Code Transpilation for Hardware Accelerators

Sahil Bhatia
Yuto Nishida, Shadaj Laddad, Hasan Genc, Sophia Shao, Alvin Cheung

Specialised Languages and Instruction Sets

Legacy/Unoptimized Code Needs Lifting

```python
def test(mat):
    rows = len(mat)
    cols = len(mat[0])
    result = []
    for i in range(rows - 1):
        row = []
        for j in range(cols - 1):
            row.append(
                - mat[i][j] + mat[i][j+1]
                - mat[i+1][j] + mat[i+1][j+1]
            )
        result.append(row)

    return result
```

Unoptimized Source Code

1 -1	2 1	3	4
5 -1	6 1	7	8
9	10	11	12

1	2	3	4
5	6	7	8
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2

```
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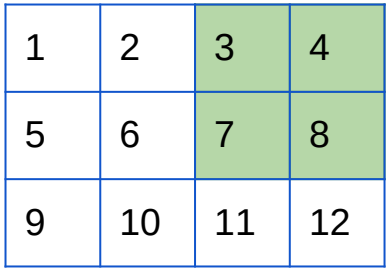


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2		

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2	2	2
2	2	

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Convolution operation with 2x2 Filter!

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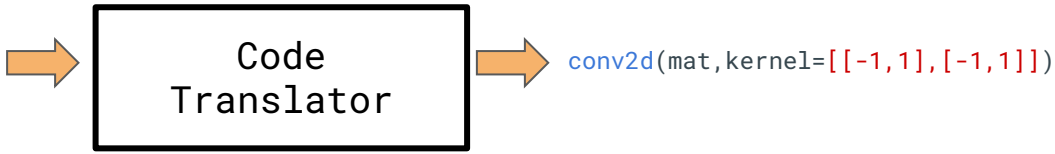
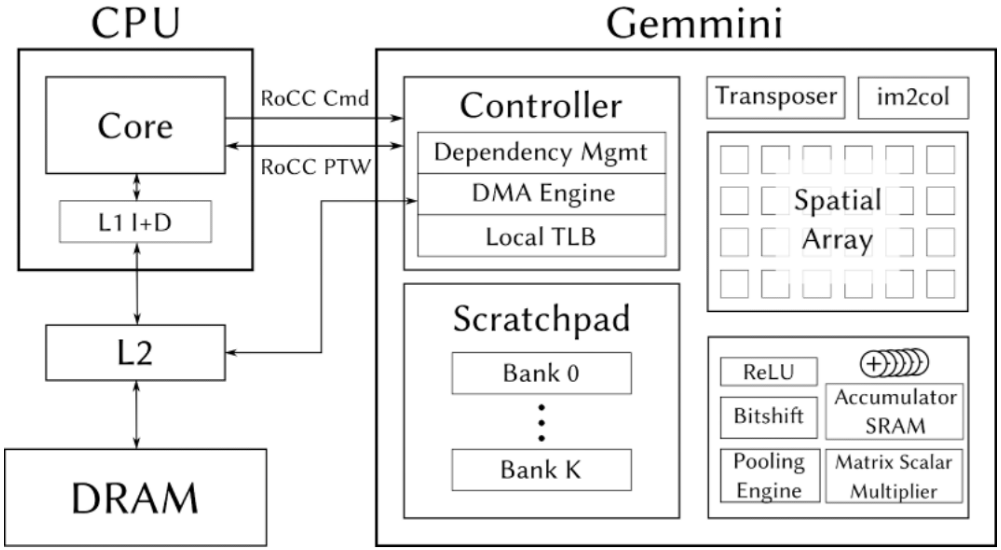


Hardware Optimized Code

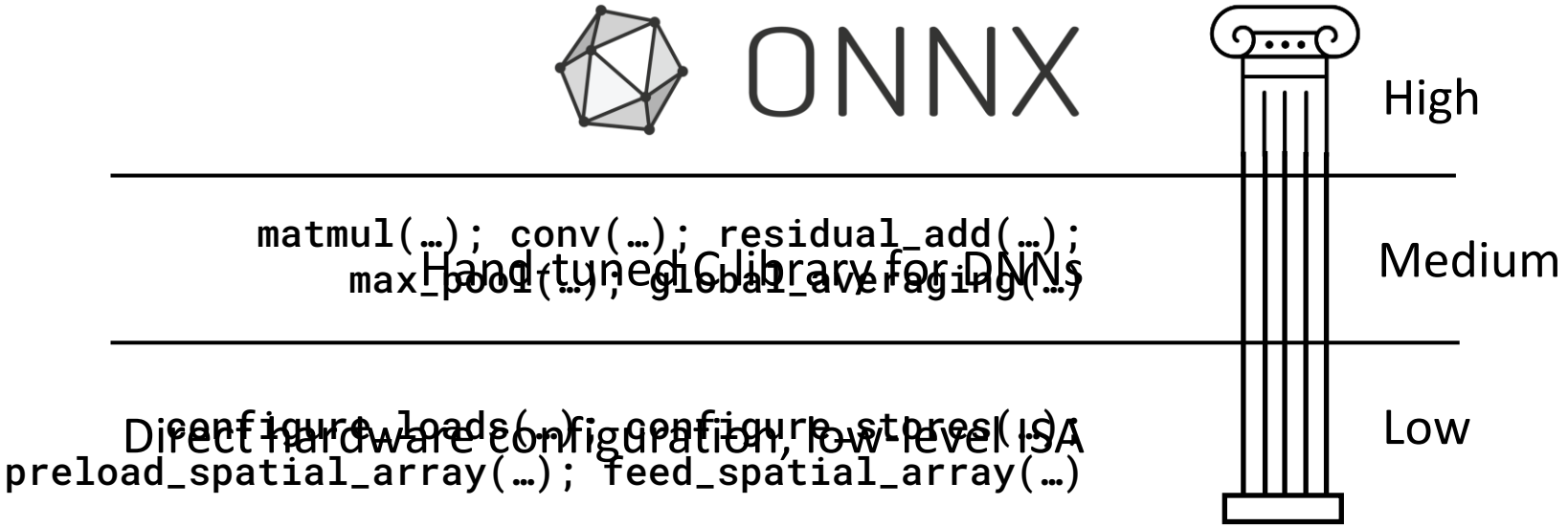
