Multiparty Computation made Practical

Using the Virtual Ideal Functionality Framework

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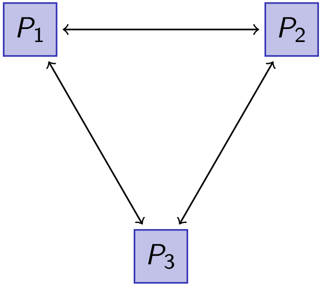
Outline

Multiparty Computation



- n players
- Wish to jointly compute f
- Player P_i has input x_i
- Players learn $y = f(x_1, x_2, \ldots, x_n)$

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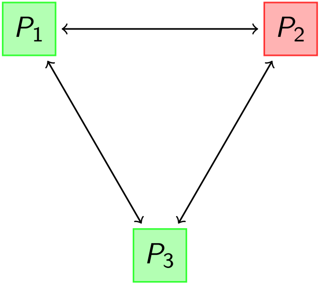

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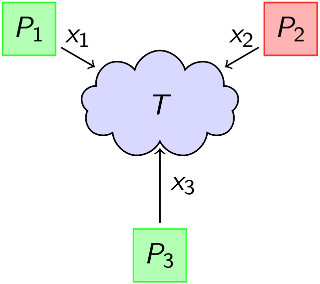
- Wish to jointly compute f
- Player P_i has input x_i
- Players learn $y = f(x_1, x_2, \ldots, x_n)$
- Up to t players are corrupt
- Must keep inputs private
- Players only learn y

Trivial "Solution"



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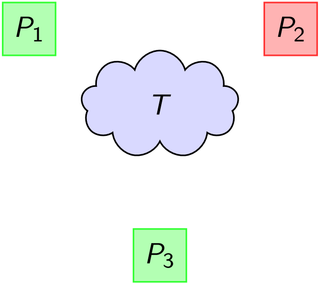

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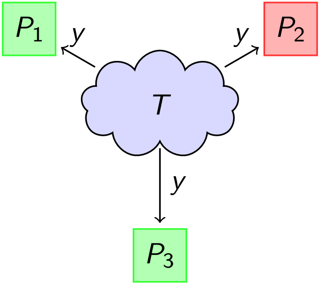

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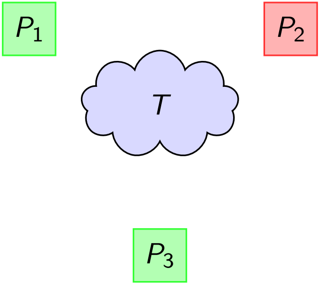

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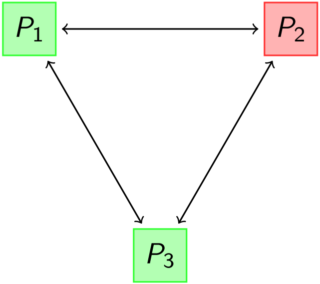
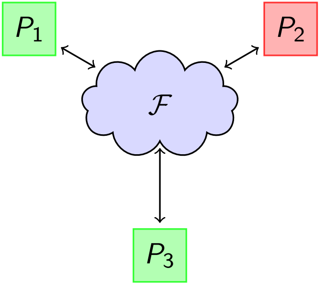
- Obviously secure!
- But who should play T?

Security Model: UC Framework

Real World



Ideal World



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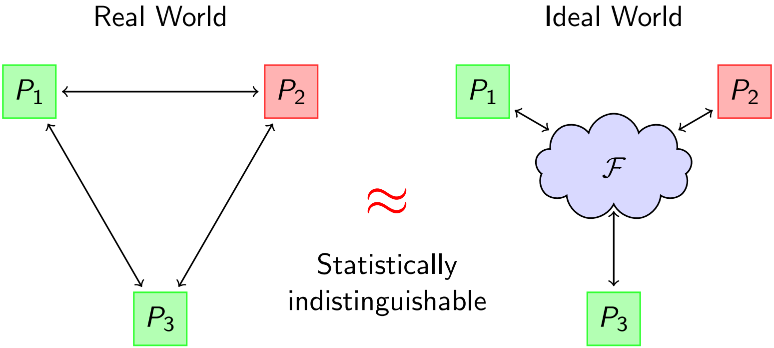


