GHOST: A stealth solver

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Outline

Outline

CSP/ COP

Constraint Satisfaction Problems (CSP)

CSP is a homogeneous framework to model combinatorial problems.

Constraint Optimization Problems (COP)

Same for optimization problems.

Examples

- AI,
- Graph problems,
- Database problems,
- Bio-informatics,
- ...

Definition of a CSP

A CSP is defined by a tuple (V, D, C) such that:

$$\text{CSP} = \left[\begin{array}{ll} V: & \textit{Set of variables.} \\ D: & \textit{Domain (set of values of variables).} \\ C: & \textit{Set of constraints.} \end{array} \right.$$

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CSP

- V = {x, y, z}
- D = {0, 1}
- C = {=, $\neq$}

Problem

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CSP

- $V = \{x, y, z\}$
- $D = \{0, 1\}$
- $C = \{=, \neq\}$

⇐ Problem

CSP formula (aka CSP instance)

$$(z = y) \wedge (y \neq x) \wedge (x = z)$$

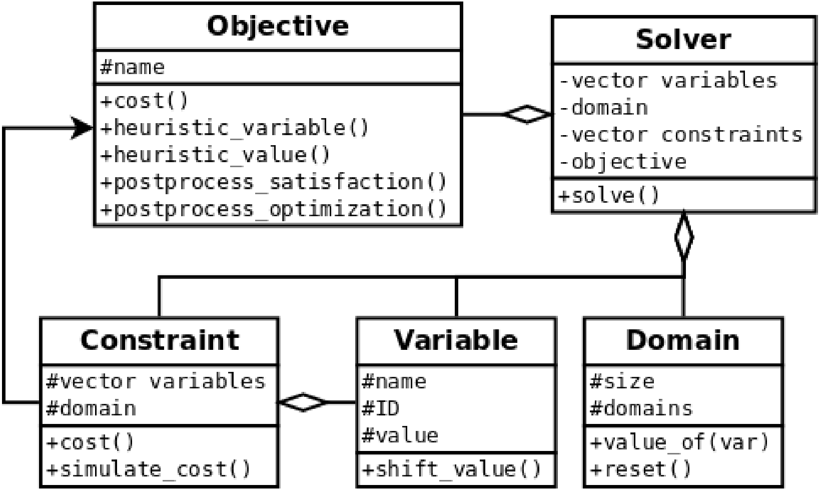
⇐ Problem instance

Outline

GHOST is a templated C++ solver aiming two users:

- The **casual user**, using GHOST to solve an already encoded problem.
- The **developer user**, who wants to use GHOST to implement and solve his/her problem.

Classes of GHOST



Casual user

```
// Variables
vector< Unit > variables = { ... }

// Specific to the target selection problem
vector< UnitEnemy  > enemies  = {  ... }

// Domain
TargetDomain domain( variables.size(), &enemies );

// Constraints
vector< shared_ptr<TargetConstraint> > constraints
{ make_shared<TargetConstraint>( &variables, &domain ) };

// Objective
shared_ptr<TargetObjective> objective = make_shared<MaxDamage>();

// Solver
Solver<Unit, TargetDomain, TargetConstraint>
  solver( &variables, &domain, constraints, objective );

// Call Solver::solve
solver.solve();
```

Uses of GHOST

Developer user

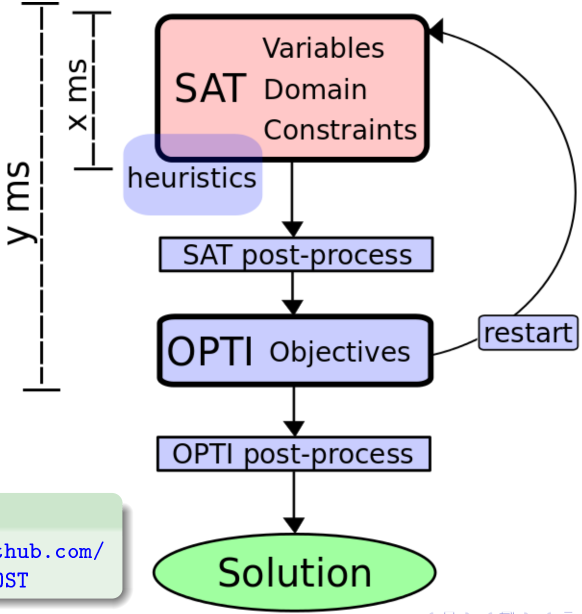
```
// Define its own variables
class Unit : public Variable {...}

// Define its own domain
class TargetDomain : public Domain<Unit>  {...}

// Define its own constraints
class TargetConstraint : public Constraints<Unit, TargetDomain>  {...}

// Define its own objectives
class TargetObjective : public Objective<Unit, TargetDomain>  {...}
```

