Support For User Generated Evolutions Of Goal Models

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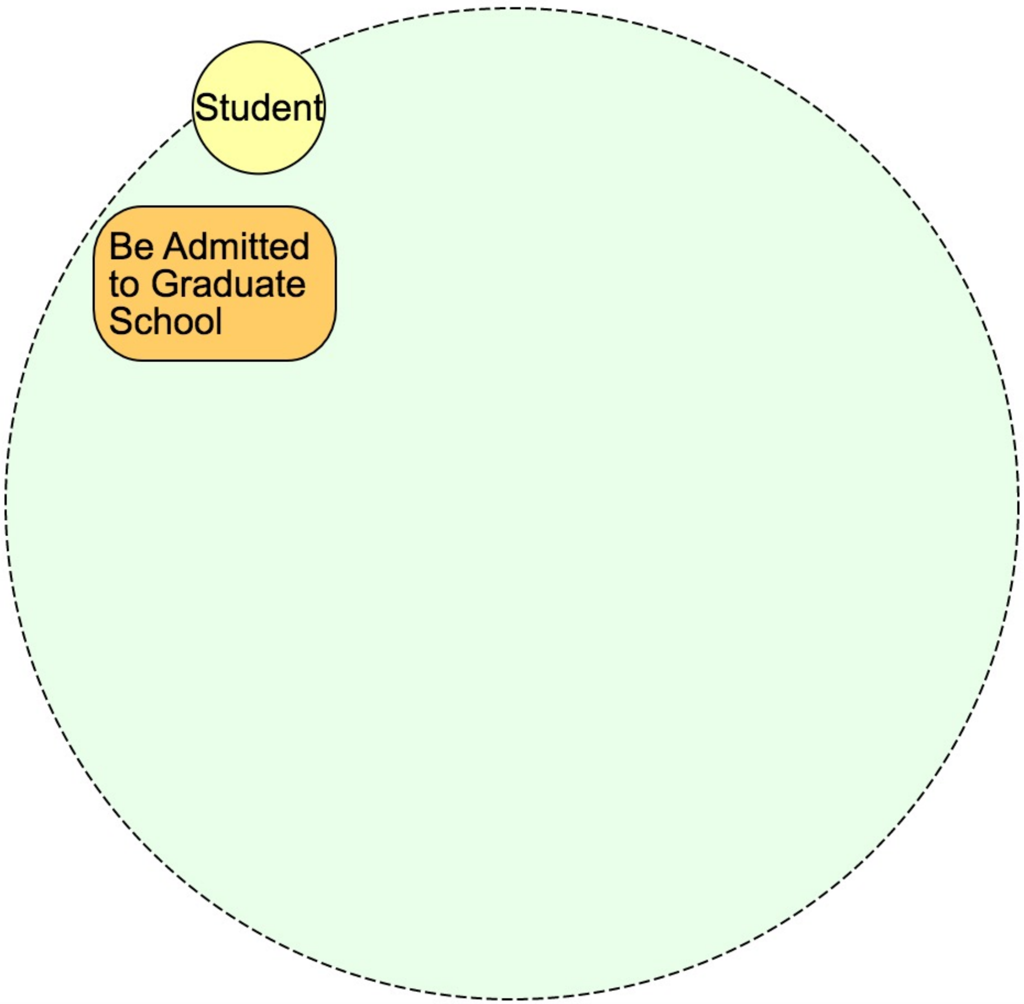
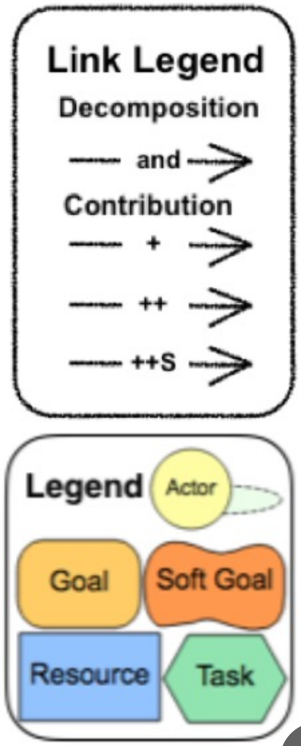
Motivating Example - GRAD

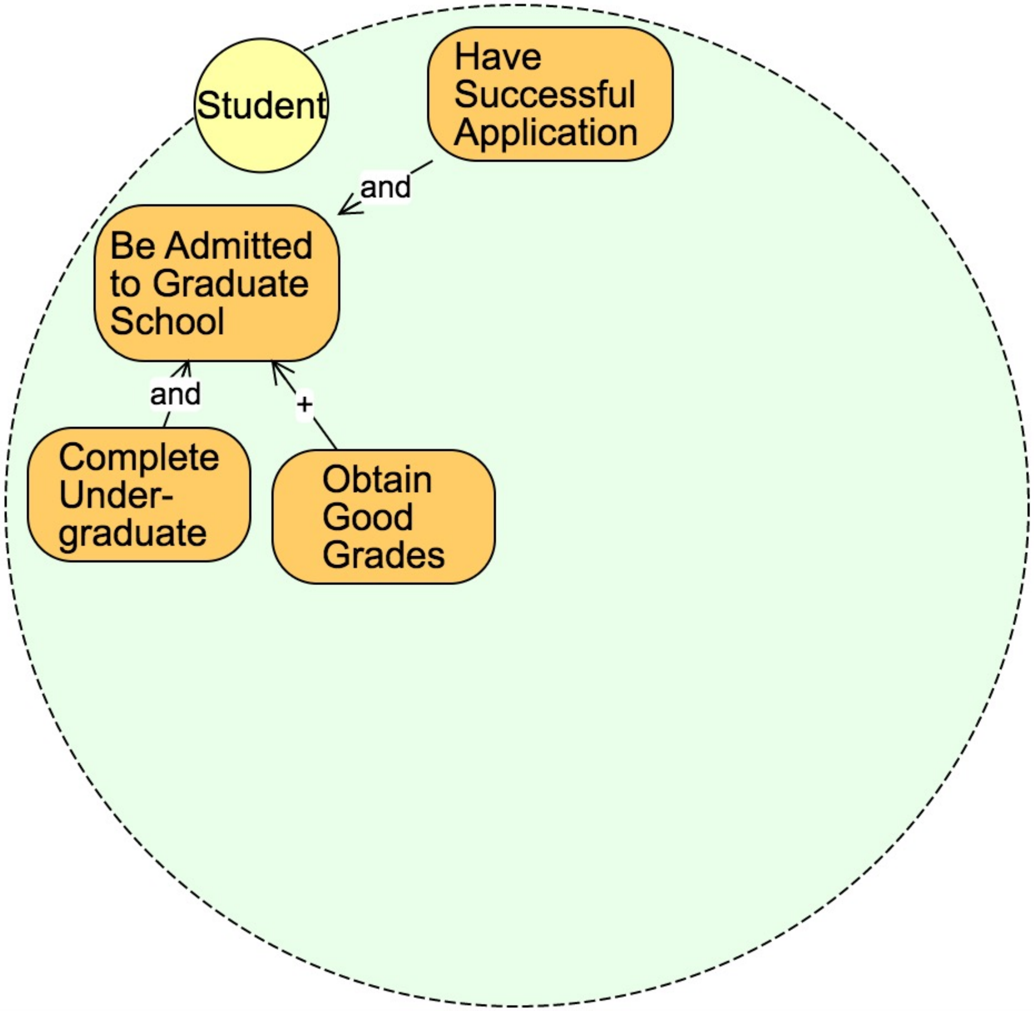
An undergraduate student interested in graduate school.

