Forcing Complexity

Toshio Suzuki[1]

Tokyo Metropolitan University

toshio-suzuki•tmu.ac.jp (•=atmark)

A joint work with Masahiro Kumabe

ELC Workshop on Randomness and Probability Through Computability

Hongo Campus, The Univeristy of Tokyo, Japan

14 May 2013

[1]This work was partially supported by Japan Society for the Promotion of Science (JSPS) KAKENHI (C) 22540146 and (B) 19340019.

Abstract

We overview our research on forcing complexity:

- Forcing complexity (of a given formula)
  $=$ Min. size of forcing conditions (its domain) which force it.

- A Dowd-generic set
  $\Leftrightarrow$ A set of strings s.t. associated query formulas have small forcing complexity (We will show precise def. later.)

  $\not\Leftrightarrow$ A resource-bounded generic set of Ambos-Spies et al.

- Connections with:
  resource-bounded randomness
  computational complexity

Outline

Abstract

Background

Results on Non-Existence

Results on Existence

Jump and a Problem

Summary

References

§1 Background

Def. Resource-bounded randomness (Ambos-Spies et al.)

$t(n)$-random
$\simeq$ random for $O(t(n))$-time computable martingales.

Two Types of Resource-bounded Genericity

- [Ambos-Spies and Mayordomo 1997], [Ambos-Spies, Terwijn, and Zheng 1997]: Time-bound of finite-extension strategy.

  $t(n)$-random $\Rightarrow$ $t(n)$-stochastic $\Rightarrow$ $t(n)$-generic.

- [Dowd 1992]: Based on analogy of forcing theorem.

  [Kumabe and S.]: There exists an elementary recursive $t(n)$ s.t.
  $t(n)$-random $\Rightarrow$ Dowd-generic.

§1 Background

Dowd introduced the following in his study of NP=?coNP question.

Def. of Dowd-generic sets (sketch)

"A certain property* of an exponential-sized portion of an oracle X is forced by a polynomial-sized portion of X. "

"A certain property" is described with *the relativized propositional calculus* (RPC).

$$\mathrm{RPC} = (\text{ propositional caluculus }) \\ + \{\xi^1(-), \xi^2(-,-), \xi^3(-,-,-), \cdots\}$$

For each n, the n-ary connective ξ^n (a *query symbol*) is interpreted to the initial segment of a given oracle up to 2^nth string.

§1 Background

Example of a formula of RPC

$(q_0 \Leftrightarrow \xi^3(q_1, q_2, q_3)) \Rightarrow [q_0 \vee (q_1 \wedge q_4)]$

Given a formula F of RPC and an oracle X, truth of F is determined by "a truth assignment + a finite portion of X".

Interpretation:

$\xi^n(i\text{th of } \{0,1\}^n)$ is interpreted as to be $X(i\text{th of } \{0,1\}^*)$,

where "ith" is that of length-lexicographic order.

§1 Background

ξ^n(ith of $\{0,1\}^n$) is interepreted as to be X(ith of $\{0,1\}^*$).
Examples ($n = 2$ and $n = 3$)

$\xi^2(0,0)$	$\xi^2(0,1)$	$\xi^2(1,0)$	$\xi^2(1,1)$
X(empty string)	$X(0)$	$X(1)$	$X(00)$

$\xi^3(0,0,0)$	$\xi^3(0,0,1)$	$\xi^3(0,1,0)$	$\xi^3(0,1,1)$
X(empty string)	$X(0)$	$X(1)$	$X(00)$
$\xi^3(1,0,0)$	$\xi^3(1,0,1)$	$\xi^3(1,1,0)$	$\xi^3(1,1,1)$
$X(01)$	$X(10)$	$X(11)$	$X(000)$

Thus, $\xi^2(q_2, q_1)$ and $\xi^3(0, q_2, q_1)$ are interpreted as to be the same.

§1 Background

Def. Force

A finite portion σ (a finite sub-function) of an oracle X is called a *forcing condition*.

σ *forces* F if for any Y extending σ, F is a tautology w. r. t. Y.

Example of force

Let F be: $(q_0 \Leftrightarrow \xi^3(q_1, q_2, q_3)) \Rightarrow \neg q_0$

F is a tautology w. r. t. the characteristic func. of the empty set.
If σ forces F then the size of σ (its domain) $\geq 2^3$.
(And, the first 2^3 bits of σ should be 0.)