Architecture of GHOST



Source code

https://github.com/richoux/GHOST

Outline

RTS problems

Problem families

Strategy

Tactic

Reactive Control

RTS problems

Problem families

Strategy

Tactic

Reactive Control

Example of problems

Build order planning

Wall-in

Target selection

Reactive control: Target selection problem

Target selection problem: Statement

- Range,
- Cooldown,
- Damage efficiency.

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Damage efficiency

		Damage type		
		Concussive	Normal	Explosive
size	Small	100%	100%	50%
	Medium	50%	100%	75%
	Large	25%	100%	100%

CSP/ COP model

- V = (Sub)set of your units.
- D = A group of enemy units.
- C = Each living, ready-to-shoot unit must aim a living enemy unit within its range, if any.

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COP objectives

- **Max damage**, where our group tries to deal as much damage as possible within the current frame.
- **Max kill**, where our group tries to kill as much enemy units as possible within the current frame.

Experiments

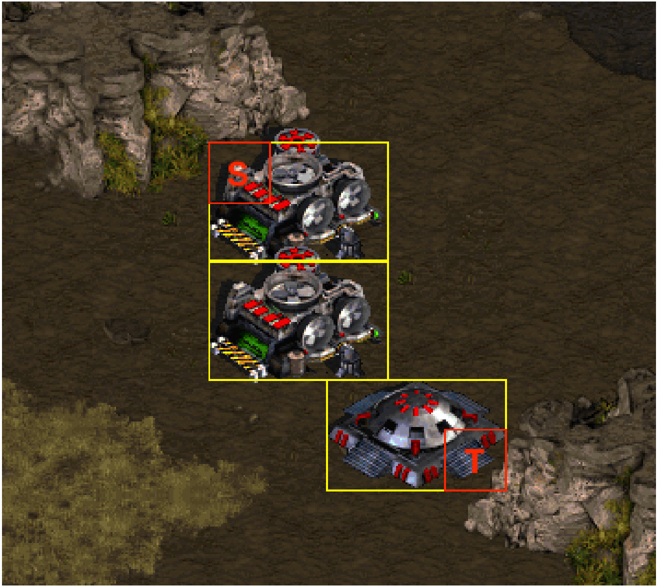
Mean of 100 runs for each objectives. SAT-Opti Timeouts: 1-3ms and 2-5ms.

				GHOST victory	
	Objective	Win %	# Draws	# GHOST living units	GHOST HP
3ms	Max Damage	86.0	3	2.8	153.4
3ms	Max Kill	80.0	2	3.0	163.2
5ms	Max Damage	91.0	1	2.8	149.6
5ms	Max Kill	82.0	3	3.0	169.5

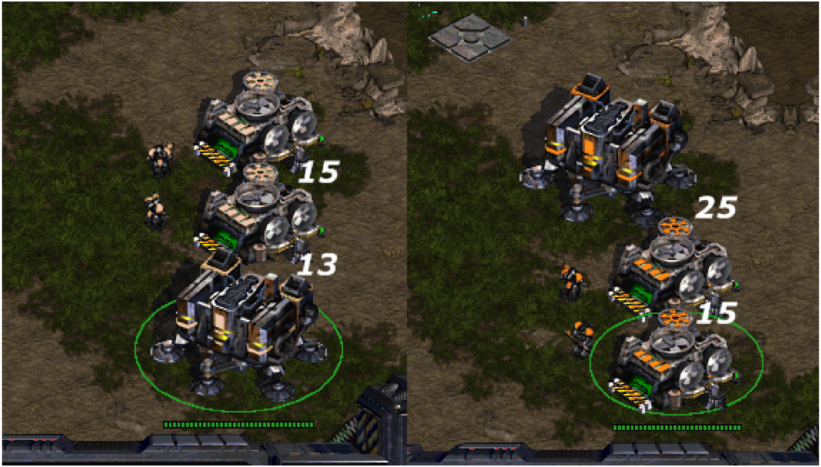
		Opponent victory	
	Objective	# Opponent living units	Opponent HP
3ms	Max Damage	1.0	37.1
3ms	Max Kill	1.1	62.8
5ms	Max Damage	1.1	58.7
5ms	Max Kill	1.0	37.2