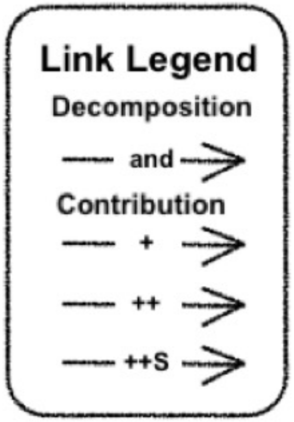




Motivating Example - GRAD

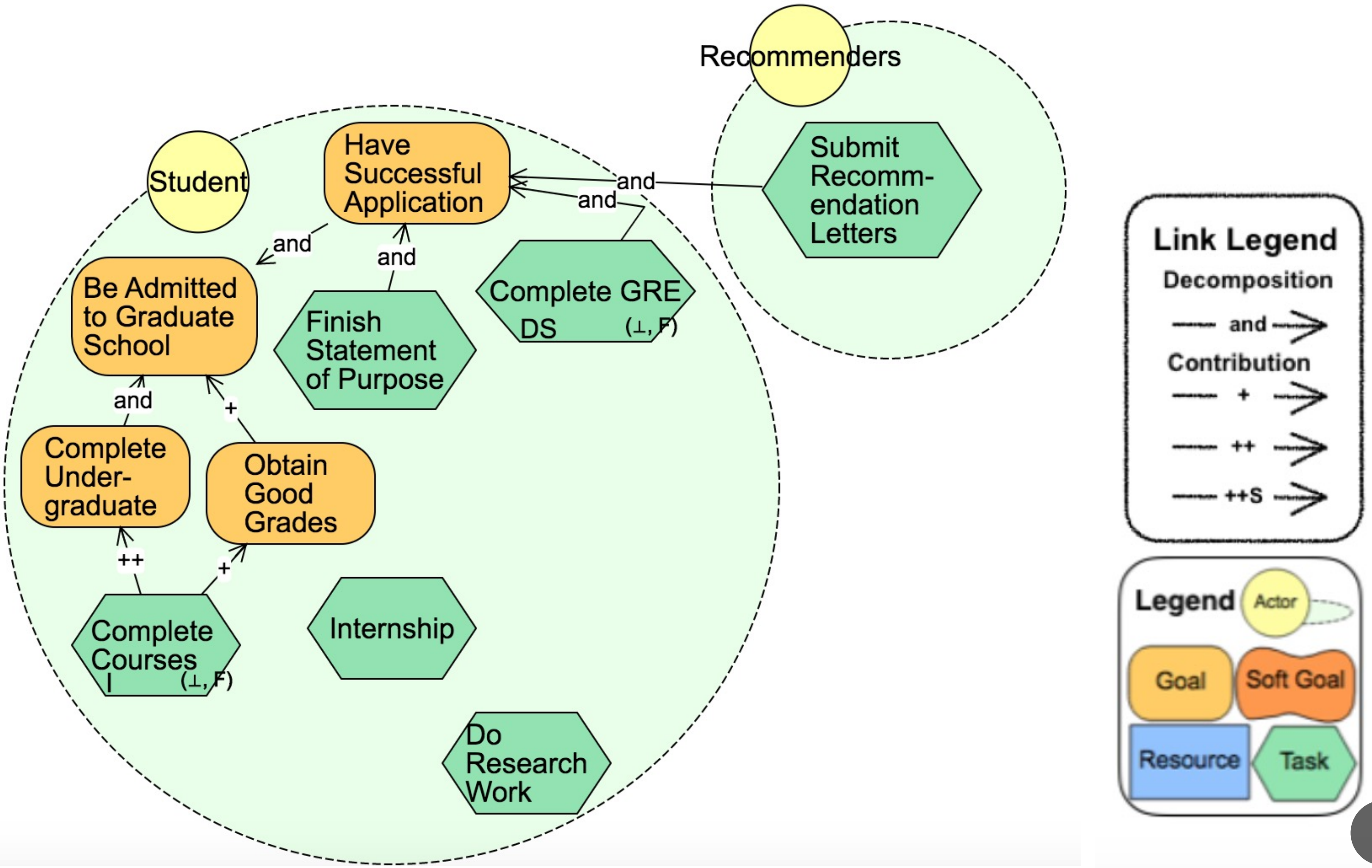
Requirements for Graduate School.





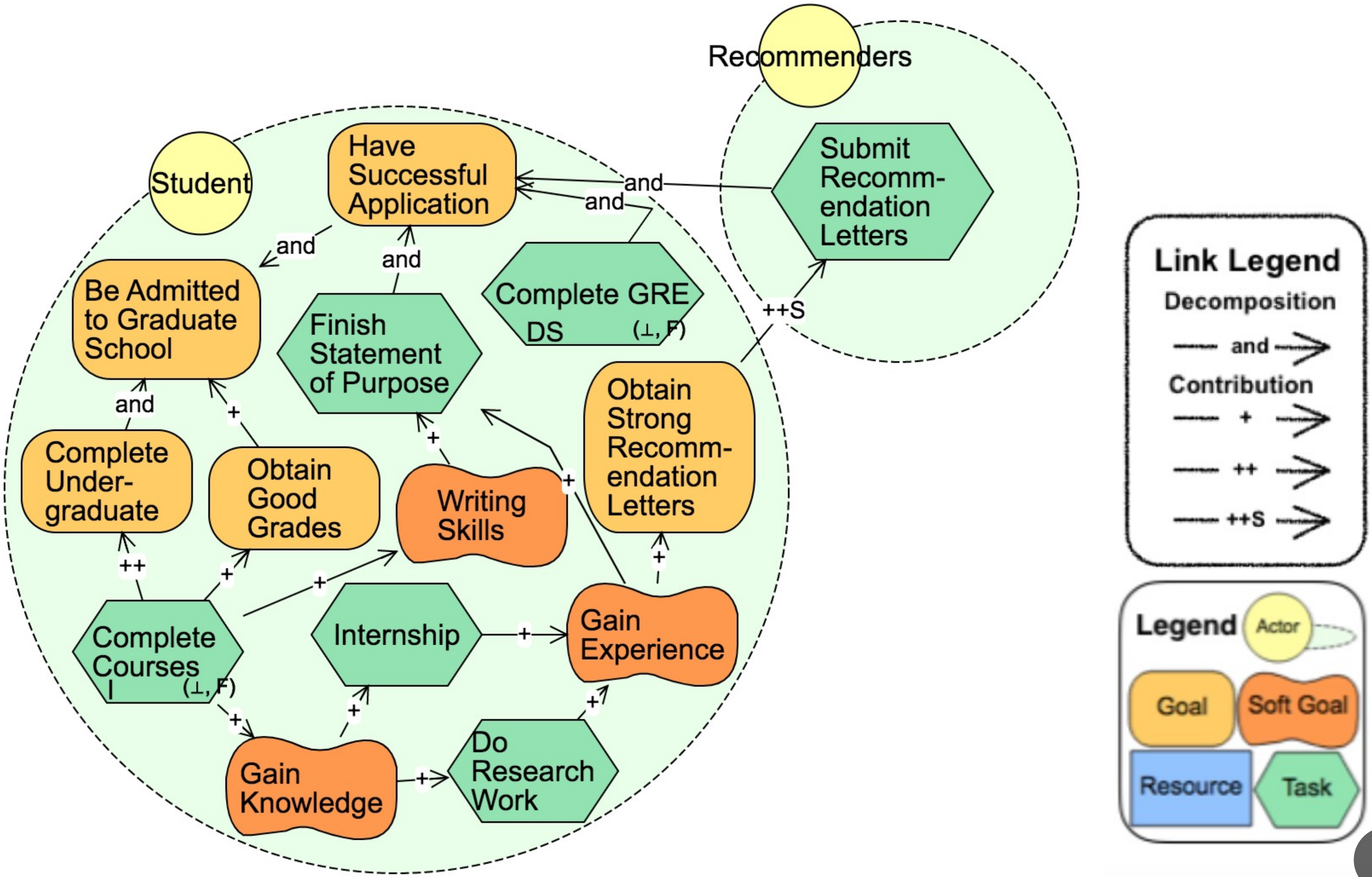
Motivating Example - GRAD

Tasks/Goal to satisfy the requirements.



Motivating Example - GRAD

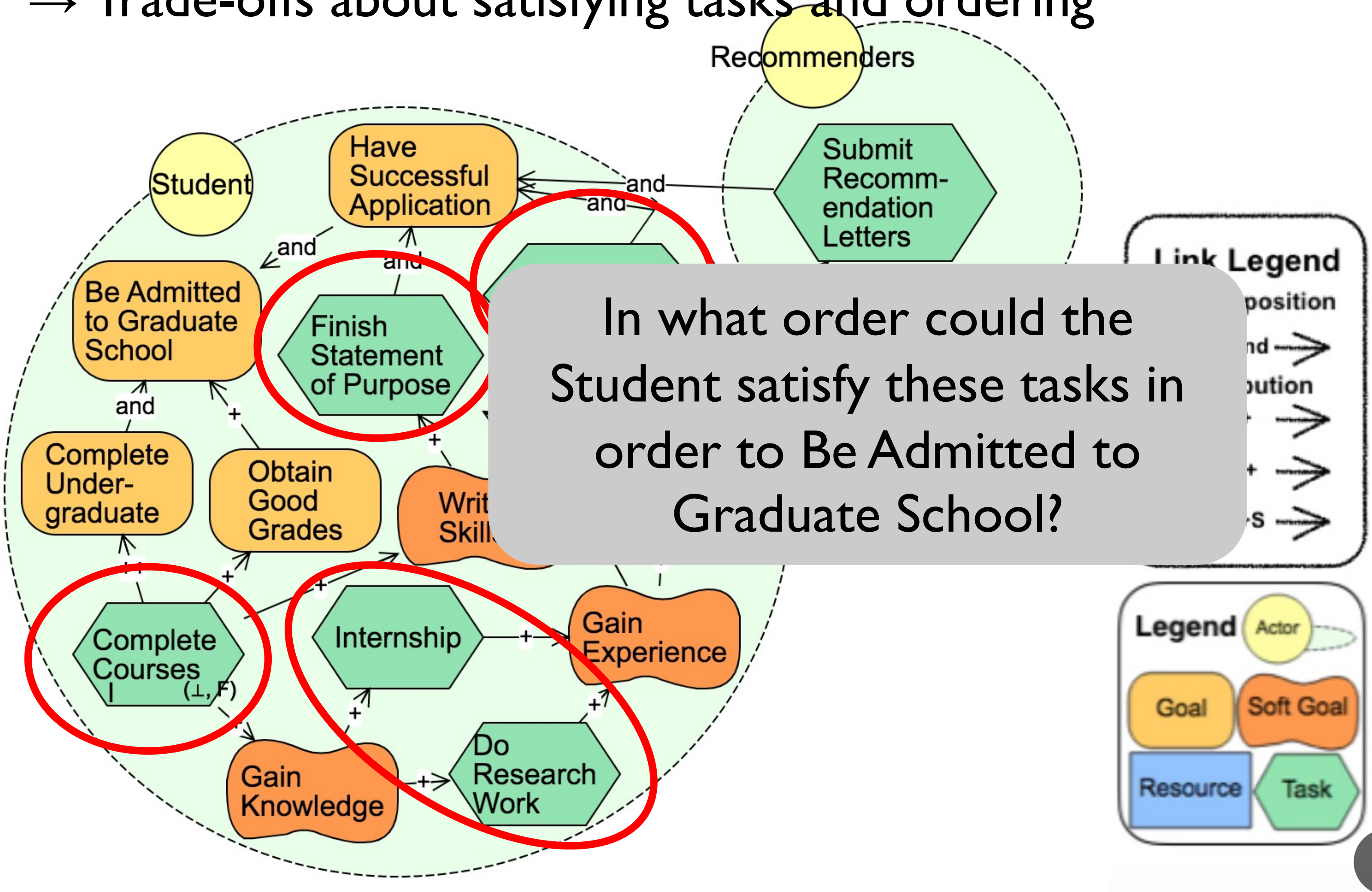
Additional Soft Goals that helps with the tasks.



