Probabilities of Allen Interval Relations

1. Detailed Description of the Planned Project (25 marks)

BACKGROUND & MOTIVATION

James F. Allen's Interval Algebra (1983) defines 13 qualitative temporal relations (such as before, meets, overlaps) describing how intervals in time relate to one another. Although widely used in computational linguistics, event scheduling, and artificial intelligence, Allen's approach is deterministic and does not inherently account for uncertainty, despite real-world temporal data frequently containing incomplete or uncertain information. This limitation motivates extending Allen's Algebra to probabilistically quantify temporal uncertainty, enabling realistic and flexible handling of temporal relations.

OVERALL GOAL & OBJECTIVES

The main goal of this project is to extend Allen's Interval Algebra by incorporating probability into temporal relations. Unlike previous work that assumed static priors or fixed transition probabilities, this project aims to derive empirical distributions dynamically through stochastic simulation, allowing relation probabilities to emerge from the model itself rather than being pre-imposed. Specific objectives include:

1. Implementing Allen's 13 temporal relations accurately and ensuring logical consistency.
2. Developing a probabilistic simulation based on a birth-death automaton model, dynamically generating intervals and measuring relation frequencies under varying pBorn and pDie parameters.
3. Creating interactive visualisations using Dash and Plotly to illustrate how relation probabilities evolve with simulation settings.
4. Extending the analysis from two-interval scenarios to three intervals, exploring the probabilities of composed relations (xRy, yRz → x?z).
5. Conducting rigorous statistical tests, such as chi-square goodness-of-fit, to validate whether observed distributions significantly diverge from uniform or match theoretical predictions.

PROBLEM STATEMENT

Deterministic approaches to temporal reasoning struggle with real-world uncertainty. This project addresses that gap through stochastic simulation, allowing nuanced exploration of emergent probabilistic structure in Allen's relations — useful in applications like uncertain event scheduling, historical reconstruction, and NLP models where temporal logic must handle ambiguity.

2. Literature Review (25 marks)

ALLEN'S INTERVAL ALGEBRA

Allen (1983) formalised 13 interval relations and a composition table for transitive reasoning, which remain foundational in temporal logic and computational linguistics.

PROBABILISTIC EXTENSIONS

Santos & Young (1999) introduced probabilistic temporal networks but lacked empirical simulation. Badaloni & Giacomin (1999) proposed fuzzy extensions for boundary uncertainty. Fernando & Vogel (2019) derived theoretical prior probabilities over finite orders, showing certain relations (e.g., before, meets) are statistically more likely — challenging the naïve 1/13 assumption. However, their work remains analytical and non-interactive.

FINITE TEMPORALITY & BIRTH/DEATH MODEL

Suliman (2021) introduced an "unborn, living, dead" stochastic model to simulate relation frequencies but relied on fixed probability assumptions. This project generalises that model by allowing relation distributions to emerge from probabilistic dynamics under varying parameter regimes — not imposed a priori, but discovered empirically. This project builds directly on Suliman's stochastic approach, but removes static constraints, allowing relation distributions to emerge dynamically through simulation rather than being predefined.

INTERACTIVE VISUALISATION

Few prior works offer visual or interactive tools to explore probabilistic Allen relations. This project implements a live Dash dashboard to support intuitive parameter sweeps, composition heatmaps, entropy visualisations, and hypothesis testing — bridging theory and application.

