Structure-Preserving Compilers from New Notions of Obfuscations

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Obfuscator

PPT Obfuscator

Circuit. $C : \{0,1\}^n \longrightarrow \{0,1\}^m$

PPT Obfuscator. $\widetilde{C} \leftarrow \mathsf{Obf}(1^\lambda, C)$

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PPT Obfuscator. $\widetilde{C} \leftarrow \mathsf{Obf}(1^\lambda, C)$

(1) Correctness. $\forall x \in \{0,1\}^n, C(x) = \widetilde{C}(x)$

(2) Polynomial Slowdown. $\exists p(\cdot), \forall C, |\mathsf{Obf}(1^\lambda, C)| \leq p(|C|)$

Security

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Existing Notions

Virtual Black Box (**VBB**).

Differing-input Obfuscation (**diO**).

Indistinguishability Obfuscation (**iO**).

VBB

VBB-simulation

For every PPT adversary A, there exists a PPT simulator Sim such that for every sampler S, we have:

$$\left\{\mathsf{A}(1^\lambda, \mathsf{Obf}(1^\lambda, C), \alpha) = 1\right\} \approx_c \left\{\mathsf{Sim}^{C(\cdot)}(1^\lambda, 1^{|C|}, \alpha) = 1\right\}$$

where $(C, \alpha) \leftarrow \mathsf{S}(1^\lambda)$.

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Auxiliary Information

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Set $pk = \widetilde{C}$
Obtain a PKE

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Impossibility Results [*]

Some programs/circuits cannot be **VBB**-obfuscated (unconditionally).

Some SKEs cannot be obfuscated into PKEs (unconditionally).

[*] Boaz Barak, Oded Goldreich, Russell Impagliazzo, Steven Rudich, Amit Sahai, Salil Vadhan, and Ke Yang. On the (im)possibility of obfuscating programs.

iO

iO-Sampler

A sampler S is an **iO**-sampler if

$$\mathbb{P}\left[\forall x \in \{0,1\}^n, C_0(x) = C_1(x)\right] \geq 1 - \mathsf{negl}(\lambda)$$

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Intuition

We need to include a secret into the circuit.

iO/diO are not enough to deal with secrets.

*Can we obtain structure-preserving transformations from notions of obfuscation weaker than **VBB**?*

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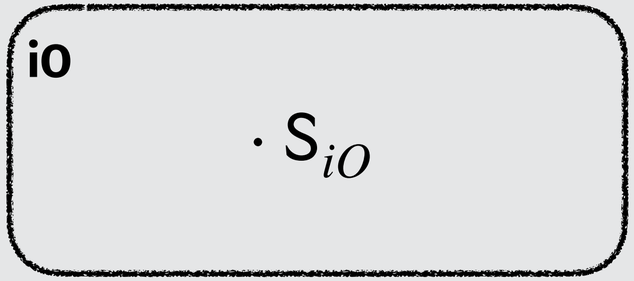

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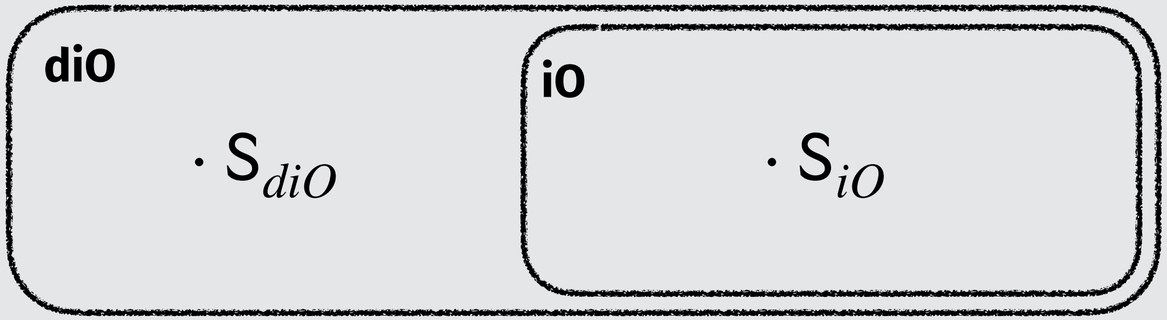

