Multi-Party Computation with Small Shuffle Complexity Using Regular Polygon Cards

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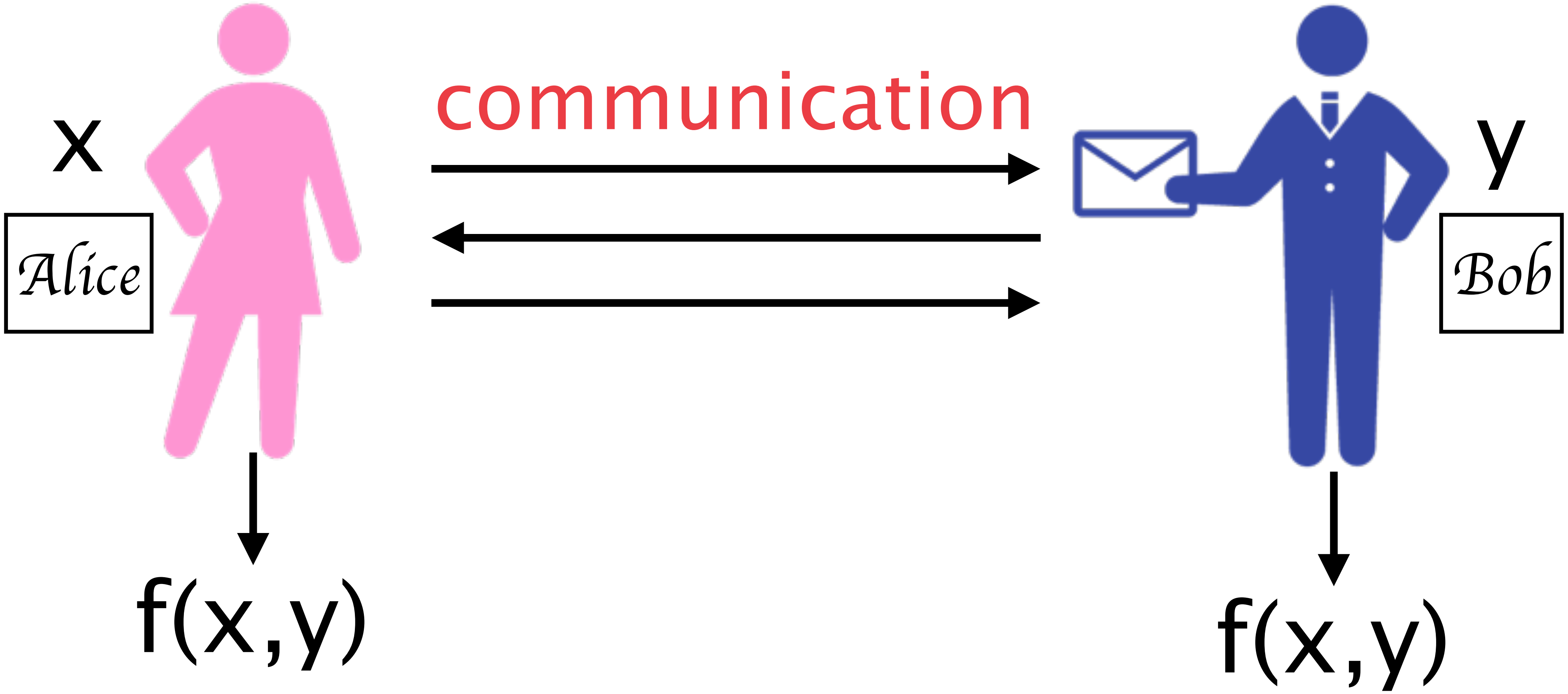
Secure Protocol (without Cards)



