2007

An Interactive Constraint-Based Approach to Sudoku

Christopher Reeson  
*University of Nebraska - Lincoln, creeson@cse.unl.edu*

Kai-Chen Huang  
*University of Southern California, kaichenh@usc.edu*

Ken Bayer  
*University of Nebraska - Lincoln, kbayer@cse.unl.edu*

Berthe Y. Choueiry  
*University of Nebraska - Lincoln, choueiry@cse.unl.edu*

Follow this and additional works at: [http://digitalcommons.unl.edu/cseconfwork](http://digitalcommons.unl.edu/cseconfwork)

Part of the [Computer Sciences Commons](http://digitalcommons.unl.edu/cseconfwork)

Reeson, Christopher; Huang, Kai-Chen; Bayer, Ken; and Choueiry, Berthe Y., "An Interactive Constraint-Based Approach to Sudoku" (2007). *CSE Conference and Workshop Papers*. 172.  
[http://digitalcommons.unl.edu/cseconfwork/172](http://digitalcommons.unl.edu/cseconfwork/172)

This Article is brought to you for free and open access by the Computer Science and Engineering, Department of at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in CSE Conference and Workshop Papers by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.
An Interactive Constraint-Based Approach to Sudoku
Christopher G. Reeson¹ · Kai-Chen Huang² · Kenneth M. Bayer¹ · Berthe Y. Choueiry¹,²
¹Constraint Systems Laboratory, University of Nebraska-Lincoln · ²Information Sciences Institute, University of Southern California
SOLVER: sudoku.unl.edu/Solver • CONSTRUCTOR: sudoku.unl.edu/Constructor

Support: UCARE grant awarded to Chris Reeson & CAREER Award #0133568 from the National Science Foundation.

Sudoku
A Sudoku...
• is well posed if it has a single solution
• is minimal if removing any ‘given’ yields more than one solution
• is symmetric if the filled cells on the grid exhibit some axial symmetry

Each cell is a variable whose domain is set of numbers 1…9. The constraints are ‘all-different’ constraints on each row, column, and block.

We can model each all-diff constraint either as a set of binary mutex constraints...

or as a single non-binary all-diff constraint of arity 9.

We implement both models to allow the player to compare and understand the effectiveness of constraint propagation operating on each model.

Solver
SOLVER is a Java applet that uses CP techniques to support the user to play Sudoku. The player can...

• load an instance from the online library
• assign values to cells and play the game without aid
• display the remaining values in the domain of each cell

Solver displays the number of hints. The user can iterate through them.

The user can choose the type of hint & the level of consistency:

• 2 types of hints: Singleton & Vital
• 8 levels: FC, AC, Single GAC, GAC, Single SAC, SAC, Single SGAC, SGAC

Conjectures:
1. SGAC solves well-posed 9x9 Sudoku
2. SGAC = relation (1,2)consistency

Observations: Human players...
...can do GAC after some training
...cannot mentally do shaving (i.e., SAC, SGAC)
...solve Sudoku using convoluted patterns with imaginative names.
Often, several patterns correspond to the same propagation mechanism

constraint propagation
Solver detects errors and highlights the variables in the broken constraint...

...cannot remove more values than...

Hint highlights the cell that the player needs to think about...

Constructor
CONSTRUCTOR supports entering & storing instances
• Counts & displays all solutions

CSP Models
Each cell is a variable whose domain is set of numbers 1…9. The constraints are ‘all-different’ constraints on each row, column, and block.

Constraint Propagation
We implement both models to allow the player to compare and understand the effectiveness of constraint propagation operating on each model.

References
2. Helmut Simonis. Sudoku as a Constraint Problem. Workshop on Modeling and Reformulating CSPs, 2005

• 2 types of hints: Singleton & Vital
• 8 levels: FC, AC, Single GAC, GAC, Single SAC, SAC, Single SGAC, SGAC

Support: UCARE grant awarded to Chris Reeson & CAREER Award #0133568 from the National Science Foundation.