GEMMINI

GEMMINI

- DNN Accelerator Generator
- Flexible Hardware Template
- Full Stack
- Full System



GEMMINI Programming Model



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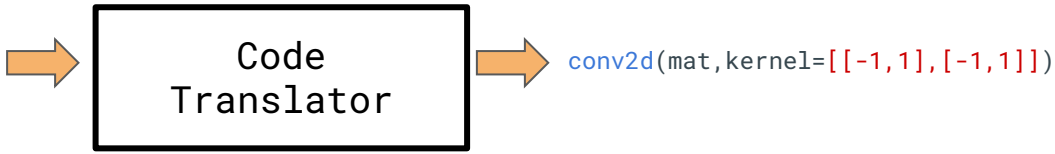

Hardware Optimized Code

GEMMINI

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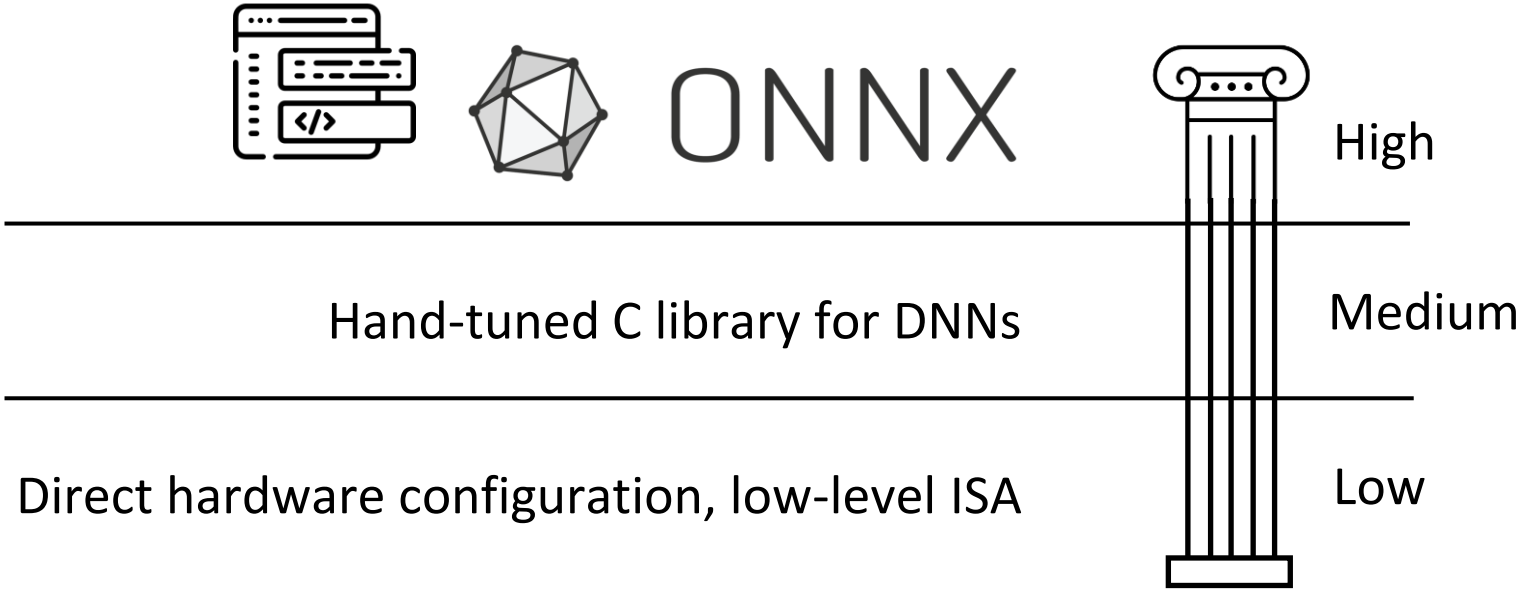

Code Translators

1. Manually Rewrite
    a. Tedious
    b. Error-Prone
    c. Infeasible for large code base

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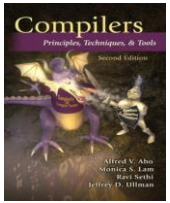
    b. Difficult to get right
    c. Hard to maintain



