

Quantifying Algorithmic Improvements over Time

Lars Kotthoff
University of Wyoming
*larsko@uwyo.edu*¹

IJCAI, 17 July 2018

¹joint work with Alexandre Fréchet, Tomasz Michalak, Talal Rahwan, Holger H. Hoos, Kevin Leyton-Brown

Contributions – Standalone Performance

dual pivot (2009)	798602199	dual pivot (2009)
median 9 (1993)	798501630	median 9 (1993)
median 9 random (1993)	798470169	median 9 random (1993)
mid (1978)	798466233	mid (1978)
median 3 random (1978)	798461169	median 3 random (1978)
random (1961)	798360514	random (1961)
median 3 (1978)	794178118	median 3 (1978)
first (1961)	784476788	first (1961)

insertion (1946)

671833

insertion (1946)

Standalone Performance

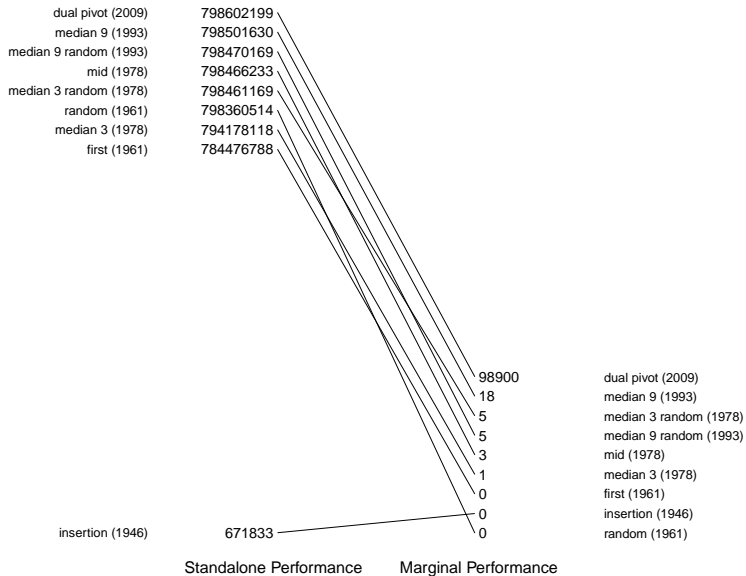
Contributions – Marginal Performance

How much does an algorithm contribute to the state of the art (defined by a coalition of all other algorithms)?

$$\phi_i = v(C_i \cup \{i\}) - v(C_i)$$

Xu, Hutter, Hoos, Leyton-Brown. "Evaluating Component Solver Contributions to Portfolio-Based Algorithm Selectors." SAT 2012

Contributions – Marginal Performance



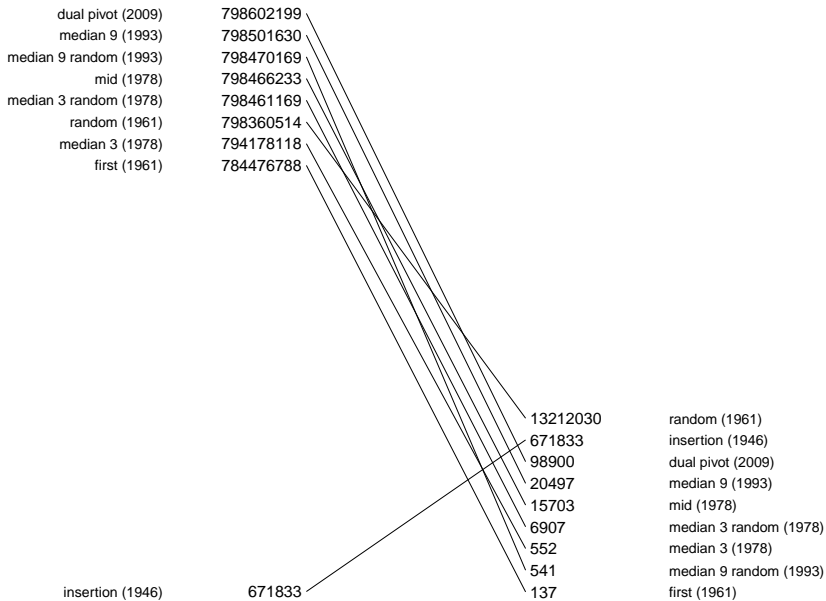
Contributions – Temporal Marginal Performance

How much does an algorithm contribute to the state of the art (defined by a coalition of all other algorithms available at the time)?

$$\phi_i^\succ = v^\succ(C_i \cup \{i\}) - v^\succ(C_i)$$

where \succ is a relation that encodes temporal precedence.