Conjectures:
1. SGAC solves well-posed 9x9 Sudoku
2. SGAC = relation (1,2)consistency

Observations: Human players...
...can do GAC after some training
...cannot mentally do shaving (i.e., SAC, SGAC)
...solve Sudoku using convoluted patterns with imaginative names.
Often, several patterns correspond to the same propagation mechanism

References
2. Helmut Simonis. Sudoku as a Constraint Problem. Workshop on Modeling and Reformulating CSPs, 2005
An Interactive Constraint-Based Approach to Sudoku
Christopher G. Reeson¹ · Kai-Chen Huang² · Kenneth M. Bayer¹ · Berthe Y. Choueiry¹,²
¹ Constraint Systems Laboratory, University of Nebraska-Lincoln · ² Information Sciences Institute, University of Southern California

Solver: sudoku.unl.edu/Solver · Constructor: sudoku.unl.edu/Constructor

Support: UCARE grant awarded to Chris Reeson & CAREER Award #0133568 from the National Science Foundation.

CSP Models
Each cell is a variable whose domain is set of numbers 1…9. The constraints are ‘all-different’ constraints on each row, column, and block.

We can model each all-diff constraint either as a set of binary mutex constraints...
...or as a single non-binary all-diff constraint of arity 9.

We implement both models to allow the player to compare and understand the effectiveness of constraint propagation operating on each model.

Constraint Propagation

Solver is a Java applet that uses CP techniques to support the user to play Sudoku.

Sudoku
A Sudoku...
• is well posed if it has a single solution
• is minimal if removing any ‘given’ yields more than one solution
• is symmetric if the filled cells on the grid exhibit some axial symmetry

Solver displays the number of hints. The user can iterate through them.

The user can choose the type of hint and the level of consistency:
• 2 types of hints: Singleton & Vital
• 8 levels: FC, AC, Single GAC, GAC, Single SAC, SAC, Single SGAC, SGAC

HINT highlights the cell that the player needs to think about...

Solver detects errors and highlights the variables in the broken constraint...

...cannot remove more values than...

Conjectures:
1. SGAC solves well-posed 9x9 Sudoku
2. SGAC = relation (1,2)consistency

Observations:
Human players...
...can do GAC after some training
...cannot mentally do shaving (i.e., SAC, SGAC)
...solve Sudoku using convoluted patterns with imaginative names.
Often, several patterns correspond to the same propagation mechanism

References:
2. Helmut Simonis. Sudoku as a Constraint Problem. Workshop on Modeling and Reformulating CSPs, 2005

Goals
To the public:
• Illustrate the power of CP

For the research:
• Investigate the use of CP to interactively support & guide human players

For education:
• Teach basic and advanced CP techniques

For insight in human reasoning:
• Understand how it differs from algorithmic approaches

Sudoku

Solver displays the number of hints. The user can iterate through them.

The user can choose the type of hint & the level of consistency:

• 2 types of hints: Singleton & Vital
• 8 levels: FC, AC, Single GAC, GAC, Single SAC, SAC, Single SGAC, SGAC

HINT highlights the cell that the player needs to think about...

Solver detects errors and highlights the variables in the broken constraint...

...cannot remove more values than...

Conjectures:
1. SGAC solves well-posed 9x9 Sudoku
2. SGAC = relation (1,2)consistency

Observations:
Human players...
...can do GAC after some training
...cannot mentally do shaving (i.e., SAC, SGAC)
...solve Sudoku using convoluted patterns with imaginative names.
Often, several patterns correspond to the same propagation mechanism

References:
2. Helmut Simonis. Sudoku as a Constraint Problem. Workshop on Modeling and Reformulating CSPs, 2005

CSP Models
Each cell is a variable whose domain is set of numbers 1…9. The constraints are ‘all-different’ constraints on each row, column, and block.

We can model each all-diff constraint either as a set of binary mutex constraints...
...or as a single non-binary all-diff constraint of arity 9.

We implement both models to allow the player to compare and understand the effectiveness of constraint propagation operating on each model.