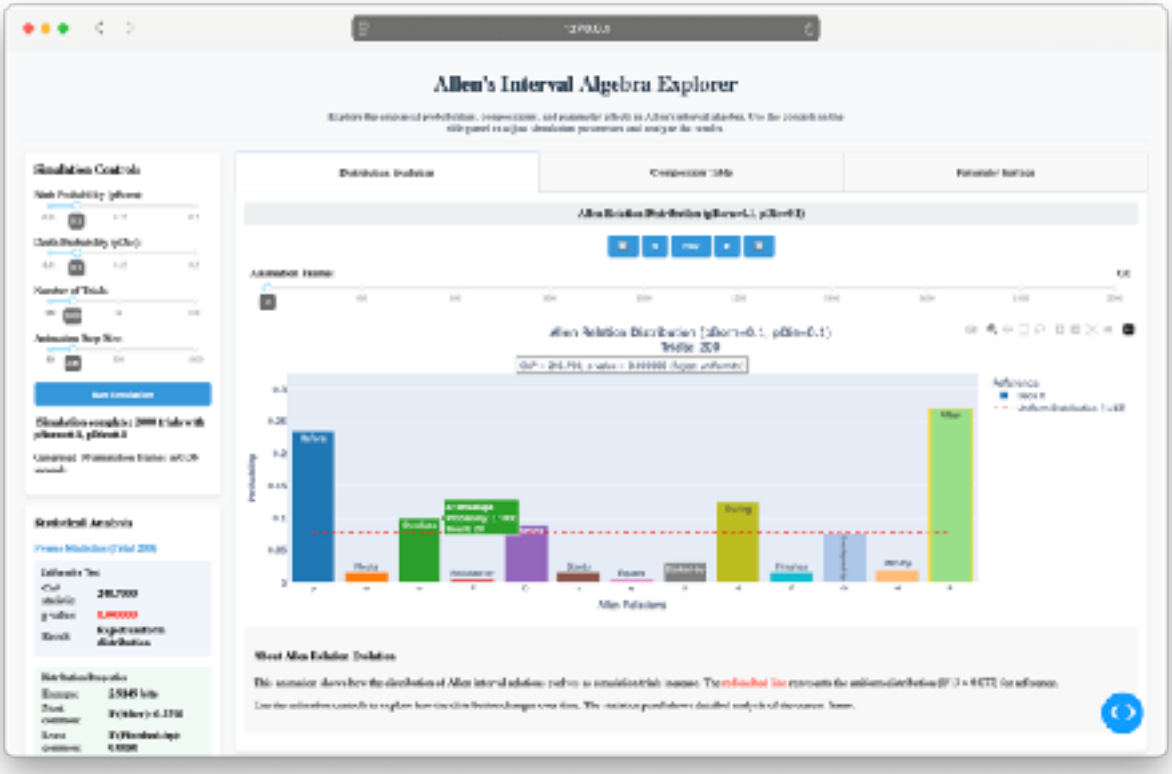
3. Plan of Work (25 marks)