Tactic:
Wall-in problem

Wall-in problem: Statement



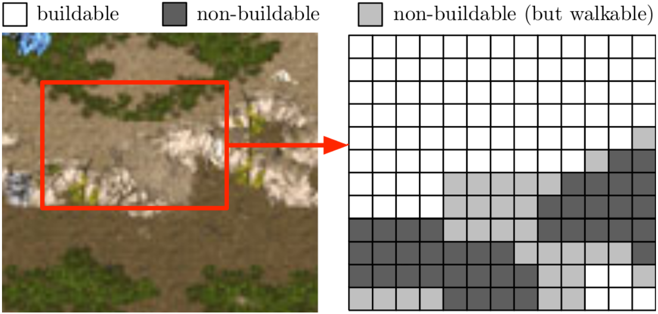
Wall-in problem: Statement



Wall-in problem: Model

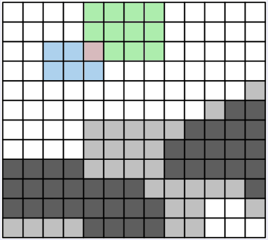
CSP/ COP model

- V = Set of your buildings.
- D = Positions around a choke (in a 16×12 rectangle).



Wall-in problem: Model

Overlap



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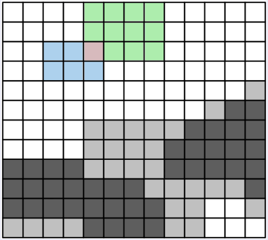
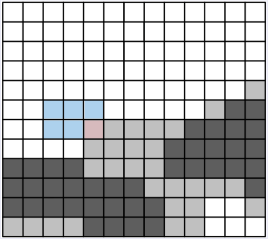


Buildable



Wall-in problem: Model

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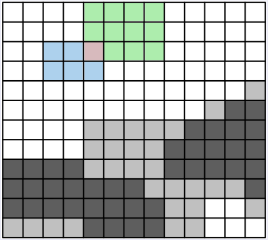

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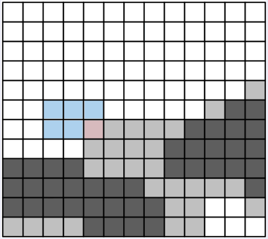
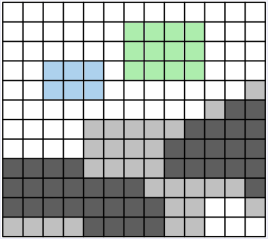


NoHoles



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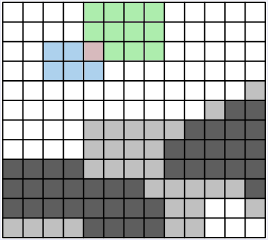

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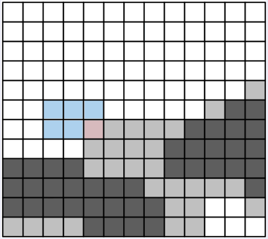

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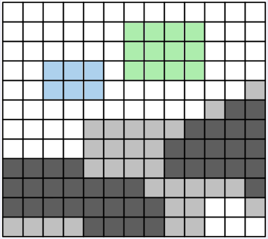
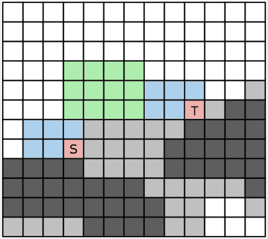


StartingTargetTile



Wall-in problem: Model

CSP Wall-in question

What is the position of my buildings to make a wall?
(and what are the buildings I use?)

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CSP Wall-in question

What is the position of my buildings to make a wall?
(and what are the buildings I use?)

COP Wall-in question

Optimize an objective function for my wall:

- Make a wall using the smallest number of buildings.
- Make a wall using the lowest technology.
- Make a wall with the fewest number of gaps.

Wall-in problem: Results

100 tests over 48 chokes from 7 StarCraft classic maps (so 4800 tests).