Motivating Example - GRAD

To satisfies all the requirements

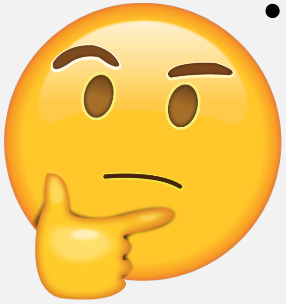
→ Trade-offs about satisfying tasks and ordering



BloomingLeaf

Evolving Intentions Framework:
Analysis of goal models when intention evaluations change over time

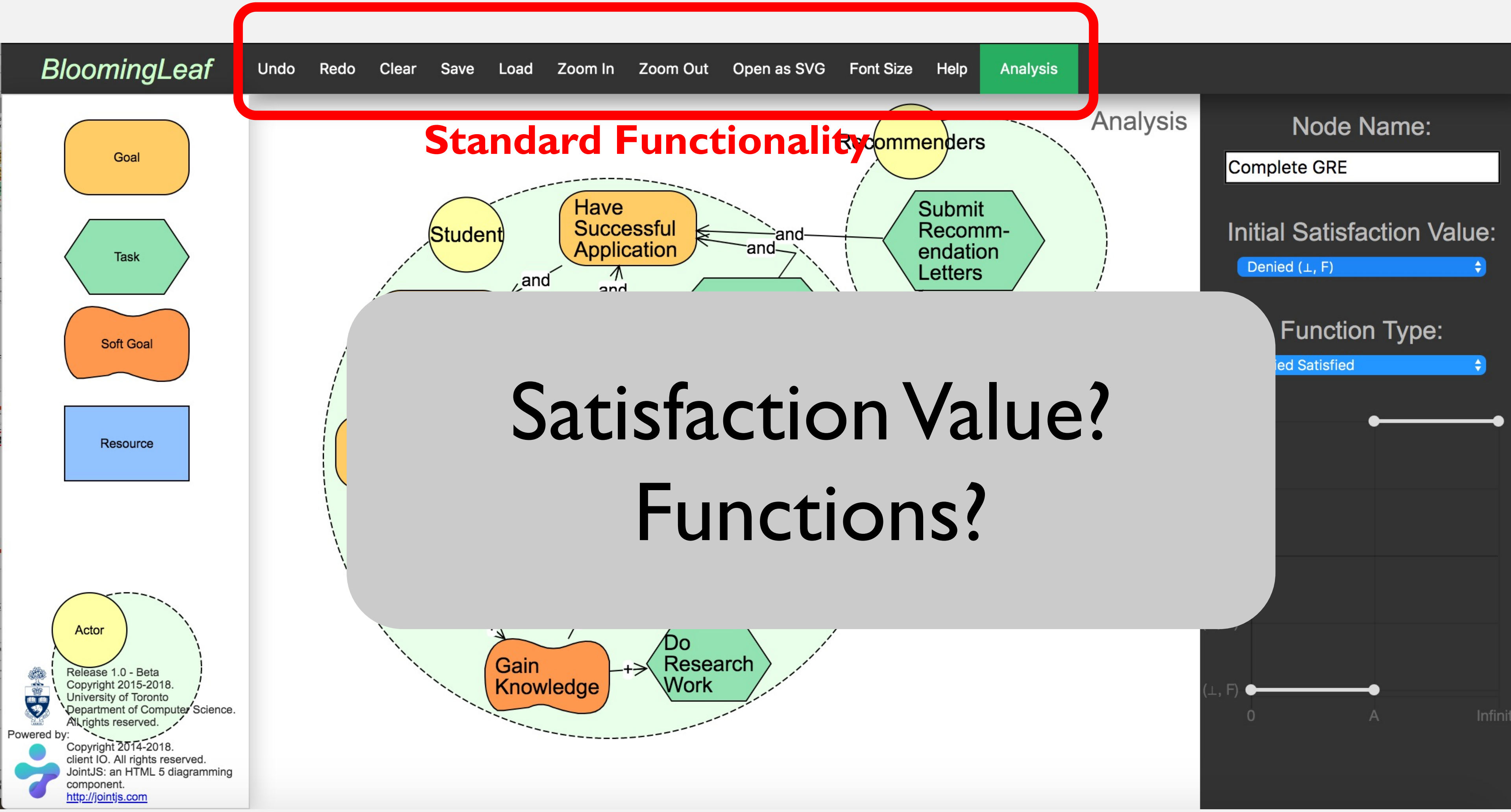
?



Will demonstrate through BloomingLeaf

BloomingLeaf

web-based goal modeling tool with automated formal analysis



Satisfaction Value?

Functions?

Evidence Pairs

	s ∈ {*F*, *P*, ⊥}: **for** fulfillment			
d ∈ {*F*, *P*, ⊥}: **against** fulfillment		**Full (F)**	**Partial (P)**	**No Evidence (⊥)**
	Full (F)	(F, F	(P, F	(⊥, F)
	Partial (P)	(F,	(P, F	(⊥, P)
	No Evidence (⊥)	(F ⊥)	(P, ⊥)	(⊥, ⊥)

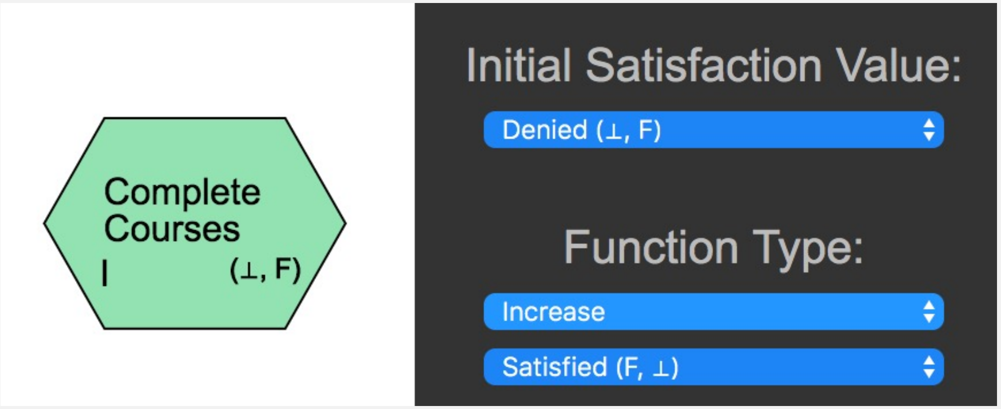
: Conflict value

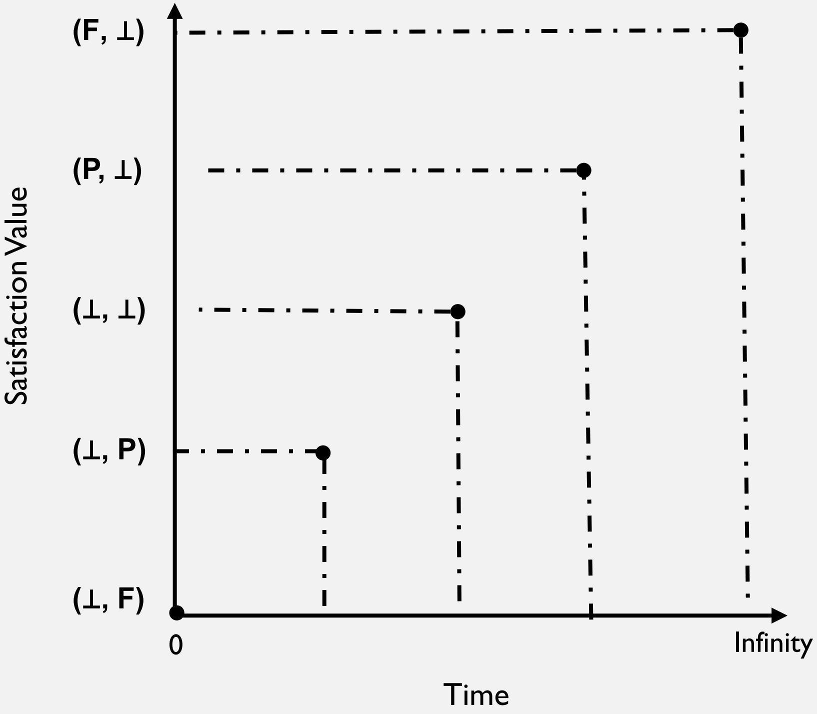
- ***evidence pairs* (s, d)**
- **s** - evidence **for** the fulfillment of an intention (satisfaction)
- **d** – evidence **against** the fulfillment of an intention (denial)

This goal is fully evidence against fulfillment (fully denied)