x

Alice

communication

y

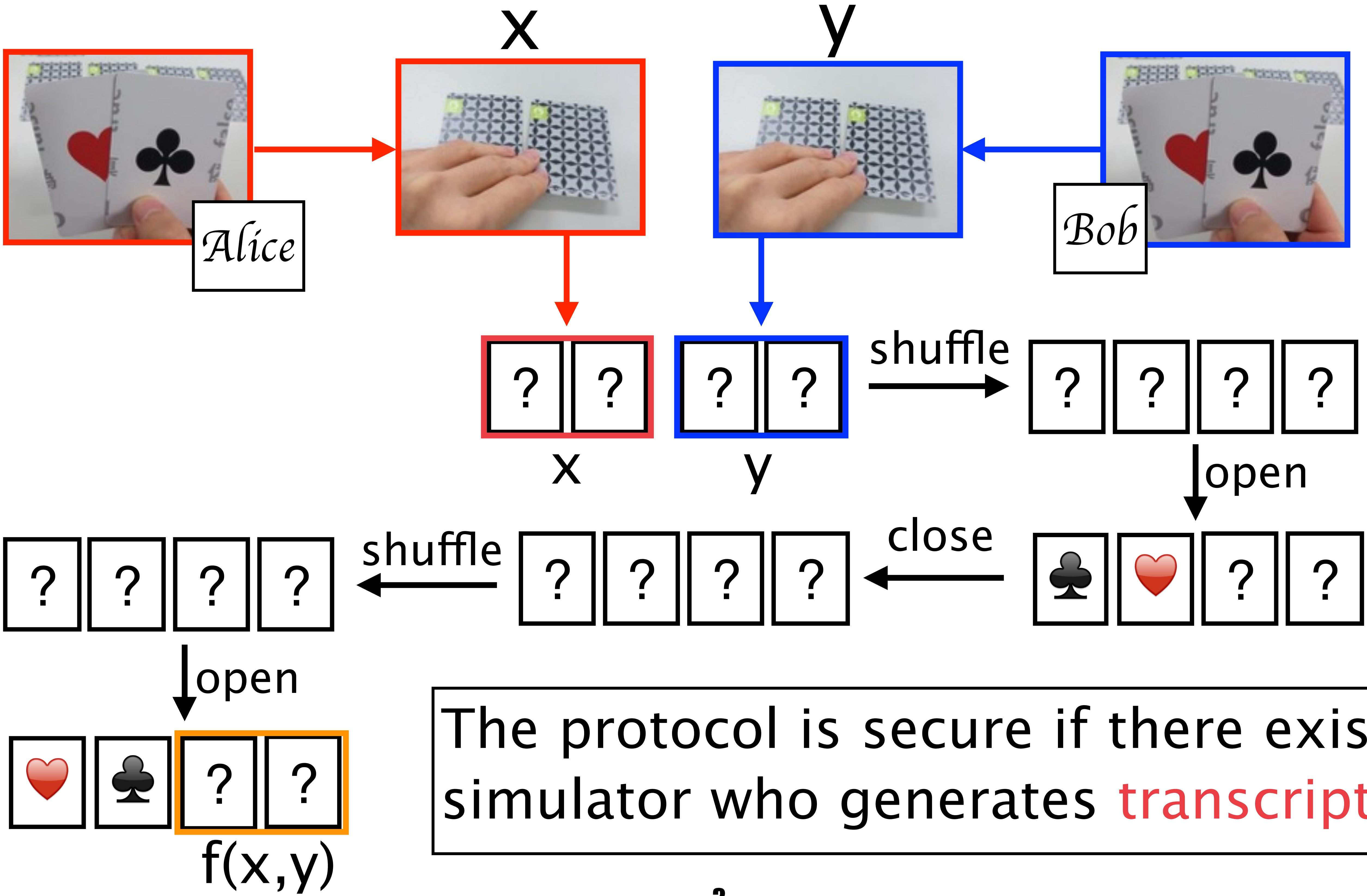
Bob

f(x,y)

f(x,y)

The protocol is secure if there exists a simulator that can generates transcripts

Card-based Protocol



x

y

Alice

Bob

? ? ? ?

x y

shuffle

? ? ? ?

open

♣ ♥ ? ?

close

? ? ? ?

shuffle

? ? ? ?

open

♥ ♣ ? ?

f(x,y)

The protocol is secure if there exists simulator who generates transcripts

Previous Works

- All previous works focus on boolean circuits

How to deal with arithmetic circuits?

- Many works aims to reduce the number of cards
  - n-ary function: 2n+6 cards [Nishida et al. 15]
- No results to reduce the number of shuffles

How to reduce the number of shuffles?

