Clinical Pathway Modelling of a Trauma and Orthopaedics Department

Matthew Howells[1], Paul Harper[1], Daniel Gartner[1], Geraint Palmer[1] and Antonio Riccioli[2]

[1]School of Mathematics, Cardiff University [2]Cardiff and Vale University Health Board

HowellsMA@cardiff.ac.uk
matthewahowells
MHowells

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1 Motivation

- **Trauma & Orthopaedic (T&O) elective wait lists face substantial backlogs** post-pandemic [1], with demand expected to rise further due to an **ageing population.**
- A recent review of OR/MS methods in Orthopaedics highlights a lack of holistic pathway modelling and the need for further research into resource and capacity planning [2].

Hybrid Simulation – Modes of Interaction

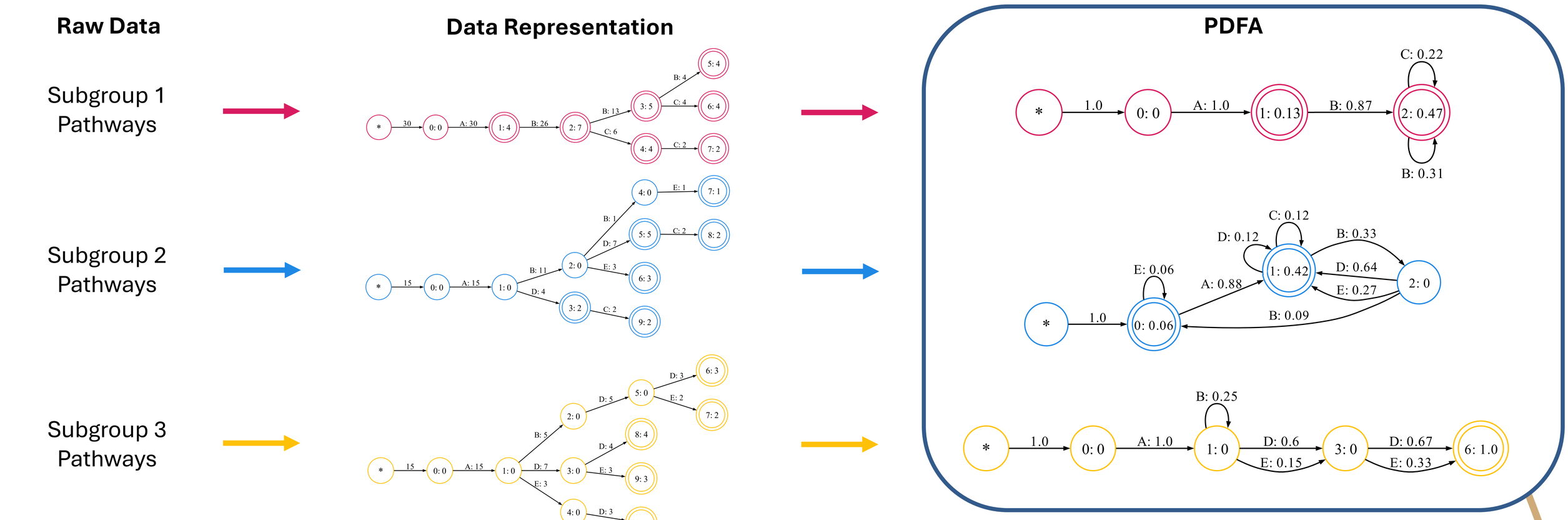
Brailsford et al. (2019) [3] outline four modes of interaction:

Enriching ☐ Sequential ☑ Interaction ☐ Integration ☐

How? SD stocks are transformed to DES time-dependent arrivals.
Why? SD captures deterioration in the community, DES captures resource use.