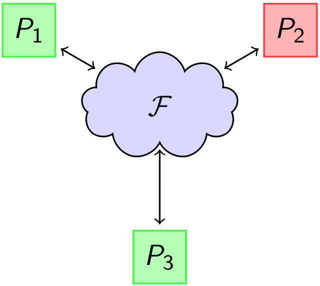
Functionality provided by VIFF

Supported operations:

- Input
- Output
- Addition
- Multiplication
- Comparison

All over arbitrary finite fields.

Ideal World



Related Projects

- FairPlay project (Haifa, Israel)
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- SIMAP project (Aarhus, Denmark)
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  - Java implementation
  - Some work done on a domain specific language

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VIFF Goals

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```

- Extensible with new operations:

```
def max(a, b):
    c = a > b
    return c * a + (1 - c) * b
```

Parallel Execution

- Networks have significant latency
- Want to run many operations in parallel
- Including primitive and compound operations

Example: Hamming Distance

```
def xor(a, b):
    assert a.field is b.field
    if a.field is GF256:
        return a + b
    else:
        return a + b - 2 * a * b
```

- Straight-forward exclusive-or
- Fast for $GF(2^8)$ elements
- Slower for $\mathbb{Z}_p$ elements
- (Already part of VIFF)

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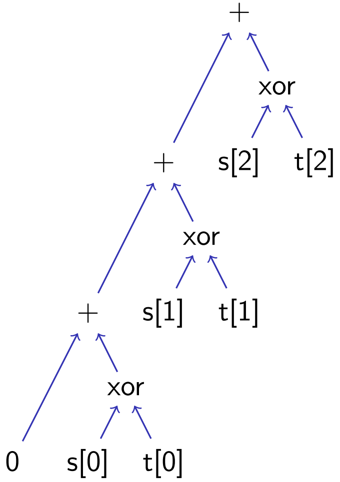
```
def hamming(s, t):
    distance = 0
    for i in range(len(s)):
        distance += xor(s[i], t[i])
    return distance
```

- Hamming distance
- xor calls should run in parallel

Hamming Distance Execution Tree

hamming(s, t) translates to:



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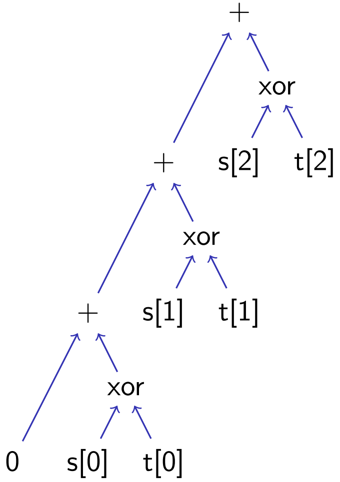

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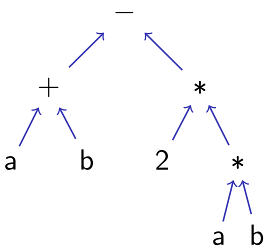
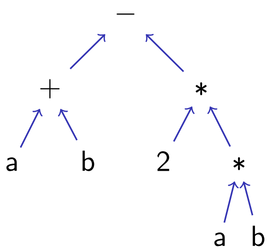


VIFF Execution Strategy

- Create execution tree as we go along
- Destroy execution tree from bottom up
  - Each node waits on nodes below
  - Bottom nodes wait on network traffic
- Composable: just plug new operations into tree!