§2 Results on Non-Existence

The case of unbounded occurrences of query symbols

Definition. t-generic sets [Dowd 1992]

X is t-generic if every tautology F with respect to X is forced by a forcing condition of polynomial-size in $|F|$.

Thm. Non-existence of t-generic sets [Dowd, 1992], [S. 2001]

There are no t-generic sets.

Dowd, M.: Generic oracles, uniform machines, and codes. *Inf. Comput.*, **96**, pp. 65–76 (1992).

S.: Forcing complexity: minimum sizes of forcing conditions. *Notre Dame J. Formal Logic*, **42**, pp. 117–120 (2001).

§3 Results on Existence

The case of bounded occurrences of query symbols:
Here, r-query denotes "the $\sharp$ of occurrences of query symbols is r."

Def. Dowd-generic sets [Dowd, 1992]

- Let r be a positive integer.
  X is r-Dowd
  if every r-query tautology F w. r. t. X
  is forced by a forcing condition of polynomial-size in $|F|$.

- X is Dowd-generic
  if X is r-Dowd for every positive integer r.
  (Polynomial bound depends on each r, unlike t-genericity)

§3 Results on Existence

Thm. Existence of Dowd-generic sets

- [Dowd, 1992], [S.2001], [S.2002]
  The class of all Dowd-generic sets has Lebesgue measure 1.

- [S. and Kumabe, 2009] Schnorr random ⇒ Dowd-generic.

S.: Degrees of Dowd-type generic oracles.
Inf. Comput., **176**, pp.66–87 (2002).

S. and Kumabe, M.: Weak randomness, genericity and Boolean decision trees.
Proc. 10th Asian Logic Conference, pp.322–344, 2009.

§3 Results on Existence

[Dowd 1992] asserts "any 1-Dowd set is not c.e." (false)

Thm. Degrees of Dowd-generic sets

- [S. 2002] There exists a primitive recursive 1-Dowd set.
  And, every Turing degree contains a 1-Dowd set.
- [Kumabe and S. 2012]
  The same holds for "Dowd-generic" in place of "1-Dowd".

Kumabe, M. and S.:
Computable Dowd-generic oracles.
Proc. 11th Asian Logic Conference, pp.128–146, 2012.

§3 Results on Existence

Thm. Resouce-bounded ramdomness implies Dowd-genericity

[Kumabe and S. ∞]
There exists an elementary recursive function $t(n)$ s.t.
$t(n)$-random $\Rightarrow$ Dowd-generic.

Gives an alt. proof: $\exists$ a primitive recursive Dowd-generic set.

Kumabe, M. and S. :
Resource-bounded martingales and computable Dowd-type generic sets. submitted to a journal (2010).

§3 Jump and a Problem

Let $1\mathrm{TAUT}^X$ denote the set of all 1-query tautologies w. r. t. X.

Question: Does $1\mathrm{TAUT}^X$ has a degree strictly higher than X?

Given a reduction concept $\leq_r$ (e.g., poly.-time Turing $\leq_T^P$),
we introduce the following statement, and we call it
"One-query jump hypothesis w. r. t. $\leq_r$" (1QJH(r), for short).

Def. One-query Jump Hypothesis w. r. t. $\leq_r$ [S. 2002]

"The class $\{X : X <_r 1\mathrm{TAUT}^X\}$ has Lebesgue measure 1 in the Cantor space".

§3 Jump and a Problem

Thm. [S. 1998]

1QJH(poly.-time Turing) $\Leftrightarrow$ RP $\neq$ NP.

Here, RP is the one-sided version of BPP.

Thm. [S. 2002]

1QJH(poly.-time truth table) $\Rightarrow$ P $\neq$ NP.

S.: Recognizing tautology by a deterministic algorithm whose while-loop's execution time is bounded by forcing.
Kobe Journal of Mathematics, **15**, pp. 91–102 (1998).

§3 Jump and a Problem

Examples of 1QJH [Kumabe, S. and Yamazaki 2008]

(1) 1QJH(monotone reductions) holds.
(tt-reductions s.t. truth tables are monotone Boolean formulas.)