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CSP results: making a wall with 20ms runs

#Runs	1	2	3	4
Average Cost	1.59	0.58	0.33	0.18
Solved %	45.83%	71.10%	80.70%	88.45%

#Runs	5	10	20	50
Average Cost	0.13	0.03	0.01	0.0006
Solved %	91.58%	97.23%	99.18%	99.95%

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COP results: optimize a wall within 150ms (with a SAT timeout of 20ms)

	Satisfaction run	Optimization run	Optimization run solved
#Buildings	3.12	2.65	96.83%
#Gaps	1.19	0.05	96.79%
Low tech	1.95	1.56	95.87%

Wall-in problem: Results

More results for #Gaps

Over 4800 tests:

- the solver found 4646 walls (96.8%) within 150ms,
- whose 4400 were perfect, i.e., gap-free.(94.7% of walls).

Strategy: Build order planning problem

Build order problem: Statement

BO: A series of actions following a specific timing, in order to achieve a goal.

Dependencies

Actions may have dependencies.

Example

To build a Factory, you need first a Barracks.

Build order problem: Model

BO can be modeled as a **permutation** problem: Huge search space reduction.

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- V = All actions you need to reach your goal.
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Build order problem: Model

BO can be modeled as a **permutation** problem: Huge search space reduction.

CSP/ COP model

- V = All actions you need to reach your goal.
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COP objective

Minimize the makespan.

Build order problem: Simulator

StarCraft simulator inside GHOST

We code a SC simulator to emulate resources gathering, units producing (including workers), supply capacity, constructions, etc.

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- Time to go build something: **5t**
- Time to go back gathering minerals after building something: **4t**
- Time to go from the base to mineral patches to start mining: **5t**
- Time for a worker to switch from mineral to gas: **5t**
- Mineral gathering rate: **0.68 mineral** per worker per t
- Gas gathering rate: **1.15 gas** per worker per t

Build order problem: Results

Two test sets

1. 3,647 BOs from TeamLiquid, GosuGamers and ICCup.
2. 8 BOs from top Korean pro-gamers.

Mean of 10 runs for each BO.

SAT-Opti Timeouts: 20-30ms.

Build order problem: Results

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Mean of 10 runs for each BO.

SAT-Opti Timeouts: 20-30ms.

Games till 10.000 frames				
Match-up	Humans	GHOST	% solved	Gain
All	656.02	619.62	94.4	**36.40**
PvP	651.51	608.06	95.0	**43.45**
PvT	660.50	628.17	93.9	**32.33**
PvZ	649.20	609.34	95.0	**39.86**
All pro	643.38	597.25	96.3	**46.13**

Build order problem: Results

Two test sets

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2. 8 BOs from top Korean pro-gamers.

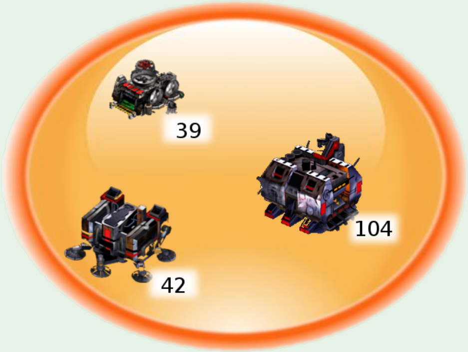
Mean of 10 runs for each BO.

SAT-Opti Timeouts: 20-30ms.

Games till 7.800 frames				
Match-up	Humans	GHOST	% solved	Gain
All	522.50	491.11	98.8	**31.39**
PvP	516.08	485.56	99.3	**30.52**
PvT	527.66	506.65	98.3	**21.01**
PvZ	515.81	458.23	99.7	**57.58**
All pro	506.38	480.88	100	**25.50**

Why searching for walls takes more time than build orders?

Wall-in CSP search space



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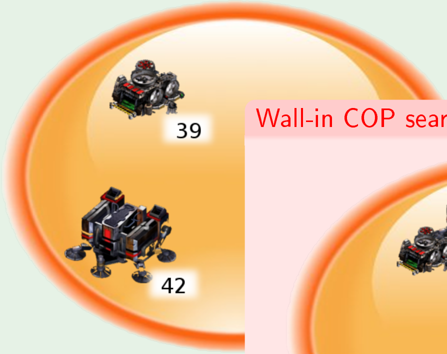

Wall-in COP search space

Outline

Conclusion

GHOST is:

- **General**: Can deal with any CSP/COP models without parameter tuning or code optimization needed.
- **Easy**: Both for casual and developer users.
- **Efficient**: We obtained good results on different RTS problems.
- **Open**: Contributions welcome!