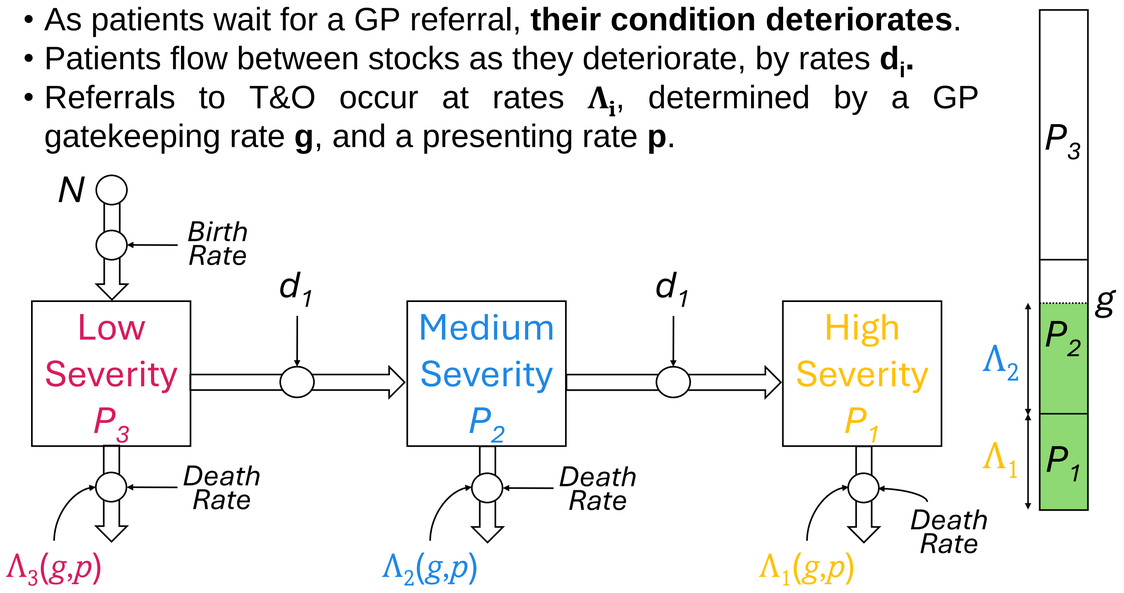
2 Learning Clinical Pathways

- Clinical pathways are patient journeys through care – we represent these as sequences of letters, each denoting a hospital activity.
- We **simplify and generalise pathways using ALERGIA** [4], a grammatical inference algorithm, to learn a **Probabilistic Deterministic Finite Automaton (PDFA)** from historic patient pathway data. PDFAs capture the probability structure of observed pathways, enabling the generation of realistic patient sequences.

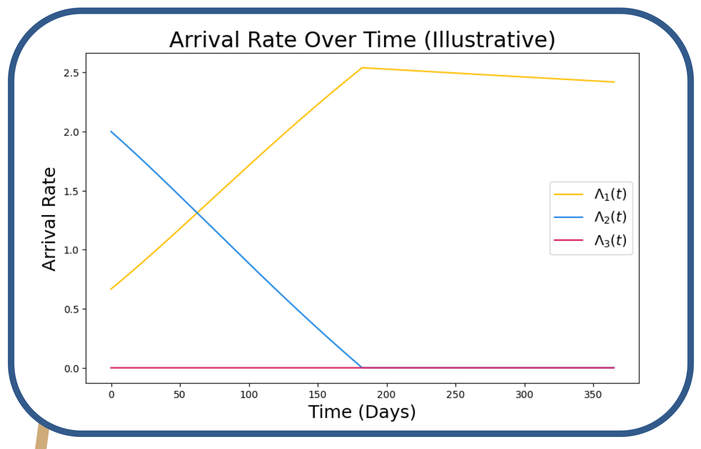


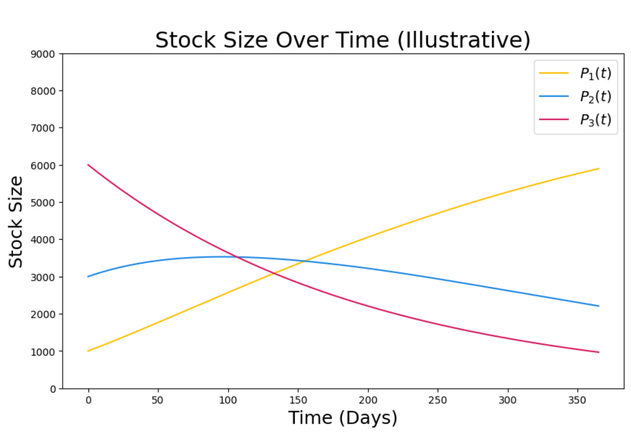
3 System Dynamics (SD)

- As patients wait for a GP referral, **their condition deteriorates**.
- Patients flow between stocks as they deteriorate, by rates $\mathbf{d_i}$.
- Referrals to T&O occur at rates $\mathbf{\Lambda_i}$, determined by a GP gatekeeping rate **g**, and a presenting rate **p**.



$$\Lambda_i(t) = P_i(t) \cdot p \cdot \min\left(\max\left(\frac{g \cdot \sum_j P_j(t) - (\sum_j^{i-1} P_j(t))}{P_i(t)}, 0\right), 1\right), \quad \forall i, j \in \{1, 2, 3\}$$