(2) $c < 1 \Rightarrow$ 1QJH(tt-reductions s.t. norm $\leq c \times |F|$) holds.
(F is an input formula and $|F| = \sharp$ of occurrences of symbols.)

Problem

In (2), can we relax the assumption of "$c < 1$"?

Kumabe, M., S. and Yamazaki, T.: Does truth-table of linear norm reduce the one-query tautologies to a random oracle? *Arch. Math. Logic*, **47**, pp.159–180 (2008).

Summary

§1 Results on Non-Existence (Thm. [Dowd 1992], [S. 2001])

No t-generic sets (No poly.-bound on forcing complexity when unbounded occurrences of query symbols).

§2 Results on Existence (Def.)

(1) r-Dowd $\leftrightarrow$ poly.bound on forcing comp. for r-query tautologies
(2) Dowd-generic $\leftrightarrow \forall r \geq 1 \quad r$-Dowd

§2 (Thm. [Kumabe and S., ∞])

There exists an elementary recursive function $t(n)$ s.t.
$t(n)$-random $\Rightarrow$ Dowd-generic.
(Hence $\exists$ a primitive recursive Dowd-generic set.)

Summary

§3 Jump and a Problem (Def.)

1QJH(r): " $\{X : X <_r 1\mathrm{TAUT}^X\}$ has Lebesgue measure 1".

§3 (Thm. [Kumabe, S. and Yamazaki 2008])

(1) 1QJH(monotone reductions) holds.
(2) $c < 1 \Rightarrow$ 1QJH(tt-reductions s.t. norm $\leq c \times |F|$) holds.
(F is an input formula and $|F| = \sharp$ of occurrences of symbols.)

§3 (Problem)

In (2), can we relax the assumption of "$c < 1$"?

Thank you.

References

- Arora, S. and Barak, B.: *Computational Complexity*, Cambridge university press, New York, 2009.
- Ambos-Spies,K. and Mayordomo, E.: Resource-bounded measure and randomness. In: *Lecture Notes in Pure and Appl. Math.*, 187, 1–47 Dekker, 1997.
- Ambos-Spies,K., Terwijn, S.A. and Zheng,X. : Resource bounded randomness and weakly complete problems. *Theoret. Comput. Sci.*, 172 (1997) 195–207.
- Dowd, M.: Generic oracles, uniform machines, and codes. *Inf. Comput.*, **96**, pp. 65–76 (1992).
- Kumabe, M. and Suzuki, T. : Computable Dowd-generic oracles. *Proc. 11th Asian Logic Conference*, pp.128–146, World Scientific, 2012.

Kumabe, M. and Suzuki, T. : Resource-bounded martingales and computable Dowd-type generic sets, submitted to a journal (2010).

Kumabe, M., Suzuki, T. and Yamazaki, T.: Does truth-table of linear norm reduce the one-query tautologies to a random oracle? *Arch. Math. Logic*, **47**, pp.159–180 (2008).

Suzuki, T.: Recognizing tautology by a deterministic algorithm whose while-loop's execution time is bounded by forcing. *Kobe Journal of Mathematics*, **15**, pp. 91–102 (1998).

Suzuki, T.: *Computational complexity of Boolean formulas with query symbols*. Doctoral dissertation, Institute of Mathematics, University of Tsukuba, Tsukuba-City, Japan (1999).

Suzuki, T.: Complexity of the r-query tantologies in the presense of a generic oracle. *Notre Dame J. Formal Logic*, **41**, pp. 142–151 (2000).

Suzuki, T.: Forcing complexity: minimum sizes of forcing conditions.
Notre Dame J. Formal Logic, **42**, pp. 117–120 (2001).

Suzuki, T.: Degrees of Dowd-type generic oracles.
Inf. Comput., **176**, pp.66–87 (2002).

Suzuki, T.: Bounded truth table does not reduce the one-query tautologies to a random oracle.
Arch. Math. Logic, **44**, pp.751–762 (2005).

Suzuki, T. and Kumabe, M.: Weak randomness, genericity and Boolean decision trees.
Proc. 10th Asian Logic Conference, pp.322–344, World Scientific, 2009.

Toshio Suzuki URI:
`http://researchmap.jp/read0021048/?lang=english`