Evolving Intentions

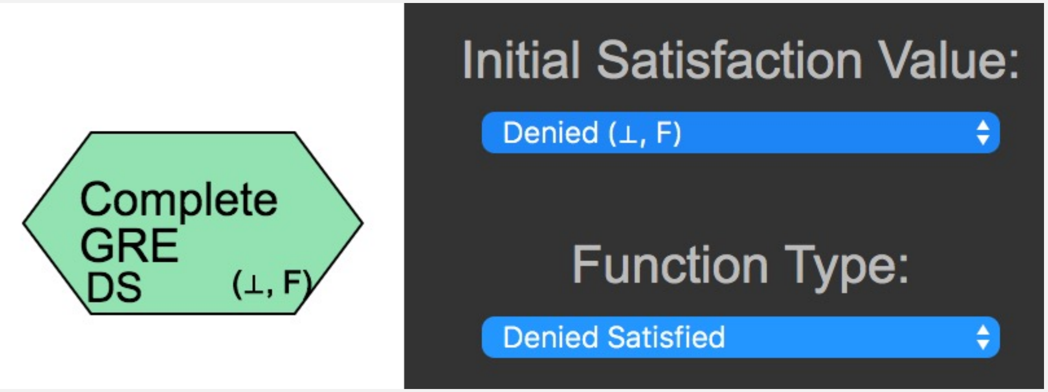
- Fulfillment of intentions changes over time
- Intentions are assigned **functions** prior to analysis
- Four atomic functions: CONSTANT, INCREASE, DECREASE, and STOCHASTIC

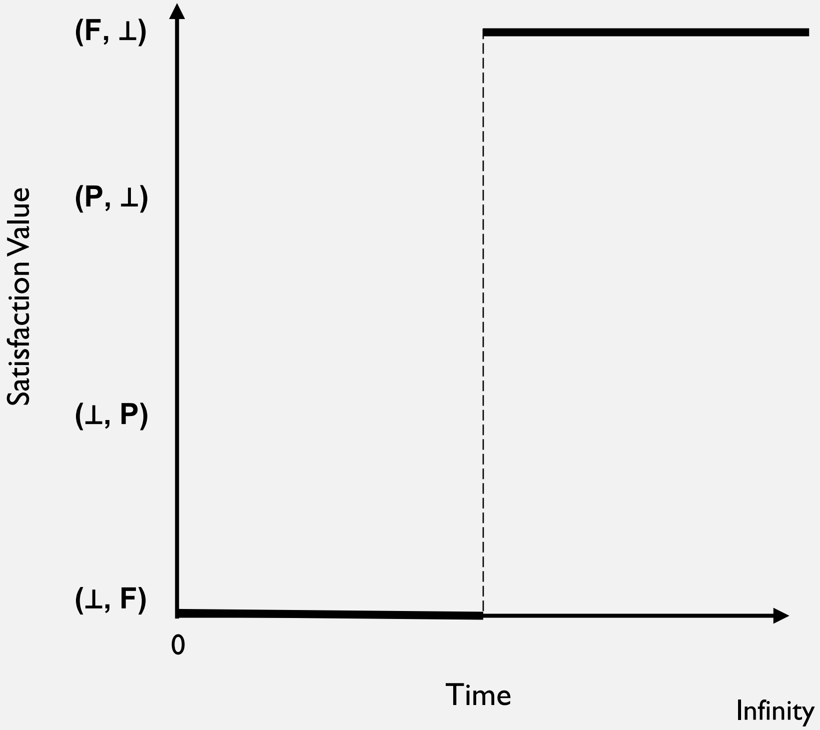




Evolving Intentions

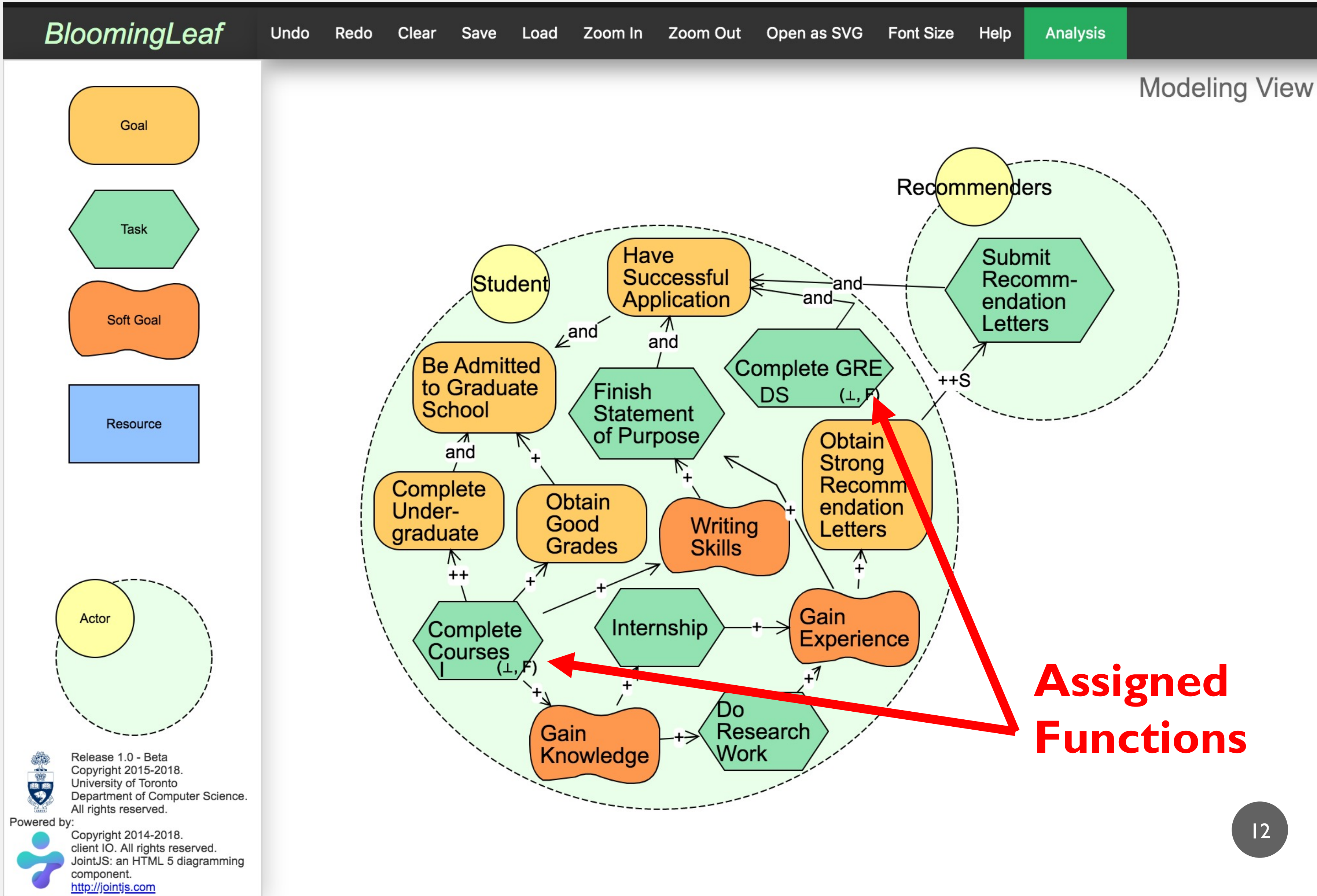
- Fulfillment of intentions changes over time
- **Functions** for the intention evolution assigned prior to analysis.
- Four atomic functions: CONSTANT, INCREASE, DECREASE, and STOCHASTIC





BloomingLeaf

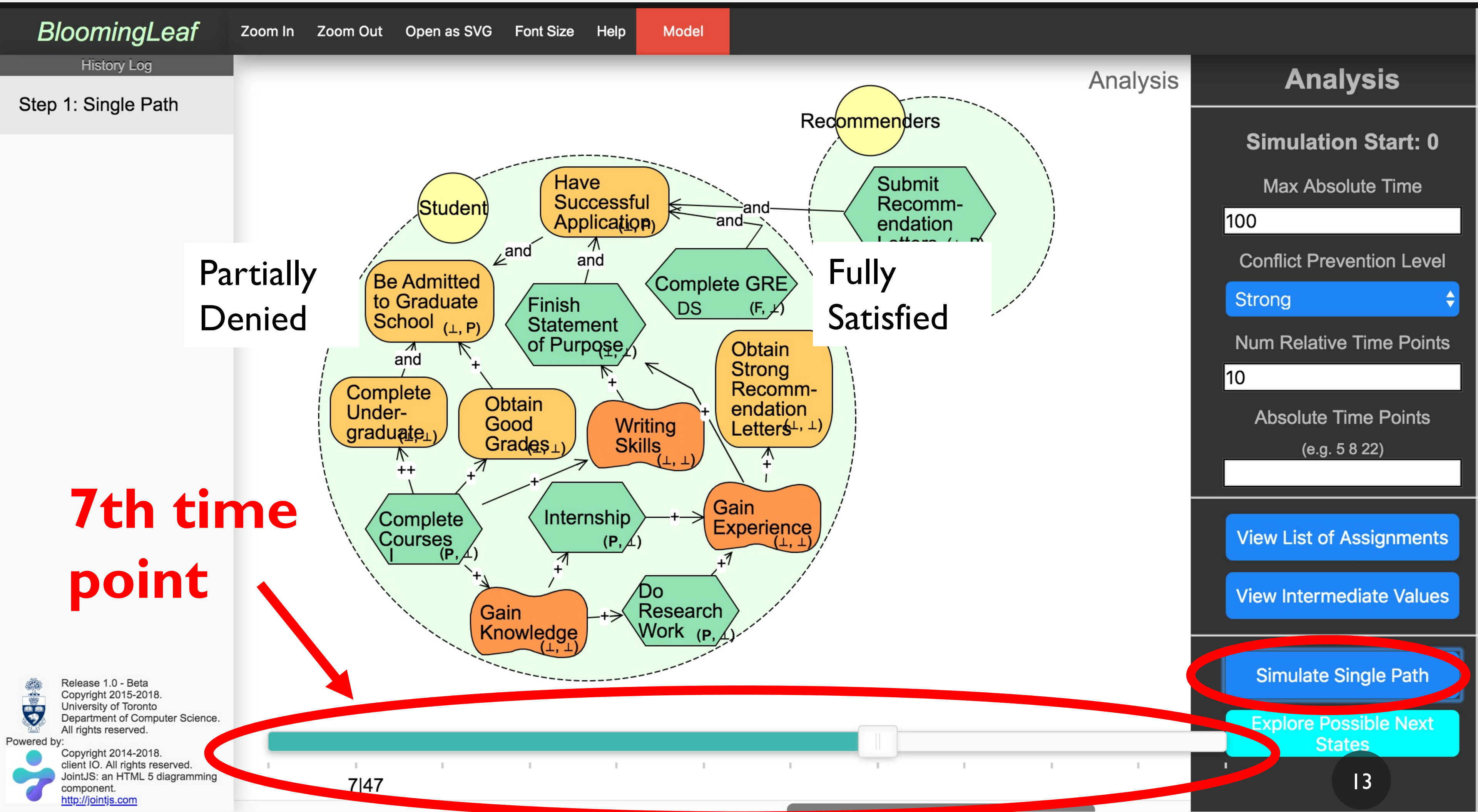
web-based goal modeling tool with automated formal analysis



