Ligetron: WASM as an Intermediate Representation and easy tooling for zkSNARKs

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ZKProof Policy @ DC

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Thanks
Stealth Software Tech.

What ZK application do you have for me today?

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An application

Alice:
wants to prove to Eve that she earns at least $100,000

Solution: Eve can request tax returns or W2s for the last year

Suppose that
1. Employer commits W2 or
2. IRS commits tax returns
on a public ledger (aka blockchain)

With ZK: Alice proves she has tax return or W2 that:

- Corresponds to the commitment on the blockchain
- Alice's name
- Indicates income > $100,000
- REVEAL NOTHING MORE!

An application

Muthuramakrishnan:
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- **Muthuramakrish's** name
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Ideal Toolchain to Instrument ZK

Step 1) Write the statement in typical high-level language

Step 2) Compile it to ZK

Obstacles towards the goal

Representation!

Why is this hard? Backends need

- Low-level operations - ADD/MUL gates
- Oblivious control flow – unroll loops

Current approaches

Approach 1

ZK-SNARKs need a flattened representation (i.e. circuit) and results in large memory overhead

Approach 2

VOLE-based ZK - Highly efficient (LPZK/EMP/Mac-n-cheese)

Interactive => Not blockchain friendly

“Not” succinct

“Not” Post-quantum security

Takeaway

1 hour back: “Prover time is the bottleneck” – Justin Thaler

Now – Prover space is the bottleneck

Introducing Ligetron

A Time and Space Efficient ZK-SNARK

Two Ingredients

1. WASM as an intermediate representation
2. A space-efficient variant of the Ligero ZK Proof System [2017]

Our Toolchain

- Step 1: Code application in C/C++/Rust/…
- Step 2: Compile to WASM using existing compiler (eg, emscripten)
- Step 3: Prover and Verifier take WASM code as input

Ligetron Performance

On a Browser!

On a desktop, it is ~100x faster!

- Prover: ~10 us/g
- Verifier: ~3 us/g

```cpp
extern "C" {

  inline int min(int a, int b) {return a <= b ? a : b;}

  inline int oblivious_if(bool cond, int t, int f) {
      int mask = static_cast<int>((1ULL << 33) - cond);
      return (mask & t) | (~mask & f);
  }

  int minDistance(const char* word1, const char* word2, const int m, const int n) {
      int pre;
      int cur[n + 1];
      for (int j = 0; j <= n; j++) {
        cur[j] = j;
      }
      for (int i = 1; i <= m; i++) {
        pre = cur[0];
        cur[0] = i;
        for (int j = 1; j <= n; j++) {
          int temp = cur[j];
          bool cond = word1[i - 1] == word2[j - 1];
          cur[j] = oblivious_if(cond,
            pre,
            min(pre, min(cur[j - 1], cur[j])) + 1);
          pre = temp;
        }
      }
      return cur[n];
  }

  bool statement(const char *word1, const char* word2, const int m, const int n) {
      return minDistance(word1, word2, m, n) < 5;
  }
```