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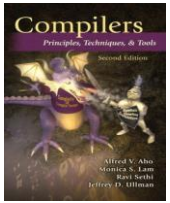
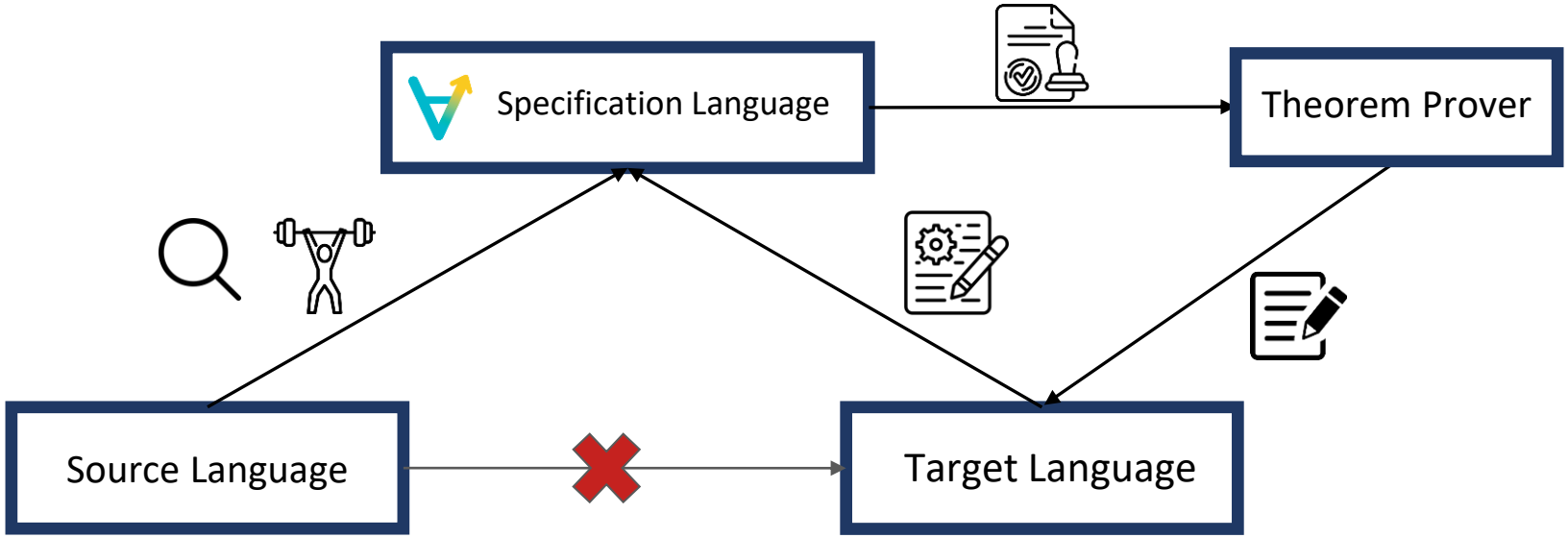


3. Neural Approaches
    a. No guarantees on correctness
    b. Struggles with new DSL/ISA

Metalift



C, C++, Python

GEMMINI

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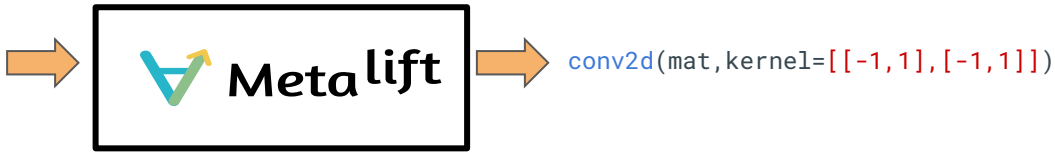
Unoptimized Source Code

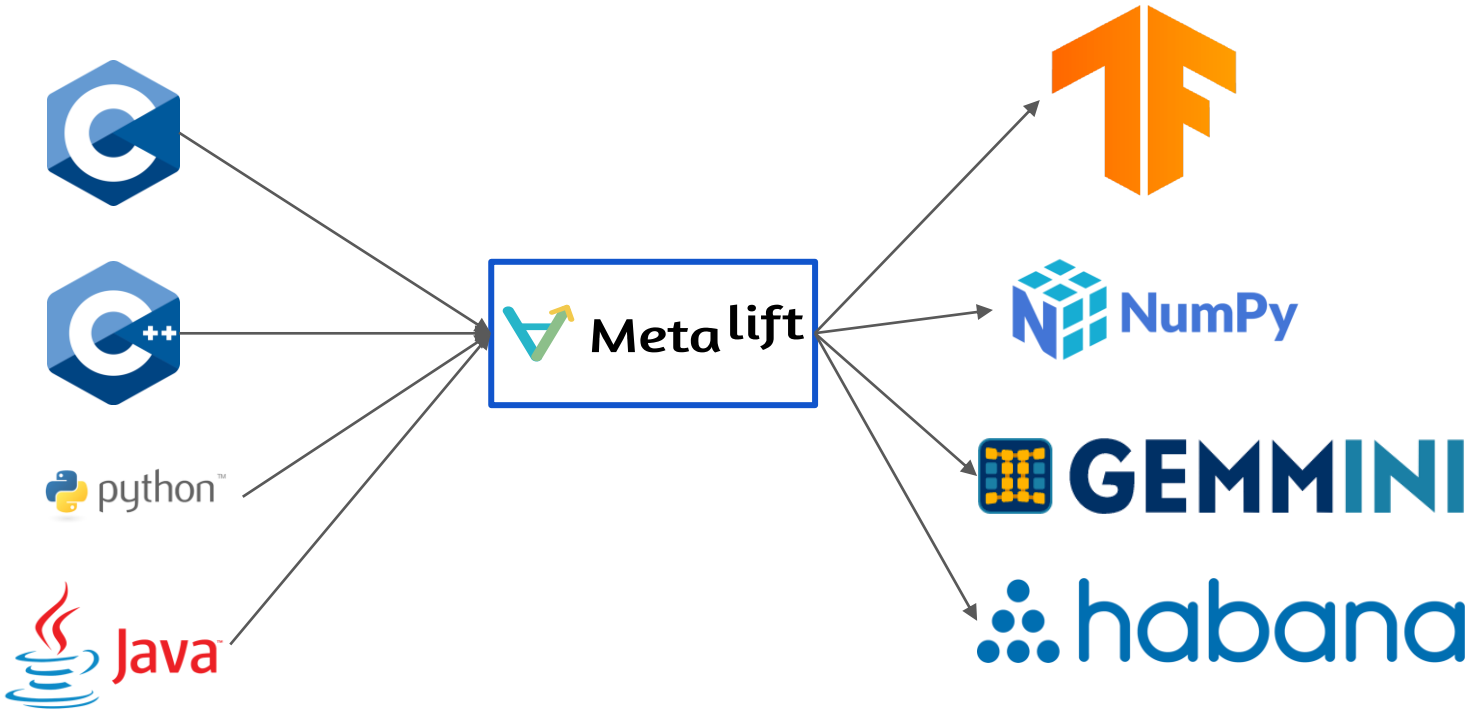


- No tedious pattern matching rules
- Code correctness guarantees
- Automated

Hardware Optimized Code

GEMMINI

Why MetaLift?



Step 1 - Defining the Semantics