Assigned Functions

Single Path Analysis

one possible evolution of the model over a pre-specified number of time points.



Single Path For The Grad Model

	Time Point 6	Time Point 7	Time Point 8	Time Point 9
Internship	(⊥, P) Partially Denied	(P, ⊥) Partially Satisfied	(P, ⊥) Partially Satisfied	(F, ⊥) Fully Satisfied
Complete Courses				(F, ⊥) Fully Satisfied
Do Research Work	(P, ⊥) Partially Satisfied	(P, ⊥) Partially Satisfied	(F, ⊥) Fully Satisfied	(F, ⊥) Fully Satisfied
Complete GRE DS	(⊥, F) Fully Denied	(F, ⊥) Fully Satisfied	(F, ⊥) Fully Satisfied	(F, ⊥) Fully Satisfied

Is it possible to fulfill Internship prior to Do Research Work?

New Single Paths

Be Admitted to Graduate School	(⊥, P) Partially Denied	(⊥, ⊥) No Information	(⊥, ⊥) No Information	(⊥, ⊥) No Information	(⊥, ⊥) No Information
Be Admitted to Graduate School	(⊥, ⊥) No Information	(P, P) Conflict Value	(P, F) Conflict Value	(F, F) Conflict Value	(F, F) Conflict Value
Be Admitted to Graduate School	(⊥, ⊥) No Information	(F, P) Conflict Value	(F, F) Conflict Value	(P, P) Conflict Value	(P, F) Conflict Value

time

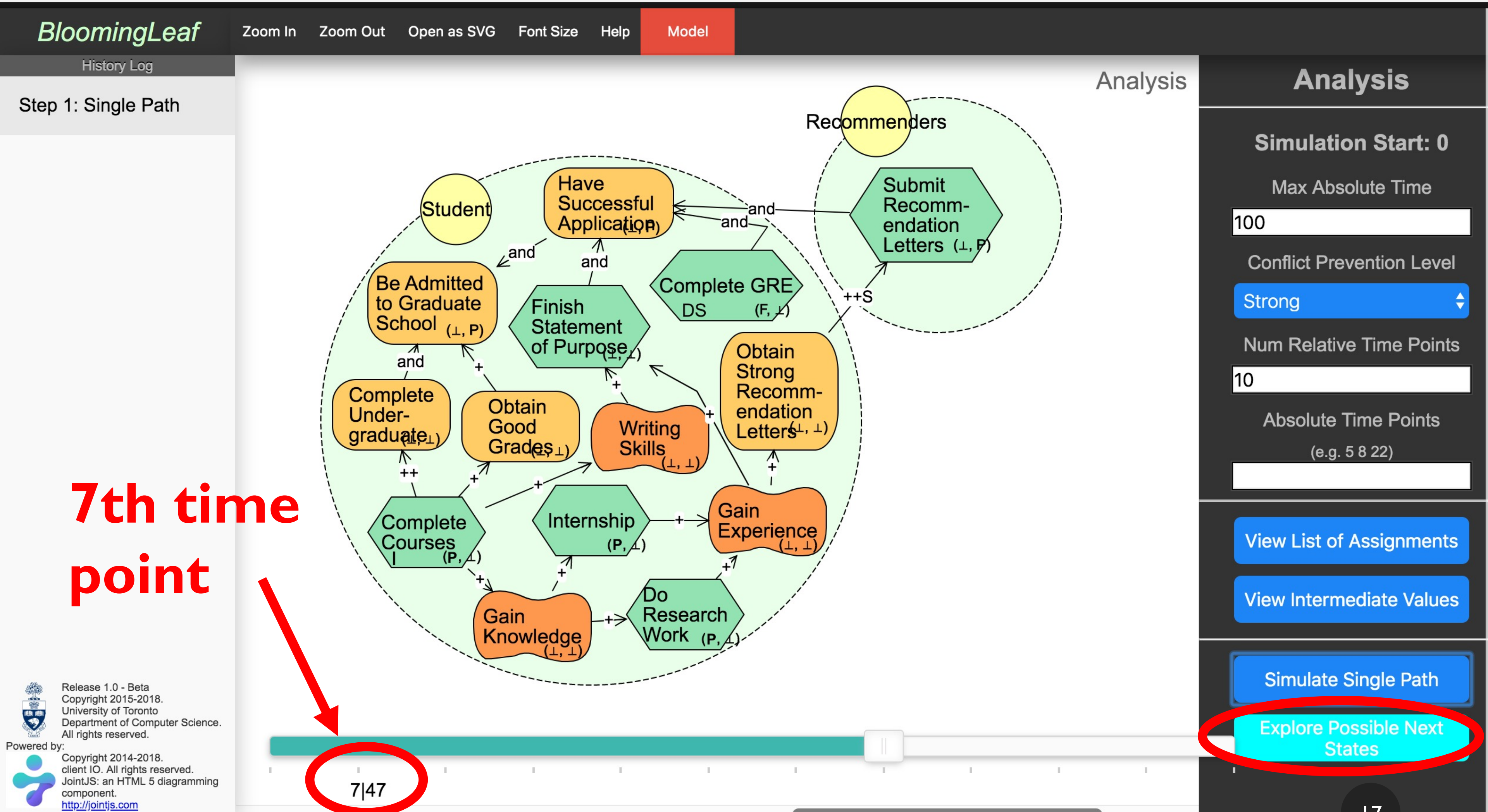
Single Path For The Grad Model

Explore all possibilities after time point 7

	Time Point 6	Time Point 7	Time Point 8	Time Point 9
Internship	(⊥, P) Partially Denied	(P, ⊥) Partially Satisfied	(P, ⊥) Partially Satisfied	(F, ⊥) Fully Satisfied
Complete Courses	(P, ⊥) Partially Satisfied	(P, ⊥) Partially Satisfied	(F, ⊥) Fully Satisfied	(F, ⊥) Fully Satisfied
Do Research Work	(P, ⊥) Partially Satisfied	(P, ⊥) Partially Satisfied	(F, ⊥) Fully Satisfied	(F, ⊥) Fully Satisfied
Complete GRE DS	(⊥, F) Fully Denied	(F, ⊥) Fully Satisfied	(F, ⊥) Fully Satisfied	(F, ⊥) Fully Satisfied

