My Research Journey

Hedieh Haddad

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Research Project: Context

- Constraint programming solvers are black-box functions with many parameters.
- Efficiency of constraint programming solvers depends heavily on their parameters.
- A lot of possible parameters, but a set of parameters not always good on each problem (no-free-lunch theorem).
- It is left to the user to manually pick the best set of parameters to obtain the best efficiency.
    - significant impact on the efficiency of the solver

Research Project: Our Idea

- HPO is the process of selecting the optimal values for the algorithm's hyperparameters and it is very successful in the other fields like ML and can improve tremendously the efficiency of the algorithms in it.

Can hyperparameter optimisation improve the efficiency of constraint programming solvers?

- *If yes, which HPO method works better?*

Research Project: Problem Statement

- Problem:
  - The numerous hyperparameters in CP solvers hinder the efficiency of HPO due to the large state-space.
- Solution:
  - Focus on particular and impactful subset of hyperparameters: search strategy.
  - We propose to encode the search strategy as a set of hyperparameters optimised using the HPO algorithms.
- WHY?

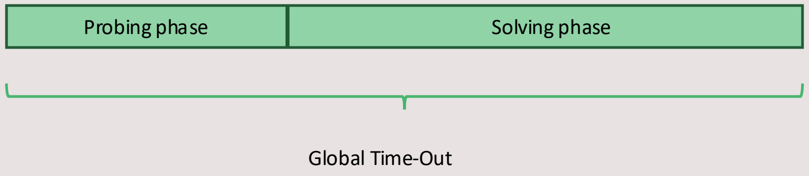
Research Project: Importance (Why?)

Why search strategies matter?

1. Core of Solver Efficiency :
    - Search strategies determine how a solver navigates the solution space, directly impacting performance.
2. No Universal Strategy:
    - No single strategy works best for all problems.
3. Need for Optimization:
    - Optimizing search strategies per problem is essential for maximizing solver efficiency and effectiveness

Research Project: Contributions

- Started with working on search strategies, a well-known and impactful parameter of CP solvers.
- Implemented and tested four HPO algorithms:
  - Grid search, Random search, Hyper-band optimization, Bayesian optimization.
- Defined my own Two-phase algorithm: 'Probe and Solve Algorithm (PSA)'
  - Probing phase: Constant K percent of global time, using HPO methods to rank search strategies.
  - Solving phase: Solving the problem with the best configuration.



Research Project: Contributions

- Bayesian optimization proved to be the most effective approach.
- We did an extended experiment analysis with more benchmarks and solvers, using four baselines, included:
    - Three popular variable selection strategies: PICK3, DomWDeg/CACD, FrbaOnDom, and the solver's default strategy.
- Then evaluated the effectiveness of dynamic search strategies compared to static ones.
- Given that static search strategies appear to be less effective than dynamic ones, we employed our algorithm on a subset of three dynamic variable selection strategies.

Accomplishments in 2024: Research

- **Comparison of Hyperparameter Optimization Methods for Selecting Search Strategy of Constraint Programming Solvers [1]**

  Hedieh Haddad, Pierre Talbot, Pascal Bouvry

- **Selecting Search Strategy in Constraint Solvers using Bayesian Optimization [2]**

  Hedieh Haddad, Pierre Talbot, Pascal Bouvry

1. PTHG-24: The Seventh Workshop on Progress Towards the Holy Grail (30th International Conference on Principles and Practice of Constraint Programming) - 2024
2. The 36th IEEE International Conference on Tools with Artificial Intelligence (ICTAI) - 2024

Accomplishments in 2024: Extra Study

- Trustworthiness in ICT, Aerospace and Construction Applications (White paper)
    - ILNAS-SnT collaboration
- Research-driven Standardization Opportunities for ICT, Construction and Aerospace (Technical reports)
    - ILNAS-SnT collaboration
- Two Poster presentations in SnT Partnership Days

Future Directions

- Focus on implementing PSA inside the CPMPY library.
- CPMPY: A Constraint Programming and Modelling library in Python, based on numpy, with direct solver access, with Tune_solver tool to Implement parameter tuning for constraint solvers based on calculating 'Hamming Distance’.
- We have tried to Implement PSA and add it to the library alongside existing Hamming approach.
- Add functionality to give users more control over improving solver efficiency by finding better hyper-parameter configurations that is not just limited to the search strategies

Goals for 2025: Research Goals

Publish 2 papers:

1. Constraints Journal: “Improving Efficiency of Constraint Programming Solver by Focusing on Hyper-parameters”
   - (Paper submission, End of March?)
2. CP Conference: “Improving the Energy Efficiency of buildings using Constraint Programming”
   - The 31st International Conference on Principles and Practice of Constraint Programming (August 10-15, 2025)
   - Application track-demonstrating the effectiveness of CP in solving real-world problems (Paper submission, 27/03)

Structure of the First Paper

Introduction

- Overview of Constraint Programming (CP) and its challenges.
- Importance of Hyperparameter Optimization (HPO) In ML, then for CP solvers.
- Contribution of this work: Bayesian Optimization in CPMPY, more control on Hyperparameters.

Background

- Fundamentals of CP and HPO, also review of HPO techniques .
- Related work and gaps in current approaches.

Methodology

- Proposed HPO techniques: Hamming Distance, Bayesian Optimization, and Grid Search.
- Initialization, timeout strategies, solver stop conditions, and timeout evolution patterns.
- Memory-based mechanisms to avoid redundant computations.
- Algorithm Definition and Code Structure

Experiments and Results

- Experimental setup and design
- A detailed description of the dataset (23 common problem provided in CPMPY library)
- Performance evaluation of proposed techniques, and Comparison with baseline methods.

Discussion and Conclusion

- Analysis of findings
- Summary of contributions and key takeaways.
- Future directions in CP solver optimization.

Structure of the Second Paper

Introduction

- Overview of energy efficiency in buildings and its Challenges during the design phase.
- Role of Constraint Programming (CP) in optimizing building design for energy efficiency.
- Contribution of this work: Developing a model to control thermal transmittance, maximize energy efficiency, and minimize construction costs.

Background

- Fundamentals of energy efficiency in buildings, CP and its applications in the construction field.
- Review of existing methods for optimizing thermal transmittance and energy efficiency.
- Related work and gaps in current approaches.

Methodology

- Description of the proposed model for controlling thermal transmittance in construction.
- Steps for maximizing energy efficiency and minimizing construction costs.
- Algorithm Definition and Code Structure.

Experiments and Results

- Experimental setup and design.
- Description of the test model, details of the datasets and parameters if needed.
- Performance evaluation of the proposed model.
- Interpretation of findings.

Discussion and Conclusion

- Analysis of findings
- Summary of contributions and key takeaways
- Future directions in optimizing building energy efficiency using CP

lessons learnt:

- **Supervisors Speak Simple Truths**, But Your Brain Overcomplicates Them.
- **Multitasking** = Missing Details
- **Don’t Avoid Debugging through the code** (It’s like wanting to go for running with your fellows and your supervisor, for over a year, but never starting. Just take that first step—running alongside them makes everything clearer.)
- **Don’t Try to Hit the Biggest Stone First**, tackle the small stone one by one.
- **Take a break** when research starts to feel like staring at a wall, then grab a beer.

Thanks! ☺