Contributions – Temporal Marginal Performance



Standalone Performance

Temporal Marginal Performance

Shapley Value

How much does an algorithm contribute to all possible coalitions of other algorithms?

$$\phi_i = \frac{1}{|\Pi|} \sum_{\pi \in \Pi^N} v(C_i^\pi \cup \{i\}) - v(C_i^\pi)$$

Shapley. "A Value for n -person Games." In Contributions to the Theory of Games, 1953.

Fréchette, Alexandre, Lars Kotthoff, Talal Rahwan, Holger H. Hoos, Kevin Leyton-Brown, and Tomasz P. Michalak. "Using the Shapley Value to Analyze Algorithm Portfolios." In 30th AAAI Conference on Artificial Intelligence, 2016.

Shapley Value

How much does an algorithm contribute to all possible coalitions of other algorithms?

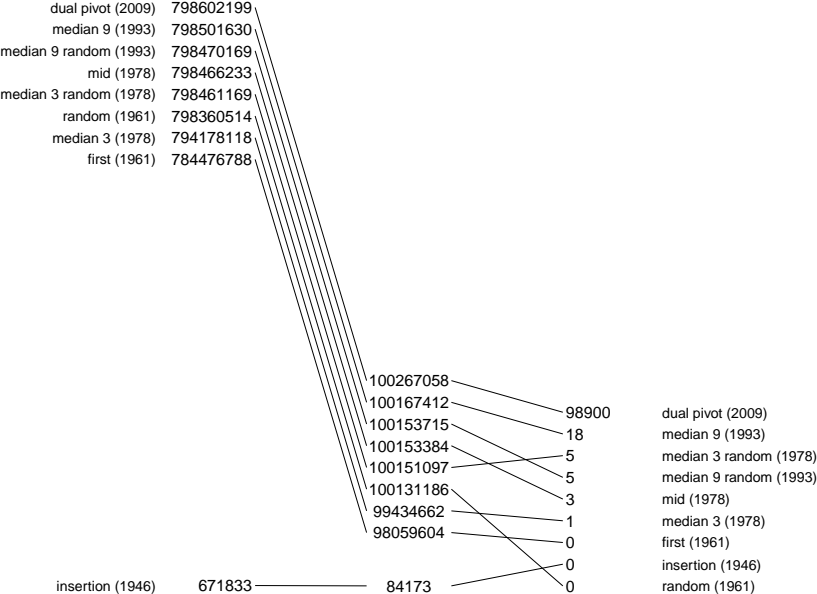
$$\phi_i = \frac{1}{|\Pi|} \sum_{\pi \in \Pi^N} v(C_i^\pi \cup \{i\}) - v(C_i^\pi)$$

We can compute this in polynomial time.

Shapley. "A Value for n -person Games." In Contributions to the Theory of Games, 1953.

Fréchette, Alexandre, Lars Kotthoff, Talal Rahwan, Holger H. Hoos, Kevin Leyton-Brown, and Tomasz P. Michalak. "Using the Shapley Value to Analyze Algorithm Portfolios." In 30th AAAI Conference on Artificial Intelligence, 2016.