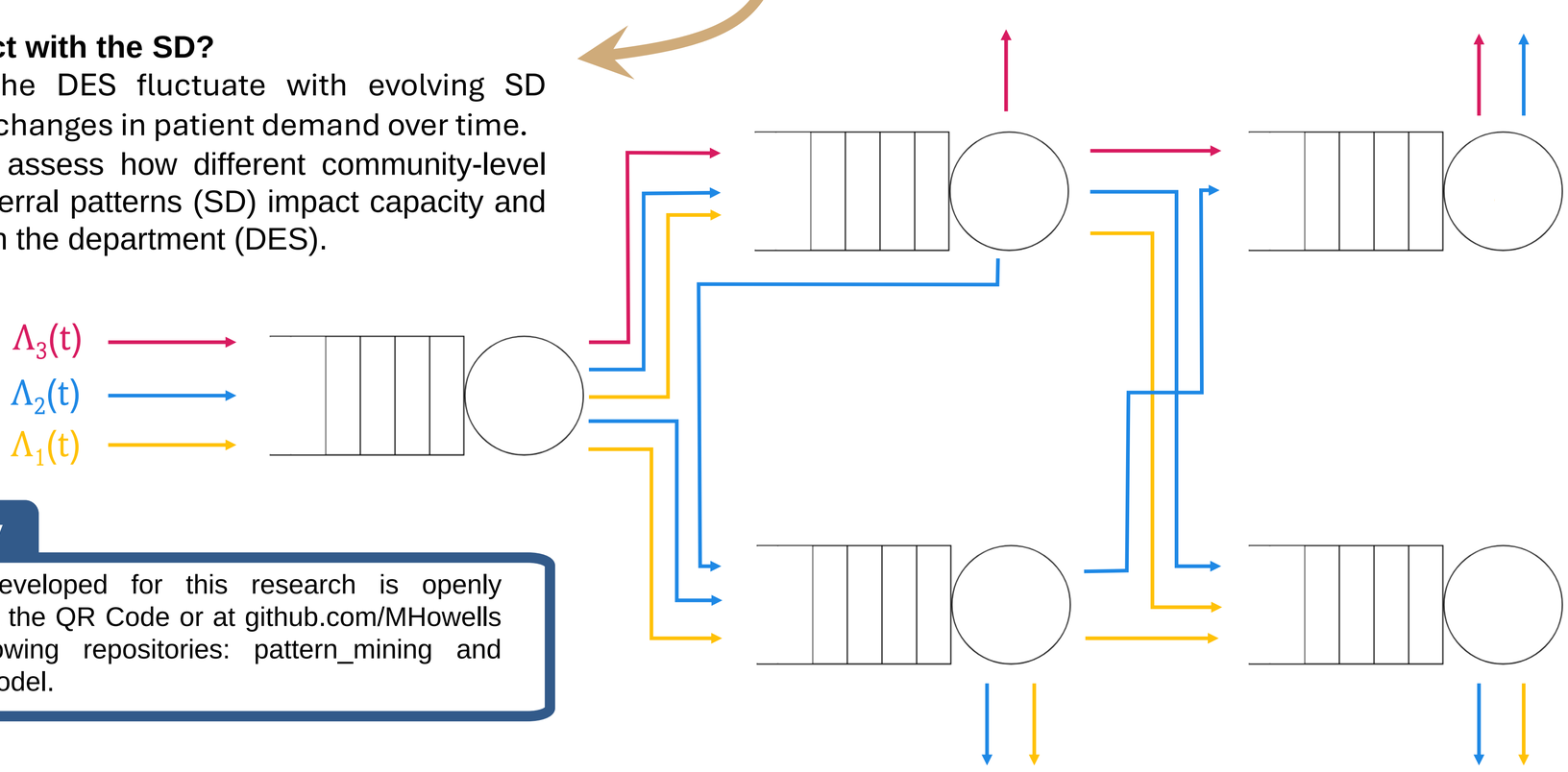




4 Discrete-Event Simulation (DES)

How does it interact with the SD?

- Arrival rates in the DES fluctuate with evolving SD stocks, capturing changes in patient demand over time.
- This allows us to assess how different community-level deterioration or referral patterns (SD) impact capacity and waiting times within the department (DES).



How does it interact with ALERGIA?

- For each patient class (or subgroup), the **corresponding PDFA,** learned via ALERGIA, generates the next activity in the DES.
- Here, the letters from the PDFA are mapped to their corresponding simulation nodes.

Code Availability

All code developed for this research is openly available via the QR Code or at github.com/MHowells in the following repositories: pattern_mining and HybridSimModel.

5 Impact

- The T&O department has collaborated closely throughout the modelling process and is enthusiastic about the research.
- The work on learning clinical pathways has been **validated by management** and has provided insights into variation in pathway adherence across subspecialties.
- The hybrid simulation model will provide the department with decision-support tools to identify and alleviate capacity bottlenecks and assess the impact of changing referral patterns and severity profiles.

References

[1] H. Graichen, "The role of an orthopaedic surgeon in the time of Covid-19 pandemic –a German perspective," Journal of Orthopaedics 19 (2020), A1-A3.
[2] M. Howells et al. "Fractured Systems: A Literature Review of OR/MS Methods Applied to Orthopaedic Care Settings and Treatments," Health Systems (2023), pp.1-26.
[3] S. C. Brailsford et al. "Hybrid simulation modelling in operational research: A state-of-the-art review." *European Journal of Operational Research* 278 (2019), pp.721-737
[4] C. De la Higuera. Grammatical Inference: learning automata and grammars. Cambridge University Press, 2010.