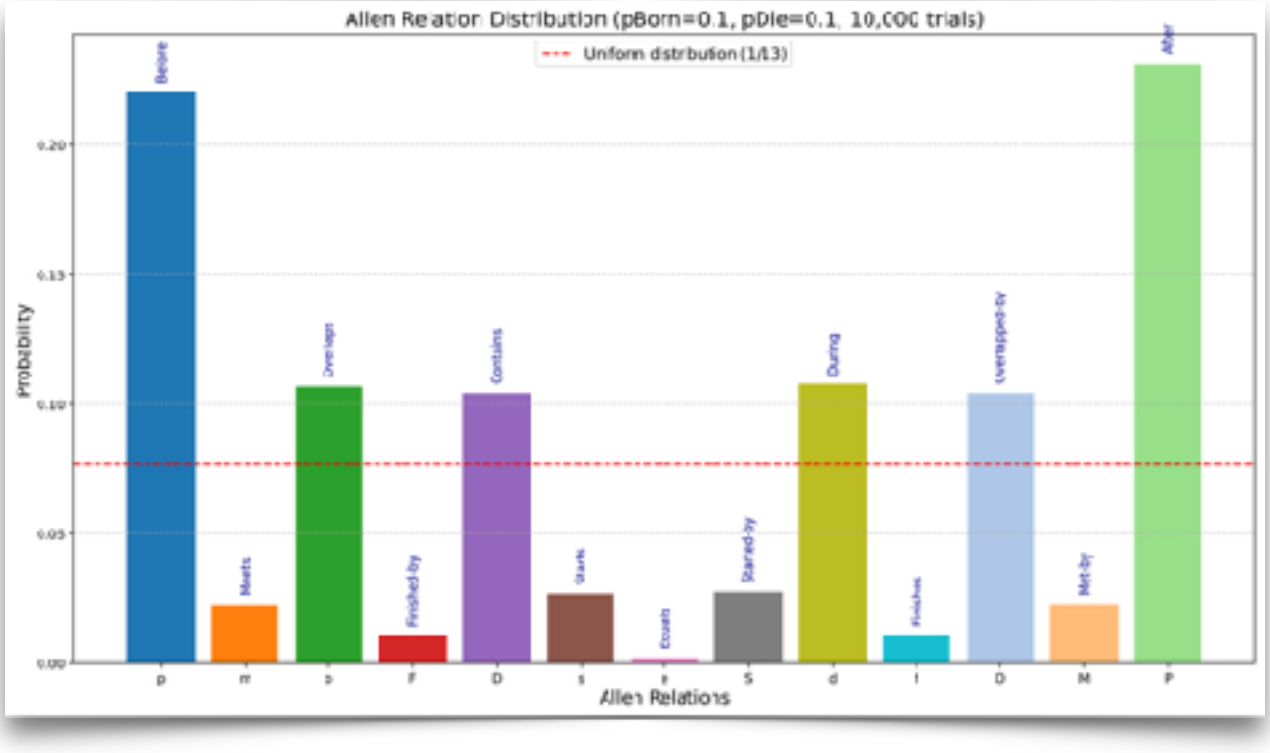
TASKS & MILESTONES

1. **Refine Core Simulation** (January) • Finalise stochastic birth/death automaton (pBorn, pDie) for generating 2-interval relation scenarios. • Implement detailed logging to capture relation counts and composition probabilities. • Conduct chi-square hypothesis tests on resulting distributions.
2. **Enhance Composition Analysis** (Late Jan – Early Feb) • Extend logic for three-interval chains (xRy, yRz → x?z). • Develop partial distribution analysis, conditioned on specific intermediate relations.
3. **Dashboard & Visualisation Polishing** (February) • Complete interactive visual tools: 3D surfaces, heatmaps, composition size/entropy views. • Add parameter sliders and export options for reproducibility.
4. **Testing & Validation** (Late Feb – Early March) • Compare empirical distributions with known theoretical priors (e.g., 1/9 vs 1/27 cases). • Investigate parameter sensitivity — how distributions shift under asymmetrical pBorn/pDie. Early simulation runs have already shown emergent asymmetries in relation distributions, reinforcing the importance of parameter sensitivity analysis.
5. **Final Report Drafting** (March – Early April) • Document empirical results and analyse deviations from expected patterns. • Integrate supervisor feedback, refine explanatory narratives.
6. **Cleanup & Submission** (Mid-April) • Final polish on the codebase, visual outputs, and reproducibility scripts. • Package the final report and all supplementary materials.

GANTT CHART

Task	Jan	Feb	Mar	Apr
Refine Core Simulation	X			
Composition Analysis	X	X		
Dashboard / Visualisations		X		
Testing & Validation			X	
Final Report Draft & Cleanup			X	X





4. Ethical & Inclusivity Considerations (25 marks)

RESEARCH PARTICIPANTS & DATA

No human participants or sensitive data are involved. Simulations use synthetic interval data. No IRB review is required.

OPEN-SOURCE CODE & TRANSPARENCY

Code is publicly available on GitHub. All dependencies and external contributions will be credited. Reproducibility is supported through version control and inline documentation.

INCLUSIVITY & ACCESSIBILITY

1. Visual design accommodates colour-blind accessibility (e.g., avoiding red-green gradients).
2. Language is kept gender-neutral and culturally neutral throughout the interface and outputs.
3. Code is modular and documented for accessibility by future researchers.

FAIRNESS & FUTURE REPRESENTATION

While current simulations are synthetic, any future work using real data will assess and address demographic representation and bias in temporal event distributions.

ENVIRONMENTAL IMPACT

Large-scale simulations will be optimised to minimise unnecessary computation and energy usage.

GENAI & ACADEMIC INTEGRITY

Copilot and other GenAI tools are used solely for scaffolding or refactoring. All conceptual and algorithmic contributions are original. Usage is acknowledged transparently per TCD guidelines.

WORD COUNT: 847
(EXCLUDING REFERENCES)

REFERENCES (SELECTED)

Allen, J.F. (1983). Maintaining knowledge about temporal intervals. Communications of the ACM.

Fernando, T., & Vogel, C. (2019). Prior probabilities of Allen's interval relations over finite orders. Proceedings of ACL 2019.

Santos, E. Jr., & Young, K. (1999). Probabilistic temporal networks. International Journal of Approximate Reasoning.

Suliman, M. (2021). Timeline Probabilities: A Final Year Project. Dissertation, Trinity College Dublin.

DECLARATION

I confirm completion of the TCD Ready Steady Write plagiarism tutorial and declare this work as my own.

CSU44099 Final Year Project – Interim Report Assignment

Interim Report: 100 marks (10% of overall CSU44099 mark)

As part of the process of completing your Final Year Project you are required to complete an Interim Report that outlines key components of the Project and includes such essential elements as goals, objectives, and a schedule. To write this plan you should have:

- Already met with your supervisor and have discussed your project;
- Carried out initial reading and planning around your project;
- Considered the Final Year Project Methods material in the context of your project;
- Defined your overall goal and objectives;
- Made a plan for the project work in Semester 2.

You need to submit your Interim Report for assessment. The report must include the following four elements:

1. A detailed description of the planned project (25 marks);
    a. Include the background to the project, the overall goal and objectives and a problem statement if appropriate
2. A review of literature that provides context, motivation and initial ideas for your project (25 marks).
    a. This will not normally be the full literature review required for the final project report.
3. A plan of work for the completion of the project (25 marks);
    a. Include a Gantt chart and tasks, schedule and milestones
4. A broad review of ethical issues related to the project, including, but not limited to, research ethics considerations (handling of research participants and their data) where applicable (25 marks);
    a. The review should include considerations of gender, race, and inclusivity implications of the project

The report should be no more than 1,000 words in length (excluding references).

Plagiarism

Please refer to: https://libguides.tcd.ie/academic-integrity/

You MUST complete the TCD Ready Steady Write plagiarism tutorial and sign the declaration when submitting this project plan, confirming that you understand what plagiarism is and have completed the tutorial.