Contributions – Shapley Value



Temporal Shapley Value

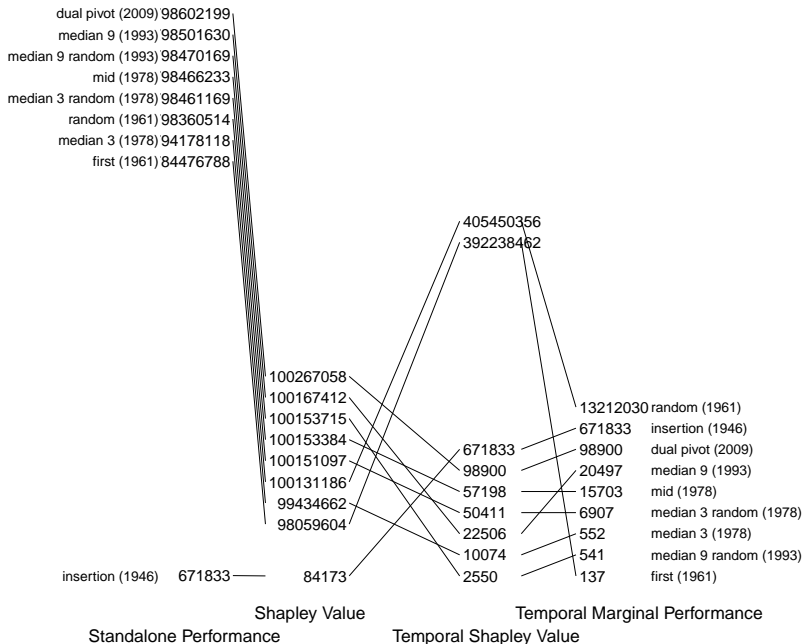
How much does an algorithm contribute to all possible coalitions of other algorithms, taking temporal precedence into account?

$$\phi_i^\succ = \frac{1}{|\Pi^\succ|} \sum_{\pi \in \Pi^\succ} v^\succ(C_i^\pi \cup \{i\}) - v^\succ(C_i^\pi)$$

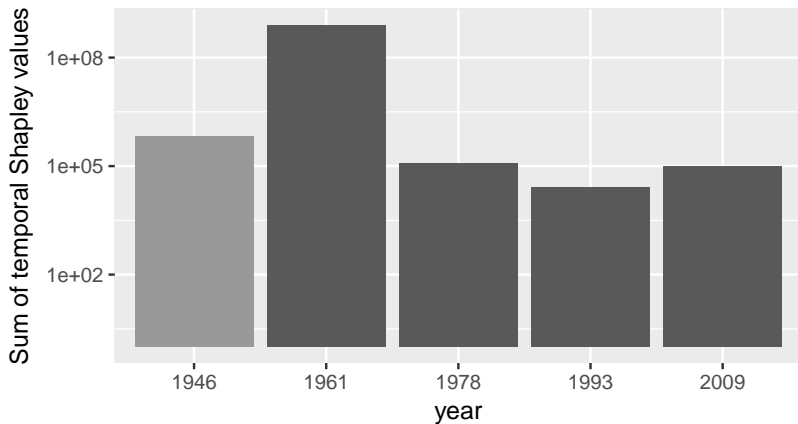
We can compute this in polynomial time as well.

Kotthoff, Lars, Alexandre Fréchet, Tomasz P. Michalak, Talal Rahwan, Holger H. Hoos, and Kevin Leyton-Brown. "Quantifying Algorithmic Improvements over Time." In 27th International Joint Conference on Artificial Intelligence (IJCAI) Special Track on the Evolution of the Contours of AI, 2018.

