Complexity of Counting

Lecture 21

#P: Toda's Theorem

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- Next: Toda's Theorem: $PH \subseteq P^{\#P} = P^{PP}$

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- If an RP algorithm for $\oplus$SAT, then an RP algorithm for SAT

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$\Sigma_x Pr_h[h(x)=0]$ → $|S|p$

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  - $Pr_h[N=1] \geq |S|\ p - 2\ (|S| \text{ choose } 2)\ p^2 \geq |S|p - (|S|p)^2 \geq 3/16$

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    - If witness n-bit long ($|X|=\{0,1\}^n$), pick $R=\{0,1\}^k$, with k random in the range [1,n]

Reducing PH to $P^{\#P}$

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- Two steps
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  - Converting the probabilistic guarantee to a deterministic #P statement

Quantifier Gallery!

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$\exists$

For at least one

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$\forall$

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  - Can all $\exists/\forall$ be removed, by repeating, so that only $\oplus$ remain?

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  - not $\oplus_x\ \varphi(x) \Leftrightarrow \oplus_{x,z}\ F_{\varphi+1}(x,z)$. i.e. $\oplus_{x,z}$ (z=1,x=0) or (z=0,φ(x))

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- $\oplus_x\ (\oplus_y\ \varphi(x,y)) \Leftrightarrow \oplus_{x,y}\ \varphi(x,y)$

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- $\oplus_x (\oplus_y \varphi(x,y)) \Leftrightarrow \oplus_{x,y} \varphi(x,y)$
- $(\oplus,\exists,\forall)$-QBF can be converted to the form $\oplus_z F(z)$, where F is a $(\exists,\forall)$-QBF, increasing the size by at most a constant factor, and not changing number of $\exists,\forall$

QBF to $\oplus$BF

QBF to ⊕BF

- Recall: with prob ≥ $\epsilon(n)$, we have $\exists_w\ \varphi(w) \Leftrightarrow \oplus_w\ A_\varphi(w)$ (and $\forall_w$ not $\varphi(w) \Leftrightarrow$ not $\oplus_w\ A_\varphi(w)$)

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    - In prenex form $\oplus_z B_\varphi(z)$ has one less $\exists/\forall$ than $\exists_w \varphi(w)$

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  - By repeating, QBF can be converted to the form $\oplus_z\, F(z)$ where F is unquantified, equivalent with prob. close to 1

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  - Let $\theta_\psi(x,r) = T(\varphi_\psi^r)(x)$. Use $\#\theta_\psi$ mod N to check if w.h.p. $\oplus\varphi$

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