Program Counters



- No parsing — execution tree never fully constructed
- No fixed evaluation order
- But we must identify results

Program Counters Implementation

- First attempt:
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- Current solution:
  - Runtime methods wrapped by a decorator
  - Calculated automatically based on call stack

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- Tested on 3 machines: USA, Norway, and Denmark
- Results for VIFF 0.4 (VIFF 0.6 is similar or better)
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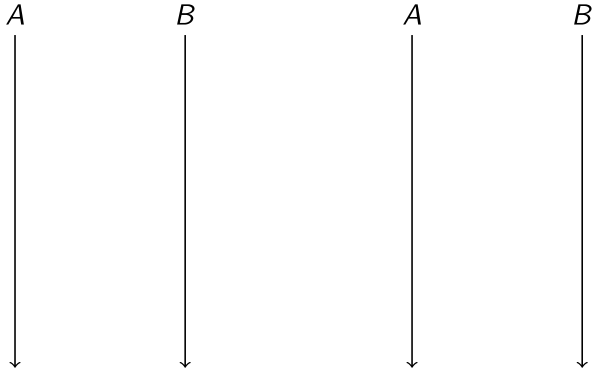

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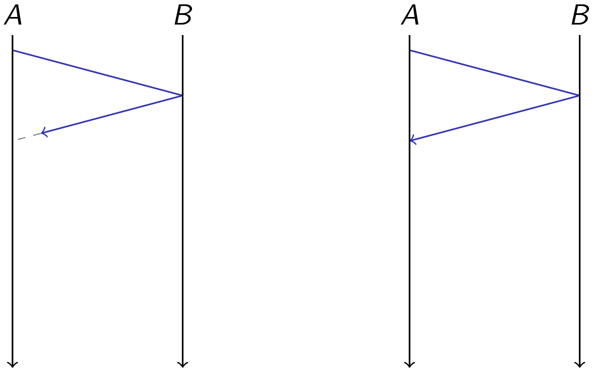

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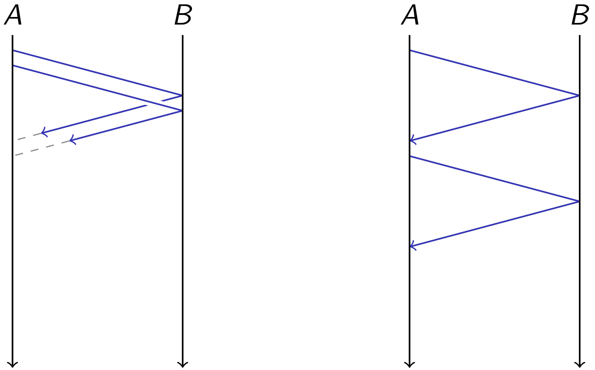

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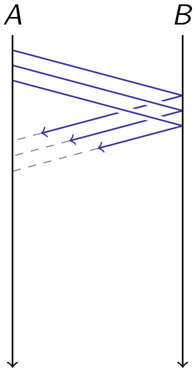

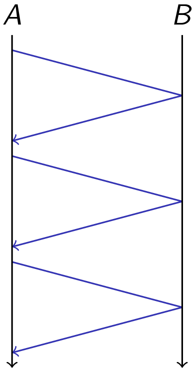

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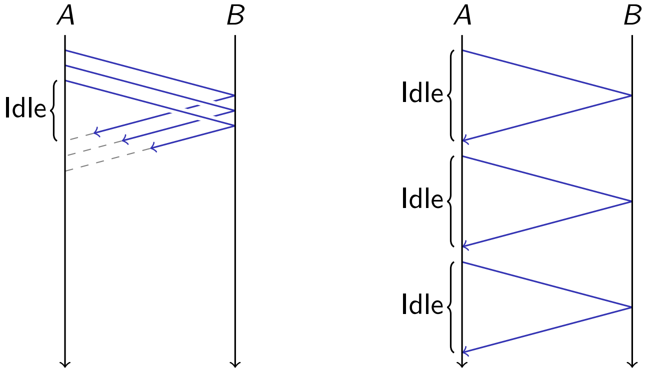
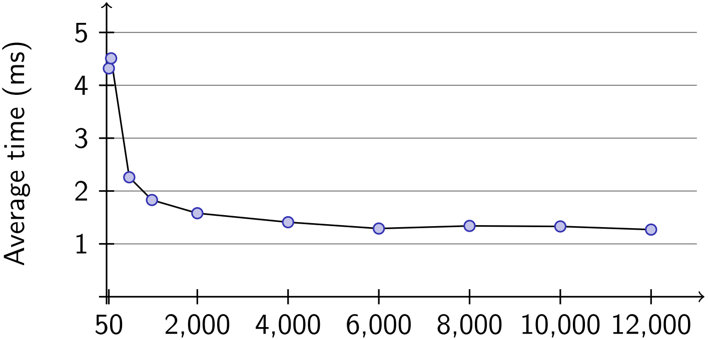