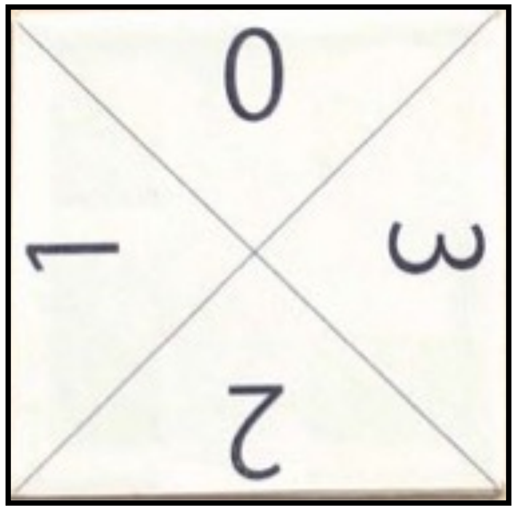
Our Contribution

- New cards for arithmetic circuits
  - Regular polygon cards

- New technique for reducing Num. of shuffles

Regular Polygon Card:

- polygon shaped
- 3-sided, 4-sided, 5-sided, and so on.



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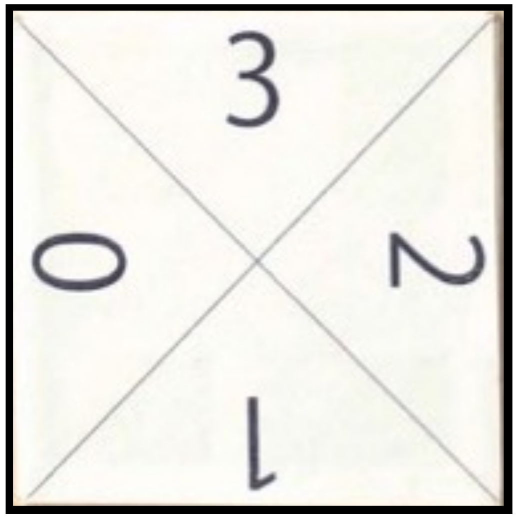

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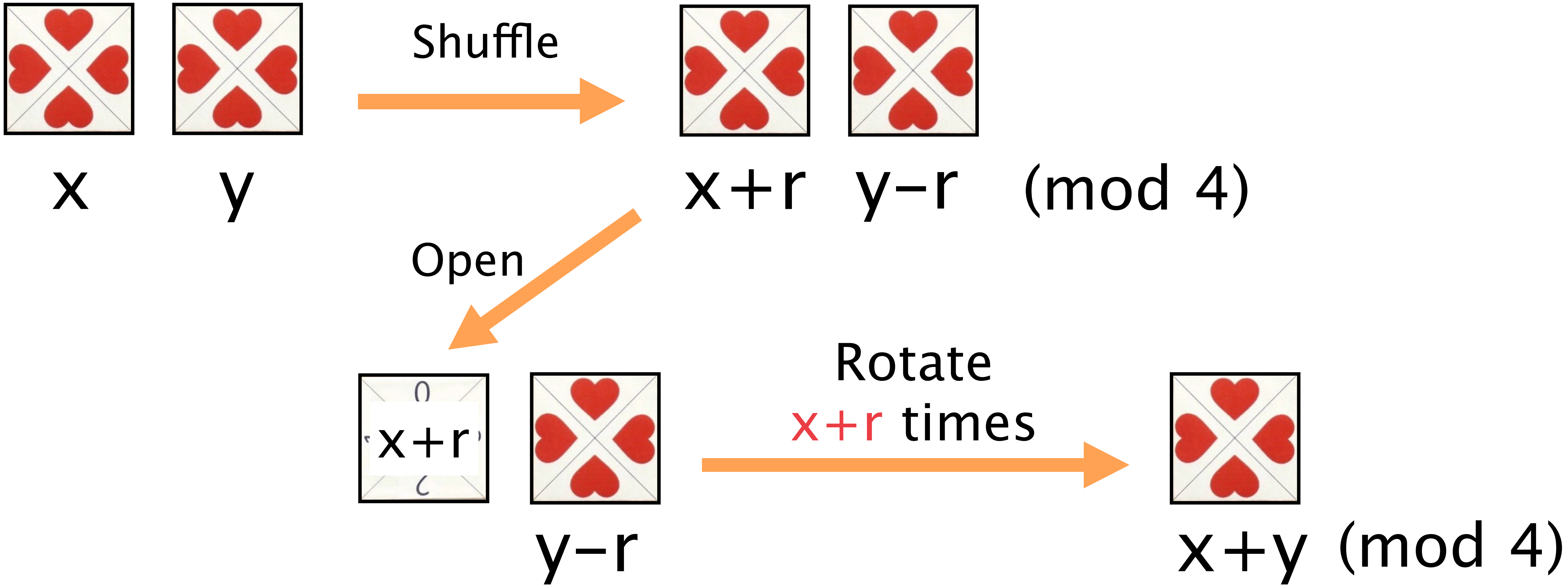
- back side has rotational symmetric pattern

