this study is to assess the optimal strategy required for the prevention and control of HIV/AIDS dynamics using optimised HIV testing and ART in Indonesia

METHOD

The model



	Physical meaning
Variable	
S	Susceptible individuals
I_1	Unaware infectious individuals
I_2	Screened and already aware infectious individuals
T	Individuals receiving lifesaving ART
A	Individuals with full-blown AIDS

Fig. 1: Flow chart of the optimal control HIV/AIDS model (1)

The model equations are given by

$$\begin{aligned}
\frac{dS}{dt} &= Q_0[1-(1-b_0u_1(t))qI_2] - \frac{\beta S(I_1+\theta_1 I_2+\theta_2 A+\theta_3 T)}{N} - \mu S,\\
\frac{dI_1}{dt} &= \frac{\beta S(I_1+\theta_1 I_2+\theta_2 A+\theta_3 T)}{N} - \alpha(1+b_1u_2(t))I_1 - \sigma I_1 - \mu I_1,\\
\frac{dI_2}{dt} &= \alpha(1+b_1u_2(t))I_1 + (1-b_0u_1(t))qQ_0I_2 - \frac{\gamma(1+b_0u_1(t))I_2}{1+\rho I_2} - \xi(1-b_0u_1(t))I_2 - \mu I_2,\\
\frac{dT}{dt} &= \frac{\gamma(1+b_0u_1(t))I_2}{1+\rho I_2} - \mu T,\\
\frac{dA}{dt} &= \sigma I_1 + \xi(1-b_0u_1(t))I_2 - \mu A - \delta(1-b_0u_1(t))A,
\end{aligned} \qquad (1)$$

Initial conditions: $S(0)>0,\ I_1(0)\geq 0,\ I_2(0)>0,\ T(0)\geq 0,\ A(0)\geq 0.$

Our goal is to minimise the sizes of classes I_2 and A, while minimising the costs associated with implementing the controls $u_1(t)$ and $u_2(t)$.

Thus, the objective functional is designed as

$$\mathbb{J} = \frac{1}{2}\int_0^{F_t}\left(2\omega_1 I_2(t) + 2\omega_2 A(t) + \varpi_1 u_1^2(t) + \varpi_2 u_2^2(t)\right)dt \qquad (2)$$

Qualitative analysis

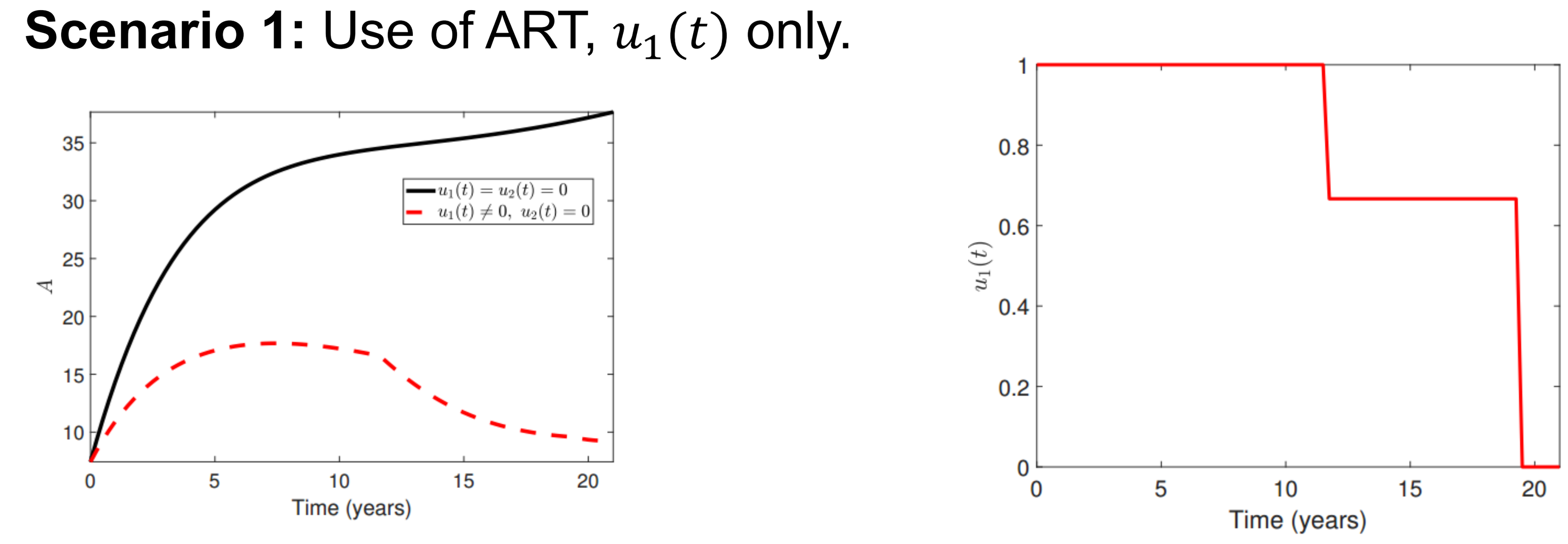
- This is carried out using the Pontryagin's maximum principle [4].