Discussion

Future works

- GHOST will be a library using BWAPI 4.
- Implement a pause/resume system for long computations.
- Parallelize the solver exploiting the available cores.
- CSP/COP cannot deal with uncertainty. Think to a new formalism.

Questions?

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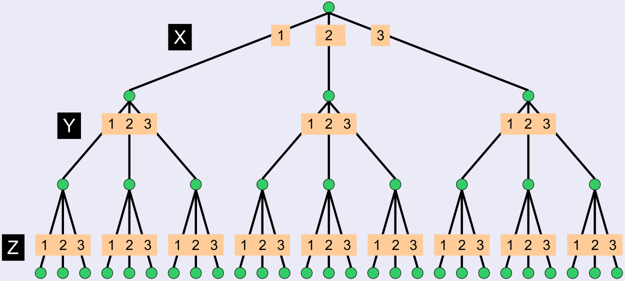
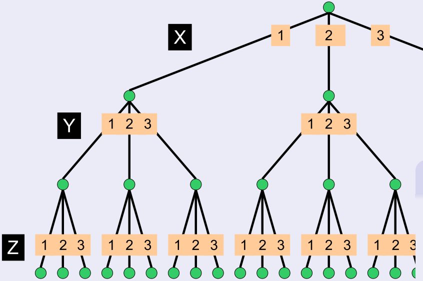
@FloRicx

Complete solvers

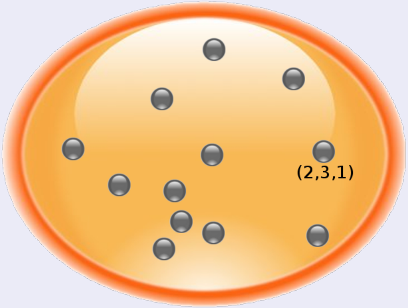


Complete Vs. Incomplete solvers

Complete solvers



Meta-heuristics



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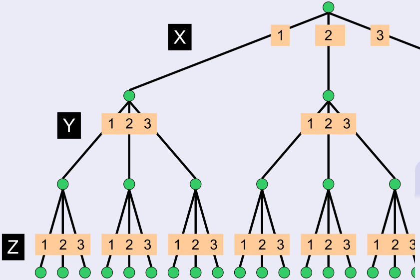

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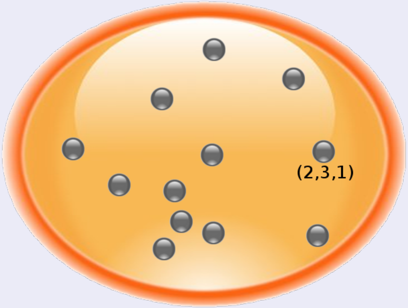
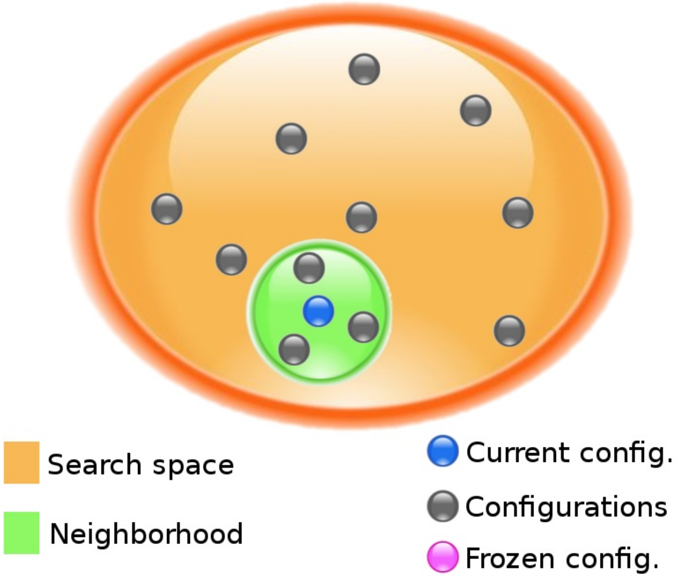
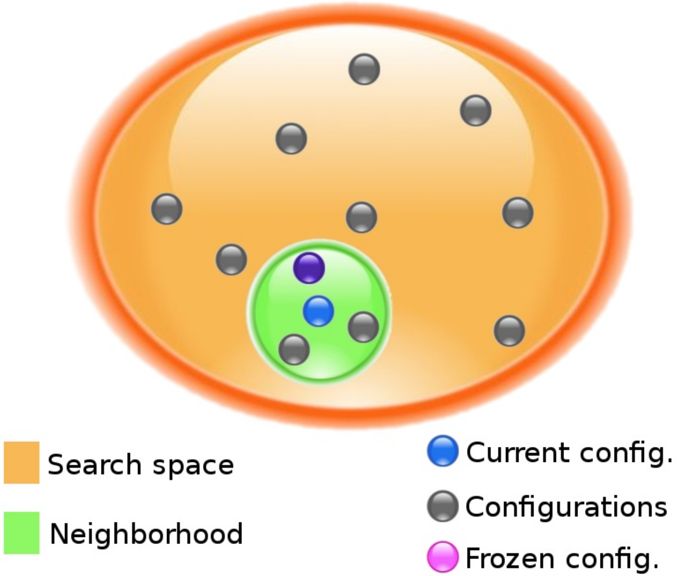