C code for Edit distance

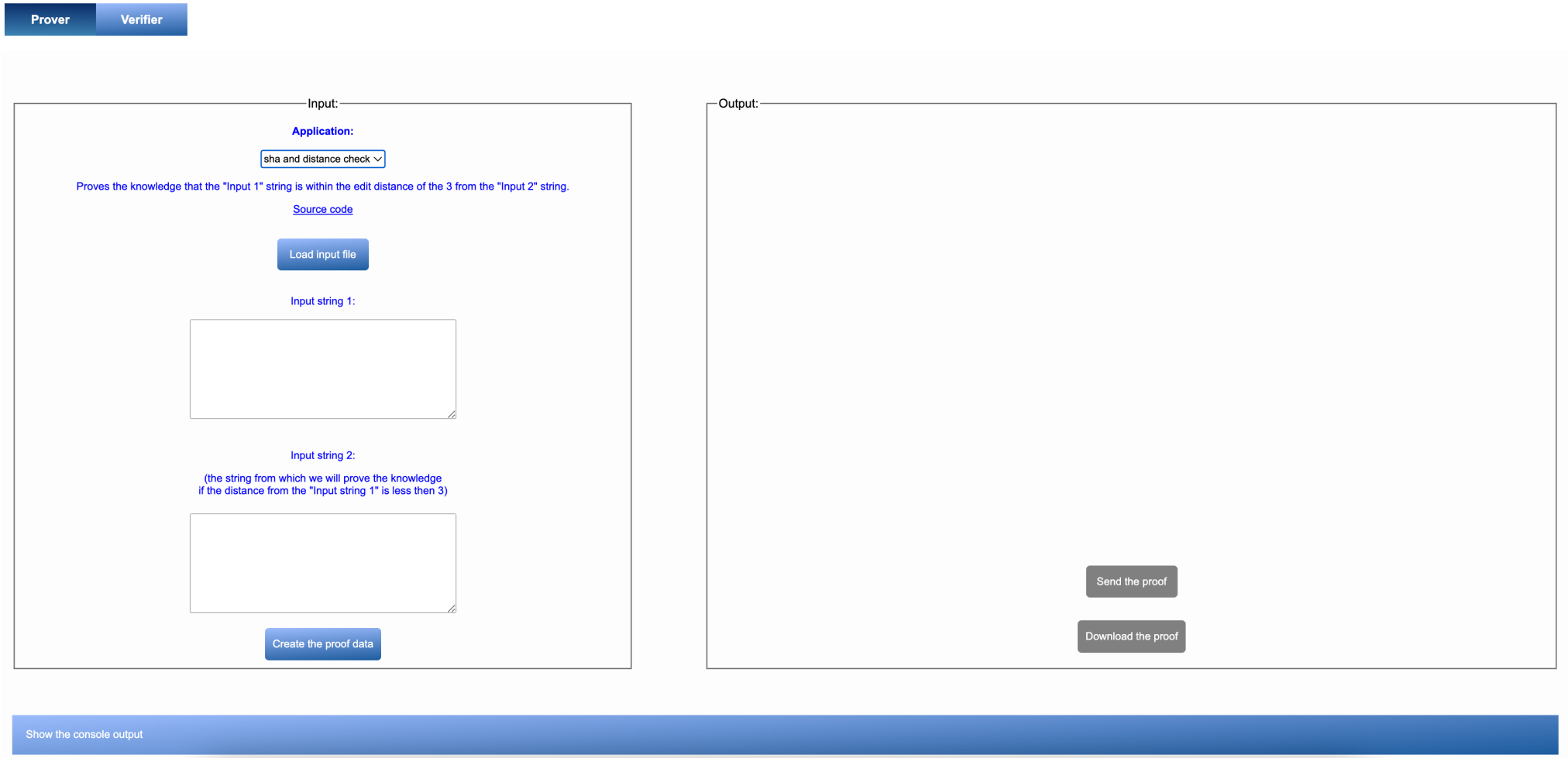
LLVM compiler

```
(module
  (type (;0;) (func (param i32 i32 i32 i32) (result i32)))
  (import "env" "__linear_memory" (memory (;0;) 0))
  (import "env" "__stack_pointer" (global (;0;) (mut i32)))
  (func $minDistance (type 0) (param i32 i32 i32 i32) (result i32)
    (local i32 i32 i32 i32 i32 i32 i32 i32 i32 i32 i32 i32 i32)
    global.get 0
    local.tee 4
    drop
    i32.const 0
    local.set 5
    local.get 4
    local.get 3
    i32.const 2
    i32.shl
    i32.const 19
    i32.add
    i32.const -16
    i32.and
    i32.sub
    local.tee 6
    drop
    block  ;; label = @1
      local.get 3
      i32.const 0
      i32.lt_s
      br_if 0 (;@1;)
```

WASM code for Edit distance

https://ligetron.com/

ZK Demo



Prover | Verifier

Input:

Application:

sha and distance check

Proves the knowledge that the "Input 1" string is within the edit distance of the 3 from the "Input 2" string.

Source code

Load input file

Input string 1:

Muthuramakrishnan

Input string 2:

(the string from which we will prove the knowledge
if the distance from the "Input string 1" is less then 3)

Muthuramakrishhan

Create the proof data

Output:

Input 1 hash: d39db8914dc6fd02cb35bc9351d6927bc3c2ce1ff27771fcfb75ccbad0c6b091

Result: true

Proof ID: 3avLlx

QR:

Execution time: 13974 ms

Circuit size: 765695

Send the proof

Download the proof

Show the console output

Text redaction

```
#include "sha256.hpp"
#include "convert.hpp"

WASM_MAIN {
    u8 out[32];
    u8 ref[32];

    int argc, buf_size;
    args_sizes_get(&argc, &buf_size);

    char *argv[argc], buf[buf_size];
    args_get(argv, buf);

    i32 len = strlen((const char *)argv[1]);

    // convert the hash from hexadecimal string representation to binary form
    hexToBin((const char *)argv[3], reinterpret_cast<u8*>(ref), 64);

    lonesha256(out, reinterpret_cast<const u8*>(argv[1]), len);

    for (int i = 0; i < 32; i++) {
        assert_constant(argv[3][i]);
        assert_one(out[i] == ref[i]);
    }

    assert_one(strlen((const char *)argv[2]) == len);

    for (int i = 0; i < len; i++) {
        if (argv[2][i] != '#')
        {
            assert_constant(argv[2][i]);
            assert_one(argv[2][i] == argv[1][i]);
        }
    }
}
```

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ZK Demo