Simulation

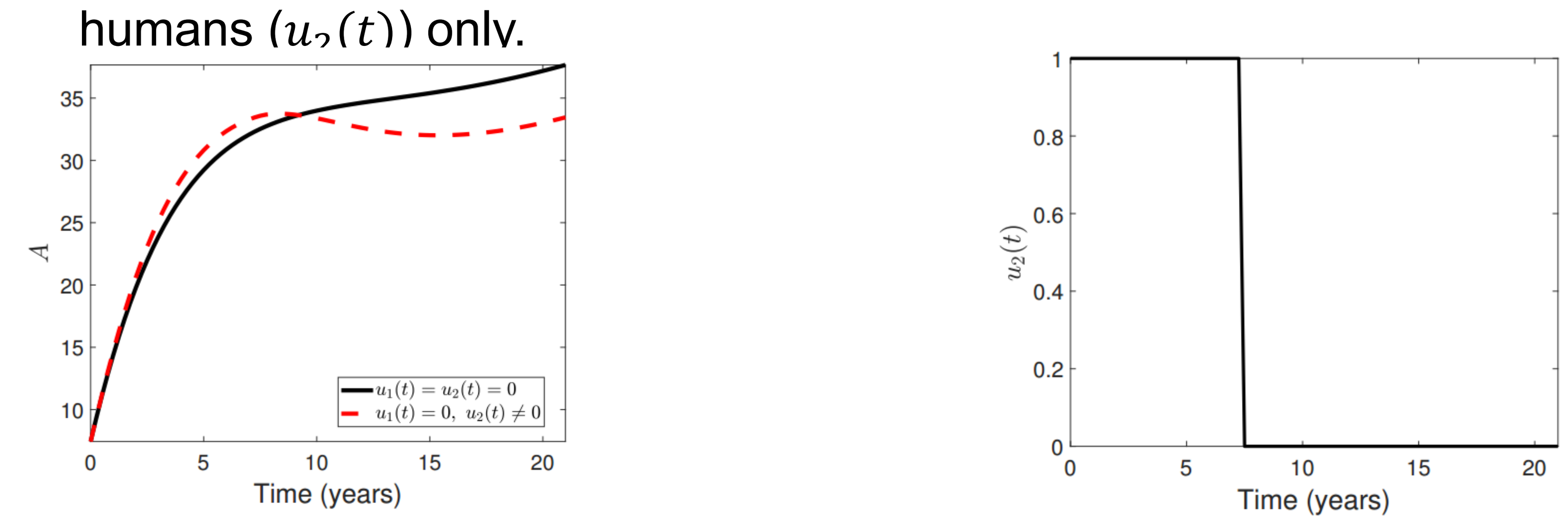
- We considered 3 different strategies for implementation: (i) Use of ART treatment (u_1) only. (ii) Enhancement control for screening of unaware HIV-infected individuals (u_2) only. (iii) Combination of $u_1(t)$ and $u_2(t)$. Parameter values were taken from a study on Indonesia AIDS cases [5].