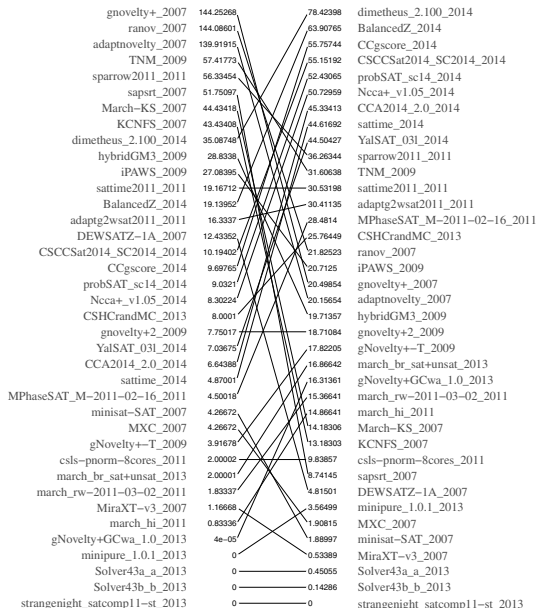
Contributions – Temporal Shapley Value



Quicksort Over Time

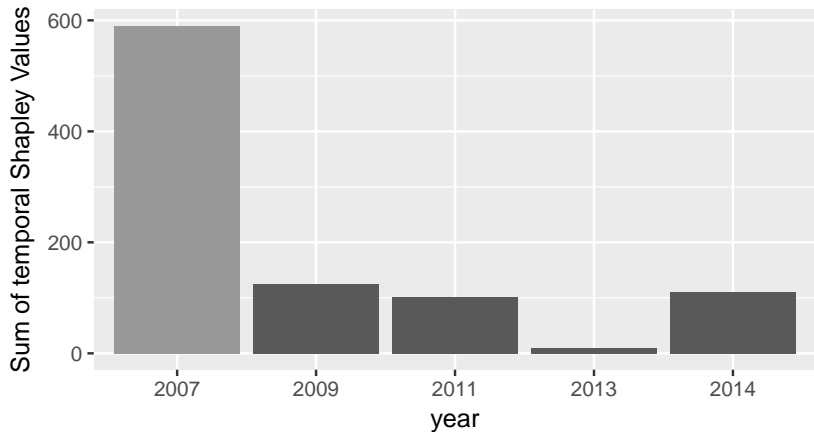


SAT Competition

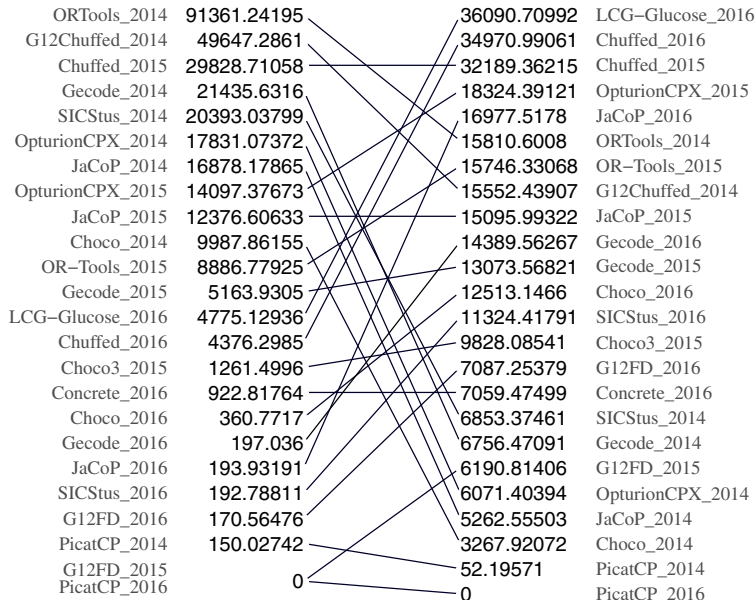


Temporal Shapley Value Shapley Value

SAT Competition Over Time

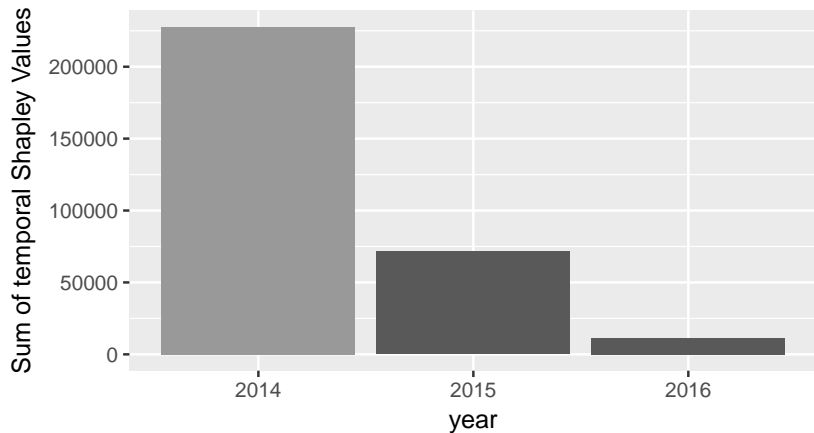


MiniZinc (CP) Competition



Temporal Shapley Value Shapley Value

MiniZinc Competition Over Time



Summary

- ▷ standalone performance does not indicate how algorithms complement each other
- ▷ marginal performance is not fair
- ▷ Shapley Value
 - ▷ provides better characterization of algorithms' performance
 - ▷ rewards algorithms that introduce novel and complementary concepts
 - ▷ enables better analysis of algorithms' performance
- ▷ Temporal Shapley Value
 - ▷ takes when an algorithm was conceived into account
 - ▷ all desirable properties of Shapley Value
 - ▷ rewards earlier algorithms, which may have inspired later algorithms

I'm hiring!



Several funded graduate positions available.