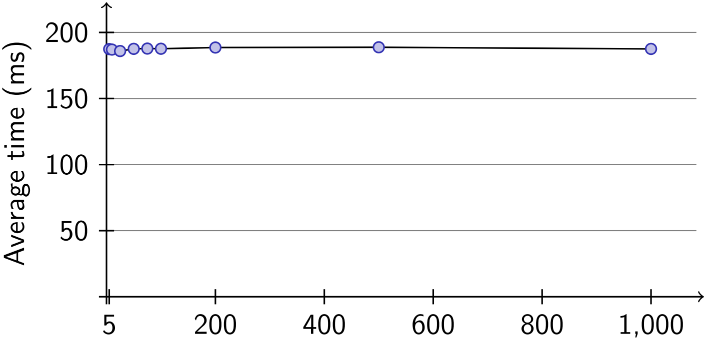
Parallel Multiplications

Multiplying random 65-bit numbers:



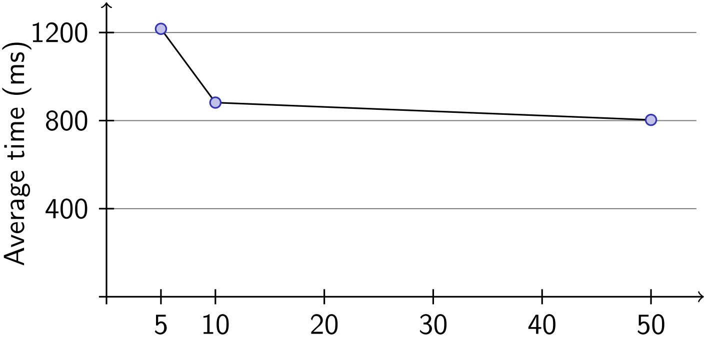
Serial Multiplications

Multiplying random 65-bit numbers:



Parallel Comparisons

Comparing random 32-bit numbers, 65-bit field modulus:



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Program Counter Overheads

- They work, but it's a bit magic. . .
- Exactly when must the program counter be updated?
- Excessive wrapping slows down method calls
- Program counter size depends on stack depth

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- Python objects have a large memory overhead:
  - Reference count (4 bytes)
  - Object attribute dictionary (144 bytes)
  - Allocation overhead ($>$8 bytes)
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- Python objects have a large memory overhead:
  - Reference count (4 bytes)
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  - ...
- 100,000 field elements with 65-bit prime:
  - Optimal: $\approx$800 KB
  - VIFF: $\approx$40 MB (expanded 50 times)
  - More memory needed for execution tree

Debugging

- Something went wrong! What now?
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- Need better
  - Logging infrastructure
  - Handling of exceptions

Type Safety

- Python is a strongly typed language
  - "12" $*$ 3 $==$ "121212" but 12 $*$ 3 $==$ 36
  - "1" $+$ 12 raises TypeError
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- Types are only checked at runtime
- Unit tests help here
- Better input validation

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Conclusion

- VIFF provides a general framework for MPC
- Automatic parallel execution
- Free Software: LGPL
- Please see `http://viff.dk/`
  - Source code
  - Documentation
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Thank you for listening!