Paper & Code

Constraint Reasoning Embedded Structural Prediction

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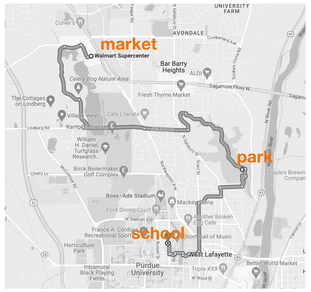
Example: Vehicle Dispatch Planning

Task: Recommend dispatching routes that
- satisfy daily delivery requests;
- meet drivers' implicit preferences.



Input: a set of locations.
{market, park, school}
Output: a visiting order of locations.
market → park → school.

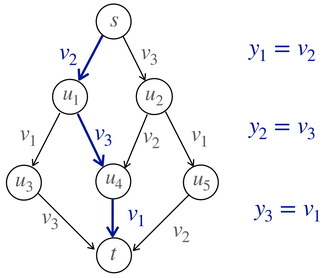
A pure Learning algorithm
market1 → market2 → market3 ✗ Not a valid route

A pure Reasoning algorithm (like a Traveling Salesman Problem solver)
school → market → park ✗ The driver does not like it.

Background: Decision Diagram

A constraint reasoning tool that represents the set of solutions to combinatorial optimization problems as a space-compact directed acyclic graph.

3 **variables** $\{y_1, y_2, y_3\}$, which can take assignments $y_i \in \{v_1, v_2, v_3\}$.

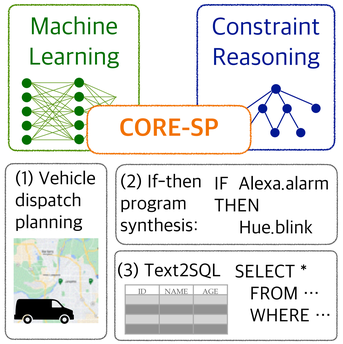


Two **constraints** C:
- First location should not be v_1.
- Three variables have different assignments.

Every $s \to t$ path in the graph corresponds to a valid variables' assignment with these constraints.

Method: An Integrated System (Learning + Reasoning)

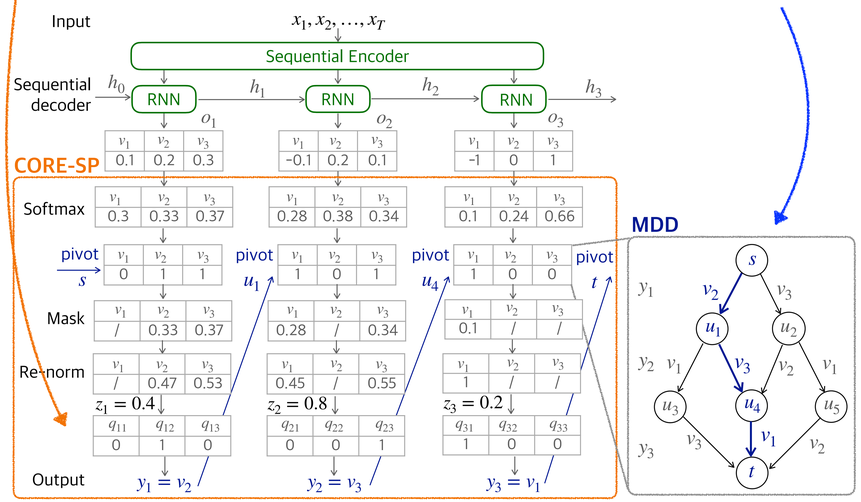
Given:
- Training data $\{(x_1, y_1), \ldots, (x_n, y_n)\}$;
- Structured-output space $Y = \{0,1\}^m$;
- Constraints C for the output space Y.



Learn: a constrained probability distribution: for $y \in Y$,

$$P_\theta(y \mid x; C) \begin{cases} > 0 & \text{if } y \text{ satisfies } C \\ = 0 & \text{if } y \text{ violates } C \end{cases}$$

A valid output from the sequence-to-sequence model corresponds to **a path** in the multi-valued decision diagram (MDD).

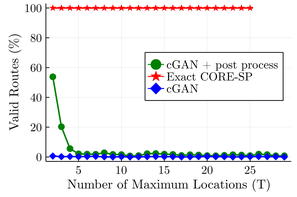


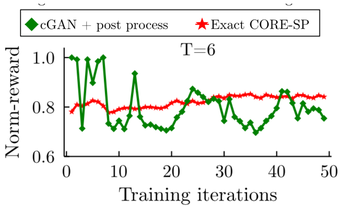
Experiments

1) The structures generated with exact decision diagram satisfy 100% of the constraints.

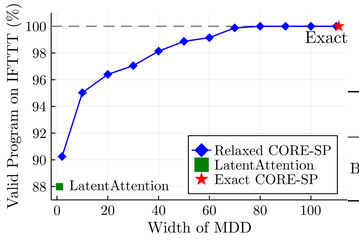
2) boosts learning performance (higher reward, accuracy on testing set) by reducing the modeling space via constraint satisfaction.

(1) Vehicle dispatch planning: Recommend dispatching routes.





(2) If-then Program synthesis: Learn a program from natural language.



Methods	Width	IFTTT Accuracy	Valid (%)
LatentAttention	N/A	42.17%	87.51%
Best relaxed CORE-SP	80	**44.12%**	99.19%
Exact CORE-SP	111	43.07%	**100%**

(3) Text2SQL generation. Learn a SQL program from natural language.

	Moderate test set SQLNova	CORE-SP
Valid SQL	94.3%	**100%**
	Hard test set SQLNova	CORE-SP
Valid SQL	83.7%	**100%**

Overall Accuracy	SQLNova	CORE-SP
Logical Accuracy	79.3%	**79.9%**
Execution Accuracy	85.5%	**86.1%**
Valid SQL	99.3%	**100.0%**