Addition Protocol

Rotate two cards “r”–times (“r” is hidden to parties)



x y

Shuffle

x+r y−r (mod 4)

Open

x+r y−r

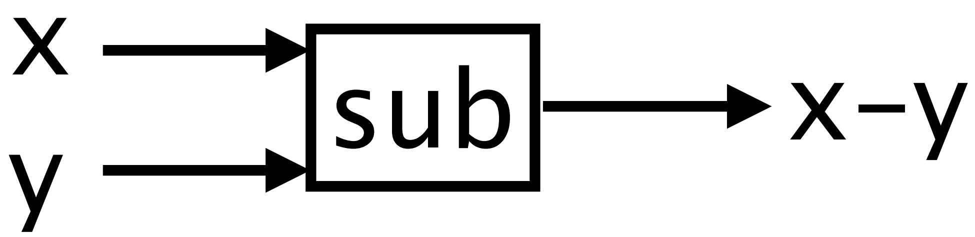
Rotate
x+r times

x+y (mod 4)

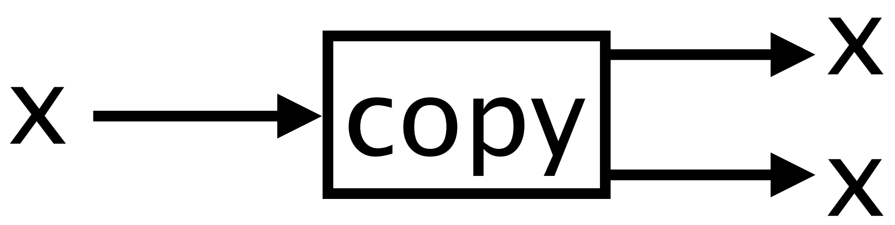
Note: “x+r” does not reveal any secret information
since nobody knows the random value “r”.