RESULTS & DISCUSSION

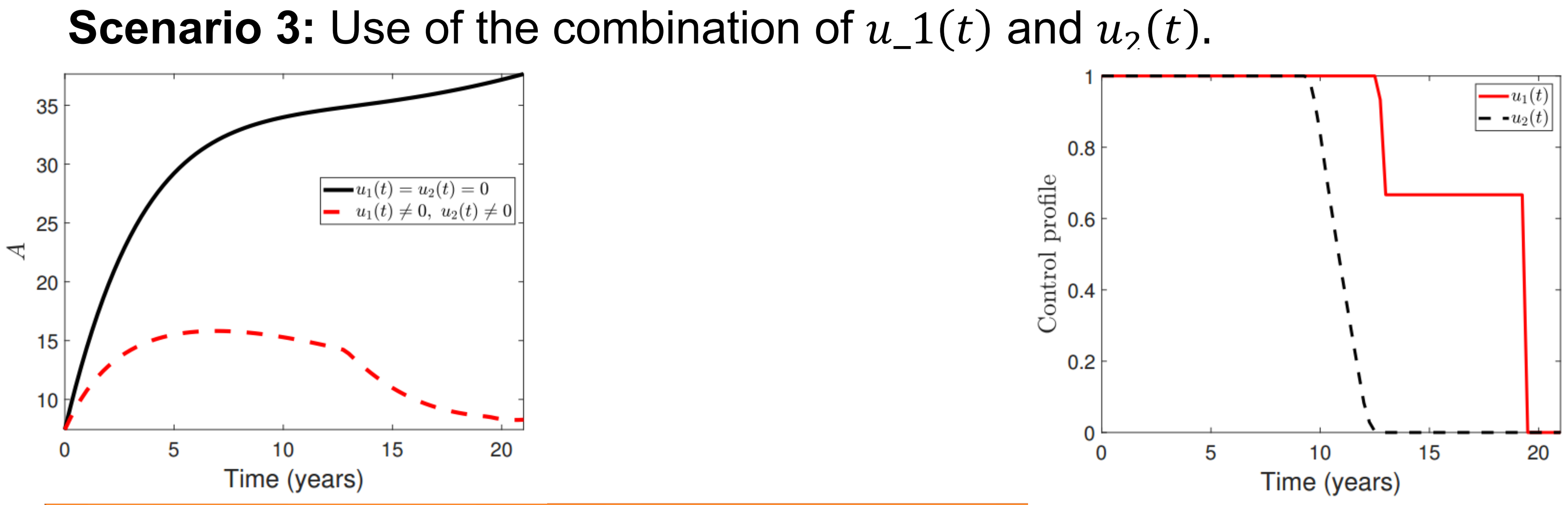
Scenario 1: Use of ART, $u_1(t)$ only.



Scenario 2: Use of enhanced screening/testing for unaware HIV-infected humans ($u_2(t)$) only.



Scenario 3: Use of the combination of $u\_1(t)$ and $u_2(t)$.



CONCLUSION

- This study extended an existing modelling framework of [2] to an optimal control framework.
- Results of the revealed that the implementation of strategy 1 (the use of $u_1(t)$ only) is as good as implementing the combined efforts of the two optimal controls under consideration (strategy 3).
- Thus, the study suggests the use of ART only when HIV testing and the use of ART are the only alternative competing interventions for HIV in Indonesia.

FUTURE WORK / REFERENCES

Future work

- The modelling framework proposed in this study does not explicitly capture the viral load suppressed individuals as well as diagnosed individuals. Hence, future work may be conducted to capture these limitations.

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