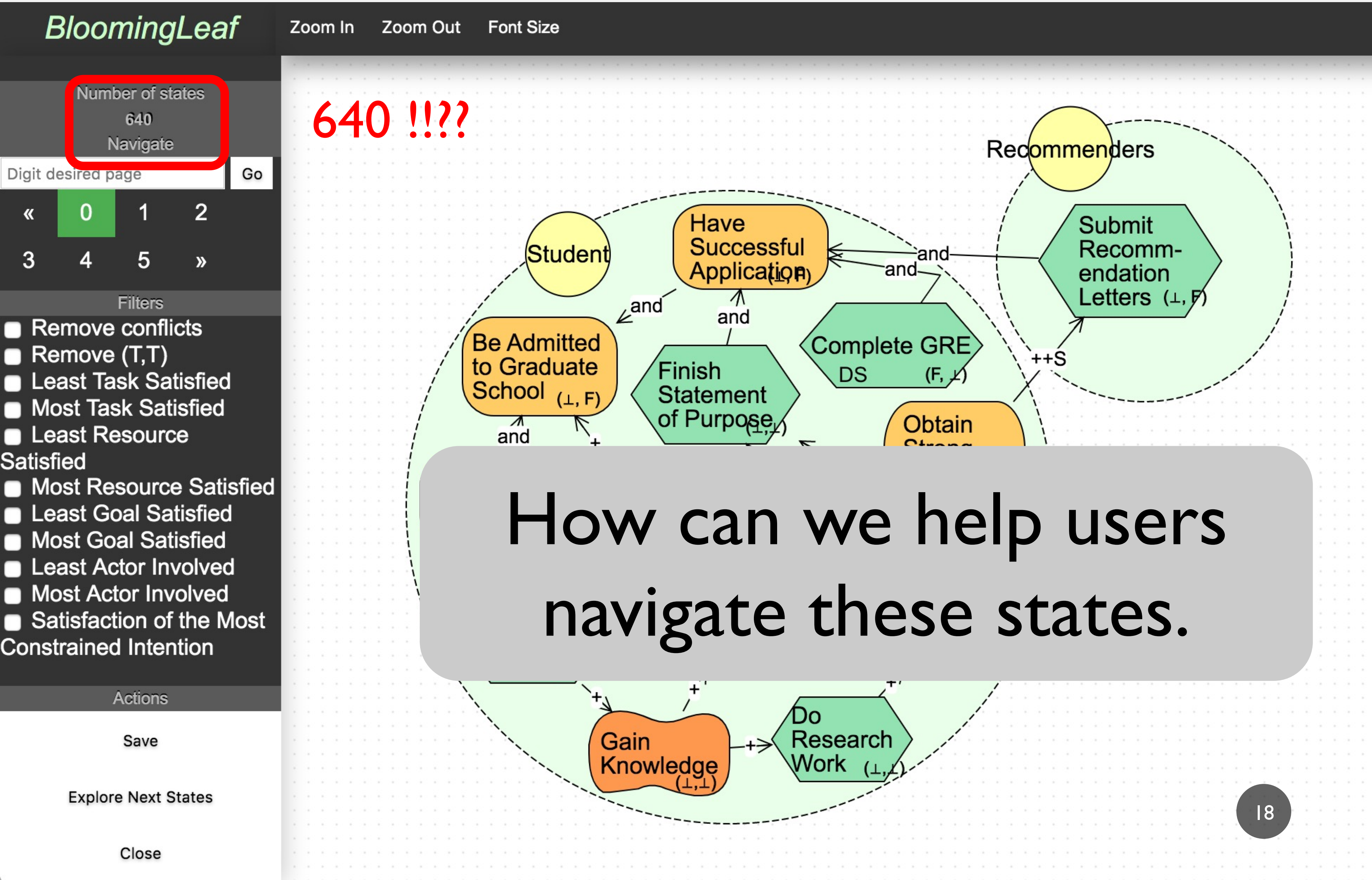
Single Path Analysis

one possible evolution of the model over a pre-specified number of time points.



Explore Next States At Time Point 7

allows users to step into any time point in the path and visualize all the possible next states



How can we help users navigate these states.

Overview

Background

- Evidence Pairs
- Evolving Intention
- BloomingLeaf Analysis

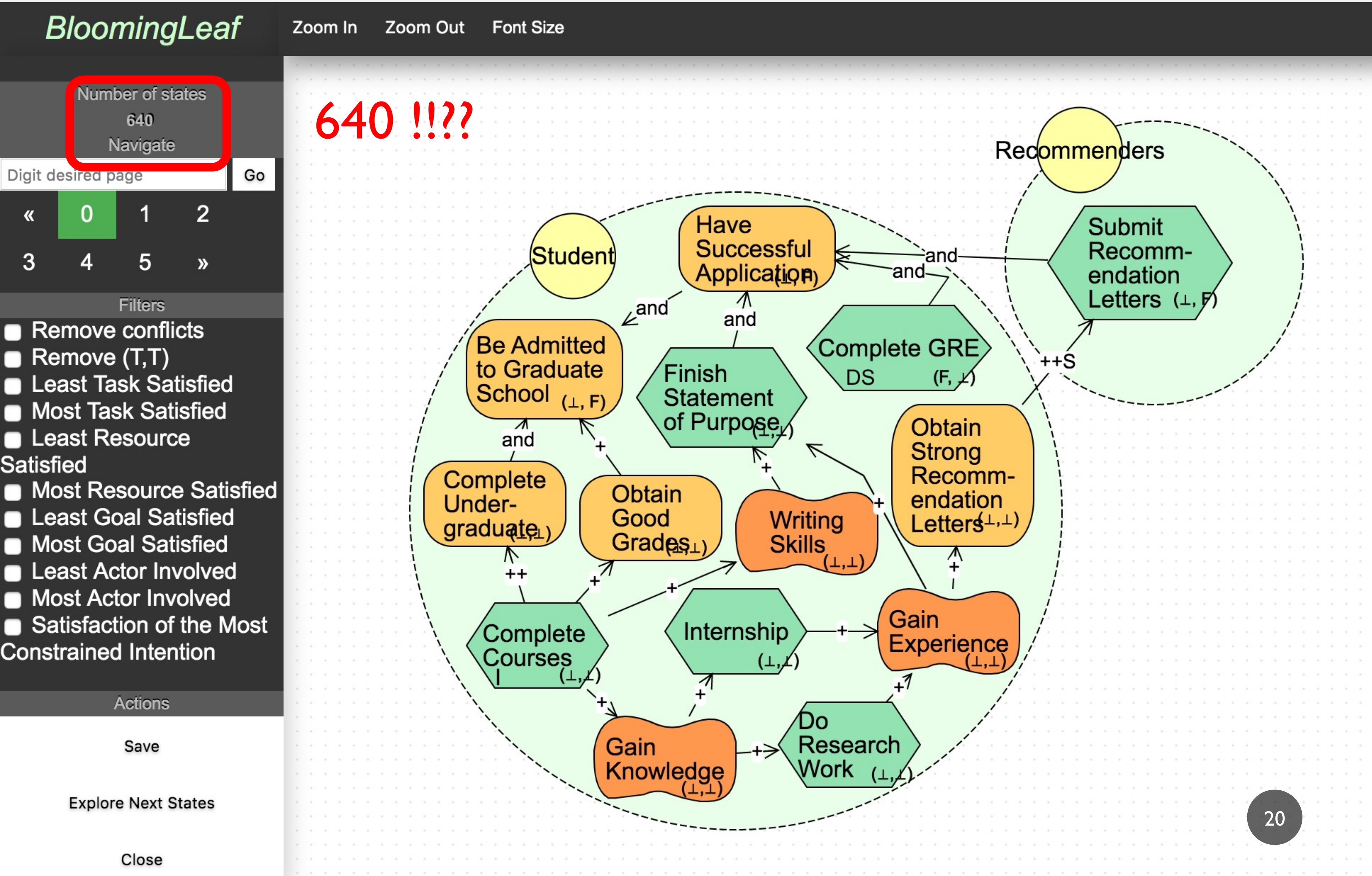
Problems

Proposed Solution

Initial Validation

Explore Next States At Time Point 7

allows users to step into any time point in the path and visualize all the possible next states



Solution Space Explosion Problem

- BloomingLeaf analysis uses Constraint Satisfaction Problems (CSPs)
  - CSPs often have high complexity

    (Exhaustive Search -> NP-Hard)
  - Domain for each intention: 9 possible evidence pairs
    - (F, ⊥), (P, ⊥), (⊥,⊥), (F, P), (P, P), (⊥,P), (F, F), (P, F), (⊥,F)
    - State space increases exponentially
  - Explore all possible next states is looking for all solutions

- Result: Huge solution space

Solution Space Explosion Problem

Huge solution space:

