Secure Two Party Computation

Preliminary presentation

Nick Tutte

Prof. Nigel Smart

February, 2015

Presentation overview

- My project focuses on Secure Multiparty Computation, in particular the two party case using Yao Garbled Circuits.
- I shall be implementing the as yet unimplemented protocol laid out by Lindell in "Fast Cut-and-Choose based Protocol for Malicious and Covert Adversaries."
- By the end of this presentation you should know,
  - What is Secure Multiparty Computation?
  - What can it be used for?
  - What "Secure" means in this context.
  - A grounding in Yao Garbled Circuits.
  - How much progress I've made so far.

What is Secure Multiparty Computation?

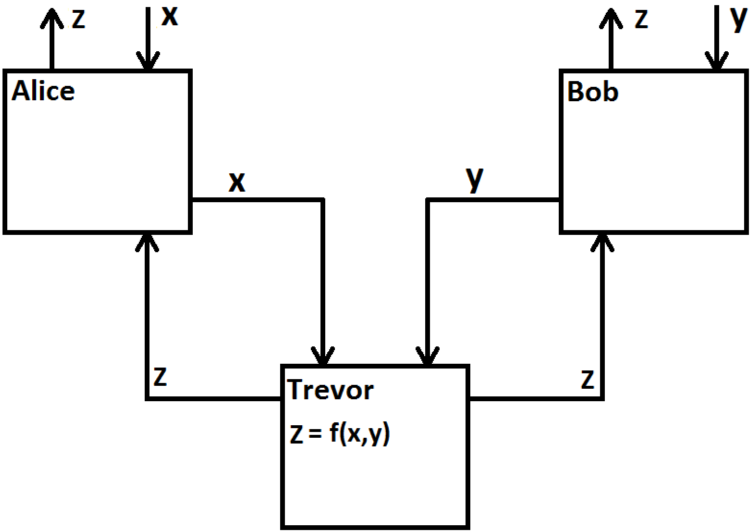
- In the problem of Secure Multiparty Computation we have a set of parties, each of whom has a secret input.
- The parties wish to co-operate to compute a function upon their collective inputs without revealing said inputs to one another.
- Some example applications are,
  - The Millionaires problem.
  - Distributed secrets.
  - Sugar Beets.
  - Database query.

Desired security properties

Before we go any further we need to define what properties we want an SMC protocol to fulfill before we consider it Secure.

- **Privacy**, the only knowledge parties gain from participating is the output.
- **Correctness**, the output is indeed that of the intended function.
- **Independence of inputs**, no party can choose it's inputs as the function of other parties inputs.
- **Fairness**, corrupt parties receive their outputs if and only if the honest parties also receive their outputs.

The Ideal Model



Security Definitions

- We measure the security of an SMC protocol in terms of what adversaries it is secure against, we define adversaries in terms of their capabilities.
- We say that an SMC protocl is secure against an adversary if the adversary can achieve no more than they would be able to achieve attacking the Ideal Model.
- We focus on three adversaries,
  - Semi-Honest
  - Malicious
  - Covert

Semi-Honest Adversaries

- Semi-Honest(SH) adversaries are the weakest adversary we shall consider.
- They are sometimes also called "honest, but curious".
- SH adversaries are limited to looking at information given to them in the process of the protocol.
- They have to follow the protocol (they cannot cheat).
- SH adversaries are very similar to traditional "Passive" adversaries.

Malicious and Coverts Adversaries

- Malicious adversaries are the strongest adversary.
- Malicious adversaries can use any arbitrary strategy. We do not assume that they follow the protocol.
- Further more Malicious Adversaries are willing for their cheating to be noticed.

- Covert Adversaries slightly weaker than Malicious Adversaries.
- Covert Adversaries can also use any arbitrary strategy, but they are adverse to being caught.
- They are willing to accept a certain probability of getting caught.

Oblivious Transfer

- A key component we will need later is Oblivious transfer(OT).
- Security definitions for OTs is are very similar to SMC, though we don't really look at the Covert case.

Receiver	**Sender**
Inputs : $b \in \{0, 1\}$	Inputs : X_1, X_2
Outputs : X_b	Outputs : $\emptyset$

Figure 1 : Definition of the functionality of a one-out-of-two OT protocol. Note k-out-of-n OT is also possible.

Even-Goldreich-Lempel Semi Honest OT

Receiver
Inputs : $b \in \{0, 1\}$
Outputs : X_b

Sender
Inputs : X_0, X_1
Outputs : $\emptyset$

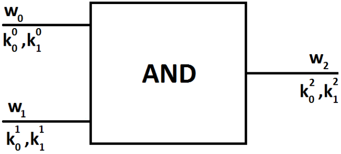
- **Receiver:** Generates a public/private key pair (E, D), where E is the public key.
- **Receiver:** Sets $PK_b = E$, choose PK_{1-b} at random from the same distribution as the public keys. Send PK_0 and PK_1 to the Sender.
- **Sender:** Encrypt X_0 using PK_0 as C_0 and encrypt X_1 using PK_1 as C_1. Send C_0 and C_1 to the Receiver.
- **Receiver:** Receives C_0 and C_1, then decrypt C_b using D. Output this decrypted value.

Figure 2 : The abstracted Even-Goldreich-Lempel protocol. Who can suggest why this is only Semi Honest?

Yao Garbled Circuits

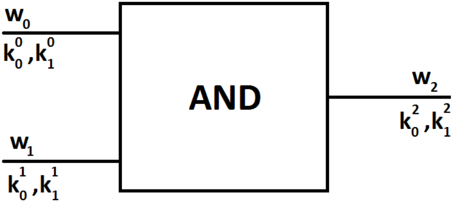
- The basic concept of Yao Garbled Circuits is that one party constructs a binary circuit corresponding to the function to be computed.
- For wire w_i we denote the value of the wire as b_i, we generate two random "garble value", denote these by k_i^0 and k_i^1.
- We then generate a random permutation for each wire w_i, denote this by π_i.
- For each gate we create an encryption table indexed by c_i and c_j (where the gates input wires are w_i and w_j).

Yao Garbled Circuits



b_0	b_1	
0	0	$E_{k_0^0}(E_{k_1^0}(k_2^0 \| b_2))$
0	1	$E_{k_0^0}(E_{k_1^1}(k_2^0 \| b_2))$
1	0	$E_{k_0^1}(E_{k_1^0}(k_2^0 \| b_2))$
1	1	$E_{k_0^1}(E_{k_1^1}(k_2^1 \|))$

Yao Garbled Circuits



$$c_0, c_1 : E_{k_0^{b_0}}(E_{k_1^{b_1}}(k_2^{G(b_0,b_1)} \| c_2))$$

where $c_i = \pi_i(b_i)$ and $G(.,.)$ is the function taking the input of the gate and returning the output of the gate.

Yao Garbled Circuits

- We extend this to all gates of the circuit.
- It then sends the circuit to the Executor, stripped of the details of the permutations and keys.
- The Builder then sends the keys relating to its inputs for its input wires.
- The Builder also sends the permutations for the Executors input wires and the Executors output wires.