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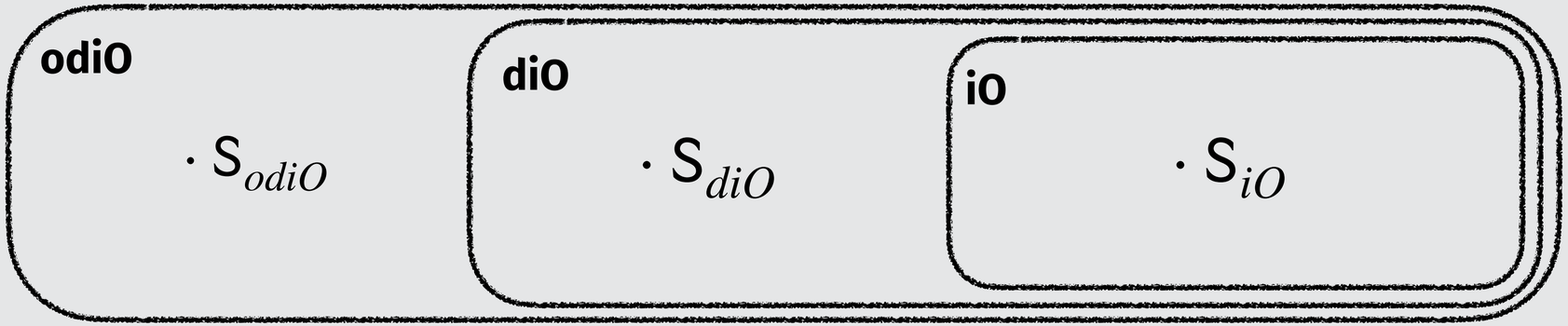

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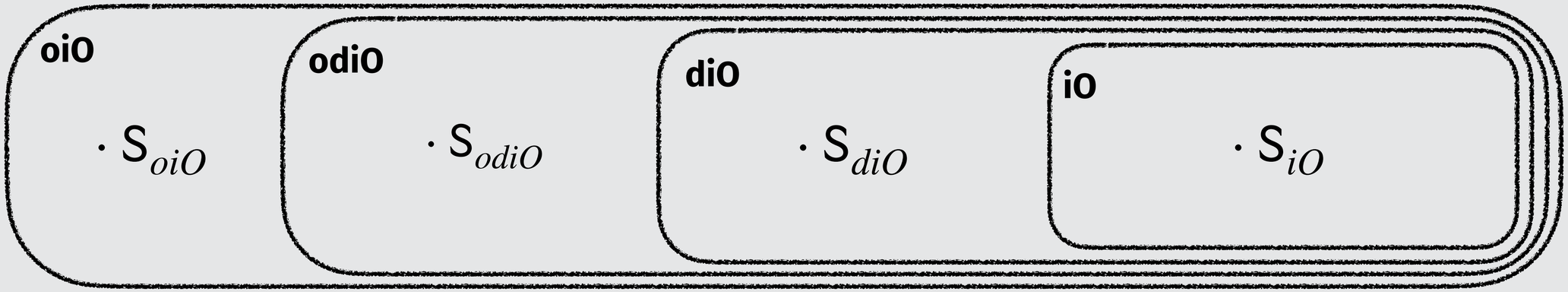