Demo.
Addition Protocol

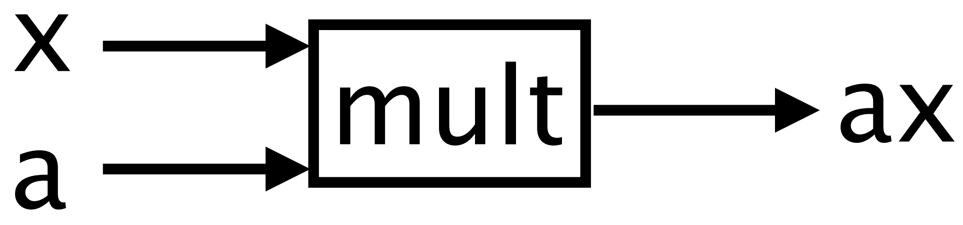
Subtraction Protocol

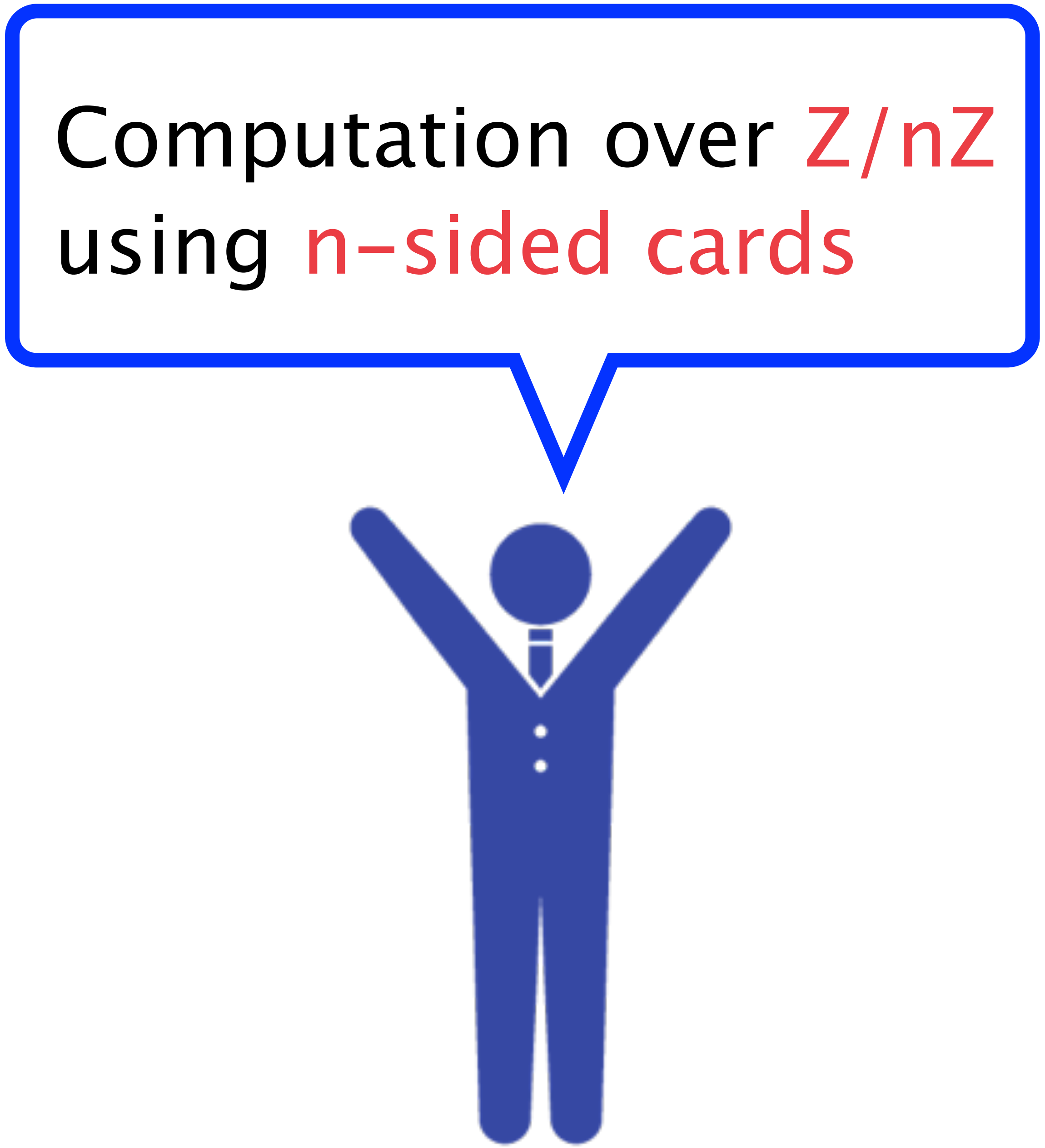


Copy Protocol



Multiplication Protocol





Computation over Z/nZ using n−sided cards

Demo.
Evaluation of f(x)

Shuffle-Efficient Protocols

Any 1-ary function f(x)	2 shuffles
Any 2-ary function f(x,y)	4 shuffles
:	
Any n-ary function	2n shuffles

Nishida et al.

$O(2^n)$ shuffles
2n+6 cards

⇔ trade-off

Our work

2n shuffles
$O(2^n)$ cards

Summary

- New cards for arithmetic circuits
  - Regular polygon cards
  - Protocols for Linear Function (Add/Sub/…)

- New technique for reducing Num. of shuffles
  - Any n-ary function with 2n shuffles