- Difficult to review
- Hard to make choices

Goal: Reduce the number of next states

Overview

Background

- Evidence Pairs
- Evolving Intention
- BloomingLeaf Analysis

Problems

- Huge solution space
- Difficult for users to review and customize

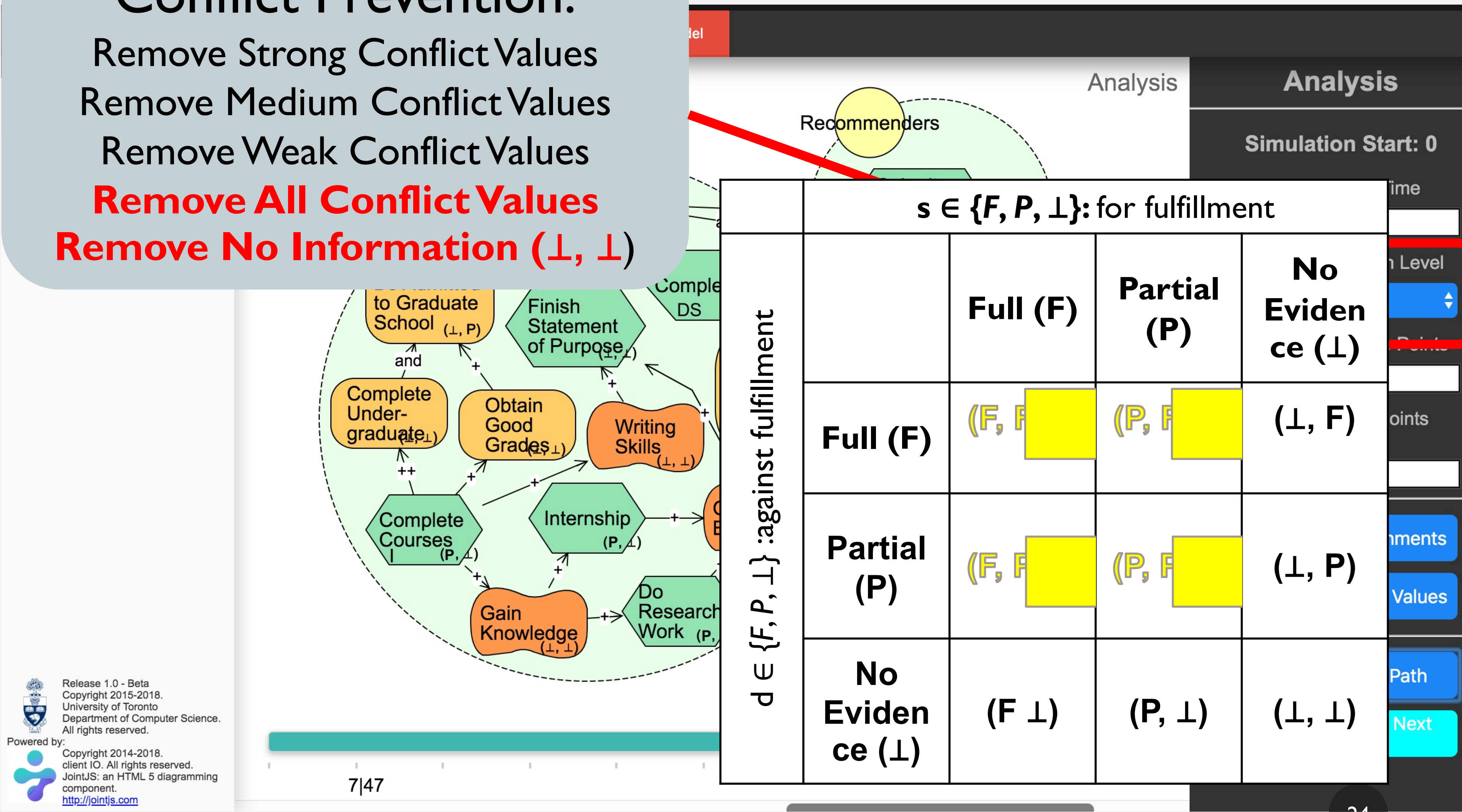
Proposed Solution

Initial Validation

Domain Reduction

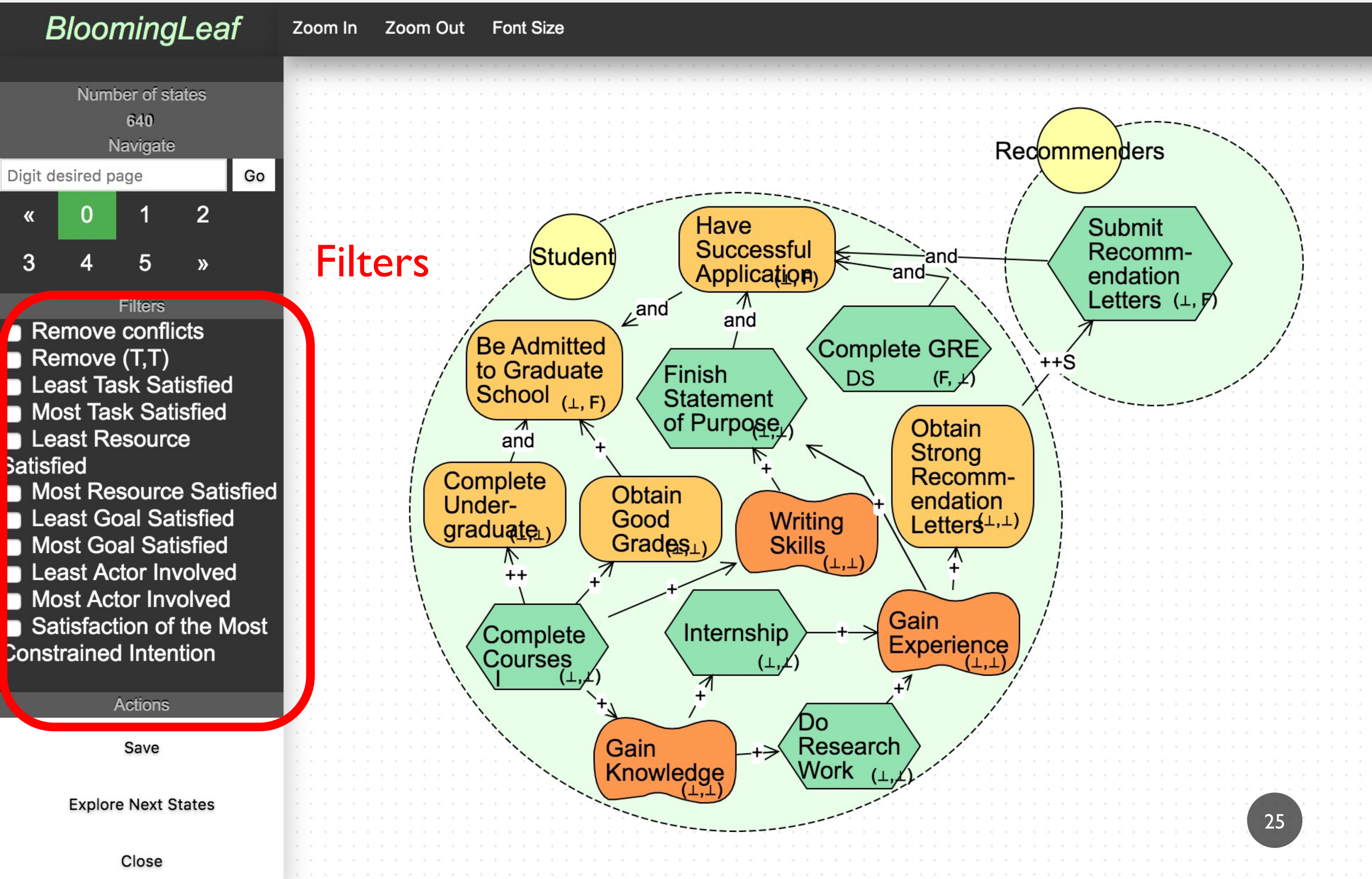
Conflict Prevention:

Remove Strong Conflict Values
Remove Medium Conflict Values
Remove Weak Conflict Values
Remove All Conflict Values
Remove No Information (⊥, ⊥)



d ∈ {F, P, ⊥} :against fulfillment \ s ∈ {F, P, ⊥}: for fulfillment	Full (F)	Partial (P)	No Evidence (⊥)
Full (F)	(F, F	(P, F	(⊥, F)
Partial (P)	(F, P	(P, P	(⊥, P)
No Evidence (⊥)	(F ⊥)	(P, ⊥)	(⊥, ⊥)

Solution Reduction



Filters

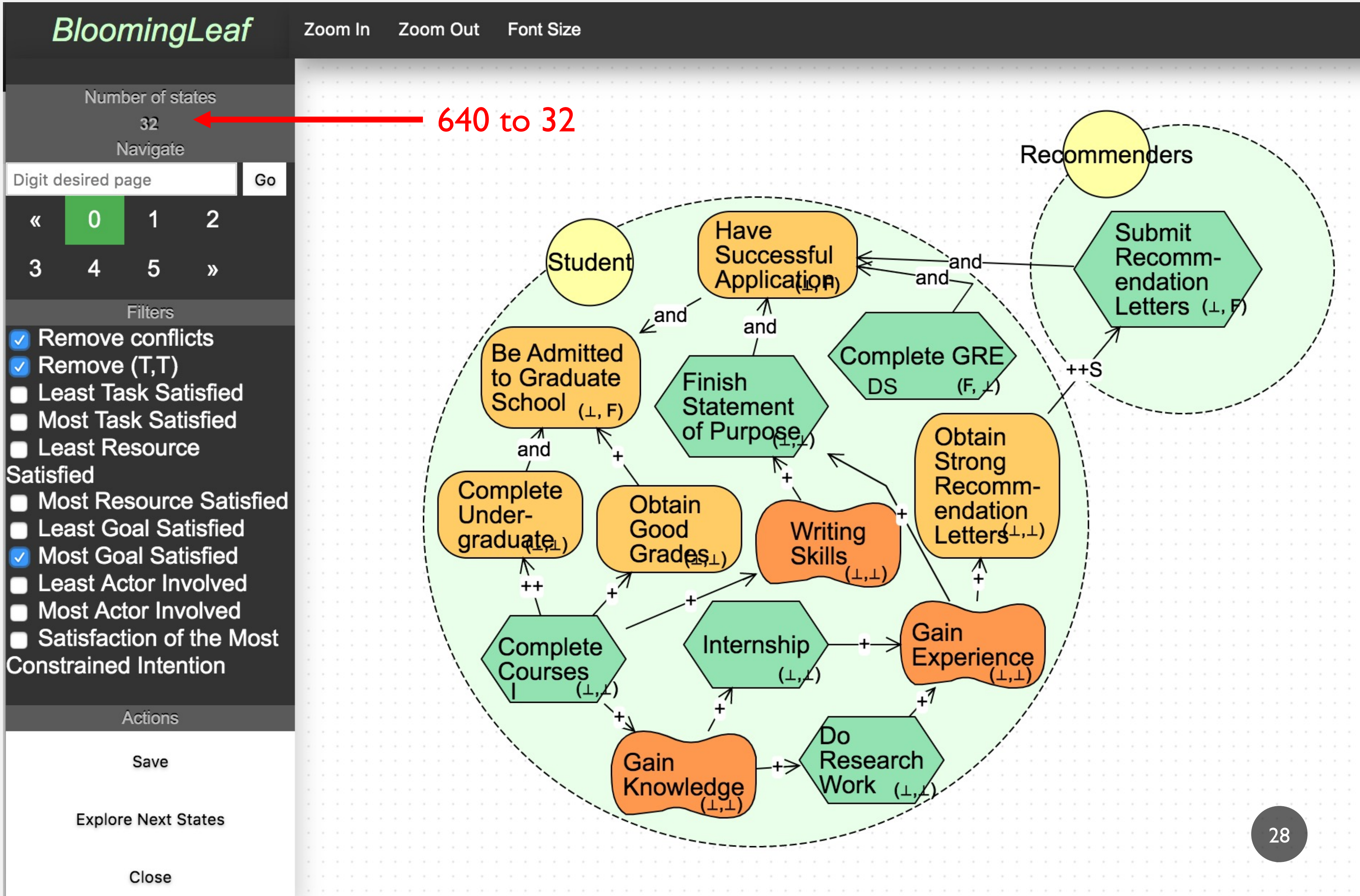
Remove Conflicts, Remove (⊥, ⊥): Also Filters

Least/Most Goal Satisfied: Keep only the solutions with the least/most number of goals that is fully satisfied.