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Implications

$$\text{iO} \Leftarrow \text{diO} \Leftarrow \text{odiO} \Leftarrow \text{oiO}$$

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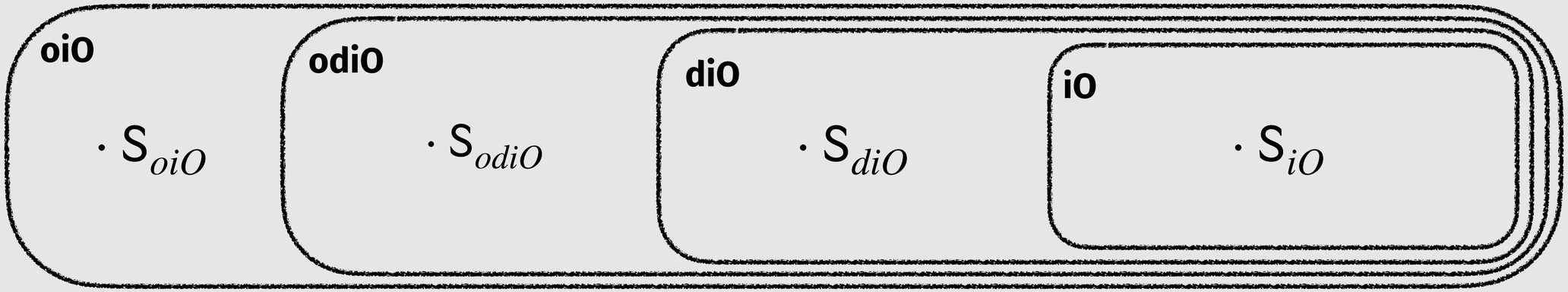

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Result

$$\mathsf{odiO} \Leftarrow \mathsf{oiO} \Leftarrow \mathsf{VBB}$$

Applications of odiO

***odiO**-based structure-preserving compilers*

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Designated verifier (DV) non-interactive argument systems

↓

Publicly verifiable (PV) non-interactive argument systems

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DV/PV non-interactive argument system

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Designated Verifier (DV)

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Designated Verifier (DV)

Syntax.

- Setup$(1^\lambda, \mathscr{R}) \to (crs, vk)$
- Prove$(crs, x, \omega) \to \pi$
- Verify$(vk, x, \pi) \to b$

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Selective Soundness.

For every $x \notin \mathscr{L}$, every PPT adversary A, we have:

$$\mathbb{P}\left[\mathsf{Verify}(vk, x, \pi) = 1 \;\middle|\; \begin{array}{r}(crs, vk) \leftarrow \mathsf{Setup}(1^\lambda, \mathscr{R}) \\ \pi \leftarrow \mathsf{A}^{\mathsf{Verify}(vk,\cdot,\cdot)}(1^\lambda, crs, x)\end{array}\right] \leq \mathsf{negl}(\lambda)$$

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Compiler

Setup$(1^\lambda, \mathscr{R})$:

1. $(crs^*, vk^*) \leftarrow \mathsf{Setup}^*(1^\lambda, \mathscr{R})$
2. $\widetilde{C} \leftarrow \mathsf{Obf}(1^\lambda, C^{\mathsf{ver}}_{vk^*})$
3. Return $crs = (crs^*, \widetilde{C})$

Prove(crs, x, ω) :

1. Return $\pi \leftarrow \mathsf{Prove}(crs^*, x, \omega)$

Verify(crs, x, π) :

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Circuit $C^{\mathsf{ver}}_{vk^*}$

$C^{\mathsf{ver}}_{vk^*}(x, \pi)$:

1. Return $\mathsf{Verify}^*(vk^*, x, \pi)$

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Here, we need oracles.

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Second Step: Replace $C^{\mathsf{ver}}_{vk^*}$ with $C^{\mathsf{ver}}_{vk^*,x^*}$.

Otherwise, we can distinguish $\mathsf{Obf}(1^\lambda, C^{\mathsf{ver}}_{vk^*})$ and $\mathsf{Obf}(1^\lambda, C^{\mathsf{ver}}_{vk^*,x^*})$.

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Third Step: A's advantage is 0.

Other Results

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***oiO**-based structure-preserving compilers*

Key Indistinguishable symmetric key encryption

↓

Public key encryption

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General Purpose **odiO/oiO**-obfuscators do not exist (unconditionally)

There exists an **odiO/oiO**-sampler that cannot be **odiO/oiO**-obfuscated.

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There exists an **odiO/oiO**-sampler that cannot be **odiO/oiO**-obfuscated.

Key Ind. SKE → PKE is impossible (unconditionally)

Does not exist an obfuscator Obf able to implement this compiler.

Applications of odiO

***odiO**-based structure-preserving compilers*

Designated verifier (DV) non-interactive argument systems

↓

Publicly verifiable (PV) non-interactive argument systems

Message authentication codes

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Signatures

IV-based symmetric key encryption

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$\mathsf{Enc}(k, m; iv) = (c, iv)$

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+

Puncturable PRF

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Thank You!