- Way faster
- Can deal with big size problems

- Not sure to find a solution
- Lost if no solutions


Search space
Neighborhood
Current config.
Configurations
Frozen config.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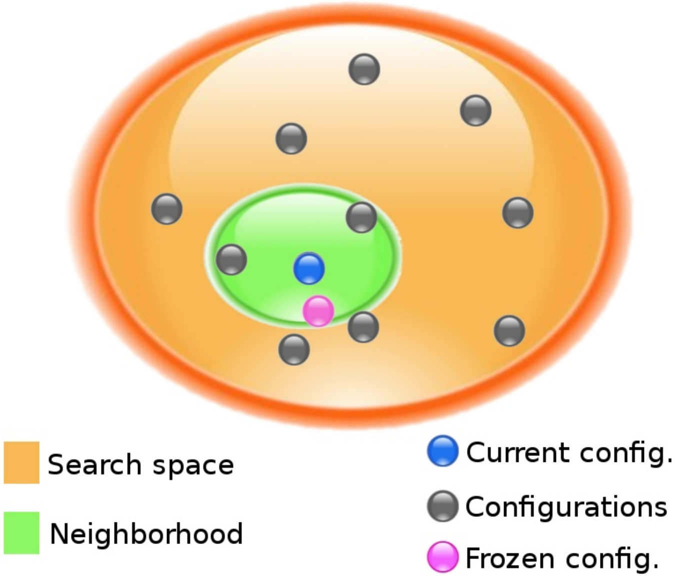
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Main idea

Constraint $x = y$ $\Rightarrow$ $\underbrace{(x = y)}_{C_1} \wedge \underbrace{(y = z)}_{C_2}$

Adaptive Search [Codognet Diaz 2001]

Main idea

Constraint $x = y$

$\Downarrow$

Error function which measures how much the constraint is satisfied
$\mid x - y \mid$

$\Rightarrow$ $\underbrace{(x = y)}_{C_1} \wedge \underbrace{(y = z)}_{C_2}$

$\Rightarrow$ Assume we have $x = 3,\ y = 6,\ z = 1$

Error(C_1) $= 3$
Error(C_2) $= 5$

Adaptive Search [Codognet Diaz 2001]

Main idea

Constraint $x = y$ $\Rightarrow$ $\underbrace{(x = y)}_{C_1} \wedge \underbrace{(y = z)}_{C_2}$

$\Downarrow$

Error function which measures how much the constraint is satisfied
$| \, x - y \, |$

$\Rightarrow$ $\left\{ \begin{array}{l} \text{Assume we have} \\ x = 3, \;\; y = 6, \;\; z = 1 \\ \\ \text{Error}(C_1) = 3 \\ \text{Error}(C_2) = 5 \end{array} \right.$

$\Downarrow$

Projection (usually addition of errors) on each variables

$\Rightarrow$ $\left\{ \begin{array}{ll} \text{Error}(x) & = 3 \\ \text{Error}(y) & = 3 + 5 = 8 \\ \text{Error}(z) & = 5 \end{array} \right.$