Filters

Name	Description	Example Usage
Least/Most Tasks Satisfied	Keep only the solutions with the least/most number of tasks with the evaluation label satisfied (F, $\perp$).	In the GRAD example, if the student is looking for the minimum number of tasks he needs to complete to be admitted to graduate school.
Least/Most Goals Satisfied	Keep only the solutions with the least/most number of goals with the evaluation label satisfied (F, $\perp$).	This would be useful for the student in the GRAD example to view the worst case and best case scenario.
Least/Most Resources Satisfied	Keep only the solutions with the least/most number of resources with the evaluation label satisfied (F, $\perp$).	Consider a business person making budgets of all the resources he needs, *Least Resources Needed* would give a lower bound estimation and *Most Resources Needed* would give an upper bound.
Least/Most Actors Involved	Keep only the solutions with the least/most number of actors involved. An actor is involved when at least one of their intentions is satisfied.	In the GRAD example, if the student were to ask whether he can finish the entire application process all by himself.
Satisfaction of the Most Constrained Goal	Keep only the solutions with the status of the most con- strained goal being satisfied. Most constrained goals are goals with the smallest domain in the model.	This usually helps when users want to explore the satisfiability of some or all goals in the model.

Filters



BloomingLeaf
Zoom In
Zoom Out
Font Size
Number of states
32
640 to 32
Navigate
Digit desired page
Go
« 0 1 2 3 4 5 »
Filters
Remove conflicts
Remove (T,T)
Least Task Satisfied
Most Task Satisfied
Least Resource Satisfied
Most Resource Satisfied
Least Goal Satisfied
Most Goal Satisfied
Least Actor Involved
Most Actor Involved
Satisfaction of the Most Constrained Intention
Actions
Save
Explore Next States
Close
Recommenders
Submit Recomm-endation Letters (⊥, F)
Student
Have Successful Application (⊥, F)
Be Admitted to Graduate School (⊥, F)
Complete GRE DS (F, ⊥)
Finish Statement of Purpose (⊥,⊥)
Obtain Strong Recomm-endation Letters (⊥,⊥)
Complete Under-graduate (⊥,⊥)
Obtain Good Grades (⊥,⊥)
Writing Skills (⊥,⊥)
Complete Courses (⊥,⊥)
Internship (⊥,⊥)
Gain Experience (⊥,⊥)
Gain Knowledge (⊥,⊥)
Do Research Work (⊥,⊥)
and
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Select A State

	Time Point	Time Point 7	Time Point 8
	Denied	(P, ⊥) Partially Satisfied	(F, ⊥) Fully Satisfied
		(P, ⊥) Partially Satisfied	(P, ⊥) Partially Satisfied

Is it possible to fulfill Internship prior to Do Research Work? YES!

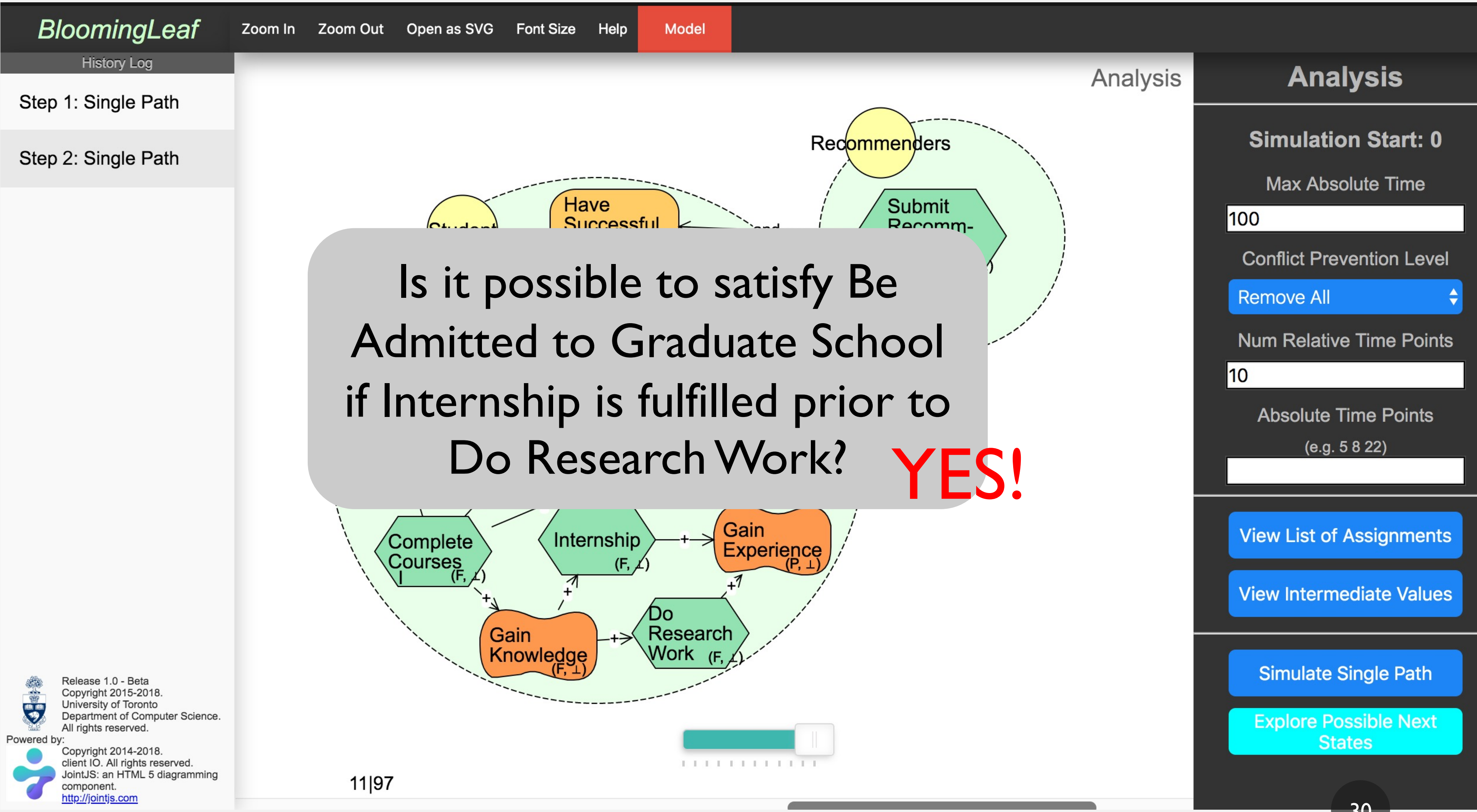
Is it possible to satisfy Be Admitted to Graduate School if Internship is fulfilled prior to Do Research Work?

Let's complete the path and find out

same as old path

new state the student selected

Answering student question…



Is it possible to satisfy Be Admitted to Graduate School if Internship is fulfilled prior to Do Research Work?

YES!

Overview

Background

- Evidence Pairs
- Evolving Intention
- BloomingLeaf Analysis

Problems

- Huge solution space
- Difficult for users to review and customize

Proposed Solution

- Domain Reduction
- Solution Reduction

Initial Validation

Research Questions

- (RQ1) To what extent does the filters approach reduce computation time and the number of returned states?
- (RQ2) To what extent do users find this approach helpful?

(RQ1) To What Extent Does The Filters Approach Reduce Computation Time And The Number Of Returned States?

Model Name	GRAD	BLE [11]	WME [11]	Scheduler [14]	Spadina Plan	Spadina Opp	Spadina Pro	Bike Lanes Full
Num.								30
Nu								37
Me								
Exp								152
Re								0
Re								056
Mo								152
Lea								152
Mo								152
Lea								152
Mo								152
Lea								152
Mo								68
Leas								448
Satisfa								51152
Measurement	Computation Time in milliseconds							
Explore Possible Next States - No Pref.	131	119	286	317	88	388	96	4141
Remove All Conflict Values	121	47	N/A	187	N/A	N/A	92	N/A
Remove No None	97	N/A	226	173	86	N/A	89	1444

N/A indicates that no measurement was collected because the model was over-constrained.

Finding: The applicability of each filter varied based on the model structure, but overall applying solution reduction filters reduced the number of returned states and computation time

(RQ2) To What Extent Do Users Find This Approach Helpful?

Participants:

Five volunteers at the University of Toronto Software Engineering group

Observations:

1. Most time spent on selecting filters
2. All of the volunteers agreed that the filters saved them time and effort.

Findings:

1. Strengthened our hypothesis that filters are useful
2. Volunteers suggested significant tool improvements

Further empirical research is required to validate the usefulness of filters.

Summary

- We presented **Filters**:
  - **Reduce the state space** of the Explore Possible Next States analysis
  - **Help users review and customize** their simulation path.

Future Work

- **Guide users in selecting the most appropriate filters**
- Allow users to update the evidence pair assignments to further prune the solution space
- Validate the effectiveness of our approach with goal model users

SUPPORT FOR USER GENERATED EVOLUTIONS OF GOAL MODELS

Thank you!

Tool:
http://www.cs.toronto.edu/~amgrubb/dev/blooming/

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