```
def conv2d(inp, kernel):
    def helper(inp, kernel, i, j):
        if i >= len(inp) - 1:
            return []
        else:
            return [conv_inner(inp, kernel, i, j)] + helper(inp, kernel, i + 1, 0)
      return helper(inp, kernel, 0, 0)

def conv_inner(inp, kernel, i, j):
    if j >= len(inp[i]) - 1 :
        return []
    else:
        return
           [inp[i][j]          * kernel[0][0] +
             inp[i][j + 1]     * kernel[0][1] +
             inp[i + 1][j]     * kernel[1][0] +
             inp[i + 1][j + 1] * kernel[1][1]]
           + conv_inner(inp, kernel, i, j + 1)
```

Step 2 - Define the search space

1. Describe the output vars using the operators in the target language

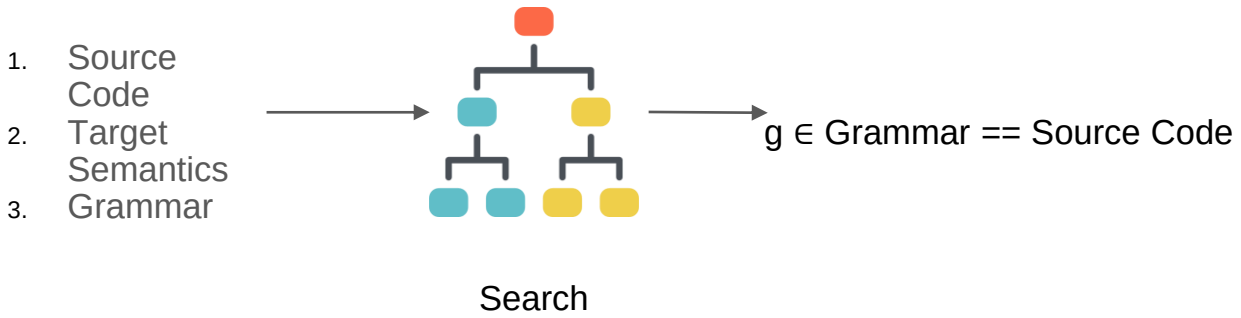
```
def grammar(mat, result):
      val    = Choose(-2,-1,0,1,2)
      result = Choose(conv2d(mat, kernel = [[val,val],[val,val]]))
```

```
result  := conv2d(mat, kernel = [[val,val],[val,val]])
val     := -2 | -1 | 0 | 1 | 2
```

Step 3 - Call our Synthesis API

1. Source Code
2. Target Semantics
3. Grammar

```
Search(grammar,target,source code)
```



Step 3 - Call our Synthesis API

```
1. conv2d(mat, kernel = [[0,0],[0,0]])
2. conv2d(mat, kernel = [[1,0],[1,0]])
3. conv2d(mat, kernel = [[1,1],[1,1]])
4. conv2d(mat, kernel = ...
5. conv2d(mat, kernel = ...
6. conv2d(mat, kernel = ...
```

```
result := conv2d(mat, kernel = [[val,val],[val,val]])
val    := -2 | -1 | 0 | 1 | 2
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Step 3 - Call our Synthesis API

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def test(mat):
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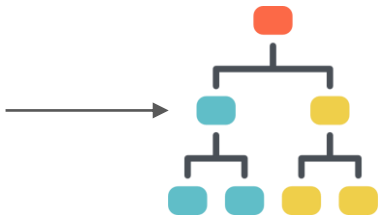

Software Synthesis

```
result = conv2d(mat,kernel=[[-1,1],[-1,1]])
```

Step 4 - Write CodeGen Rules

1. Synthesized code is in high level language

```
conv2d(mat,kernel=[[-1,1],[-1,1]])
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conv2d(mat,kernel=[[-1,1],[-1,1]])
```

- conv2d ⇒ tiled_conv_auto (Gemmini)
- conv2d ⇒ torch.nn.conv2d (Pytorch)
- conv2d ⇒ tf.nn.conv2d (Tensorflow)

From the **same representation** we can target **three different back-ends**!

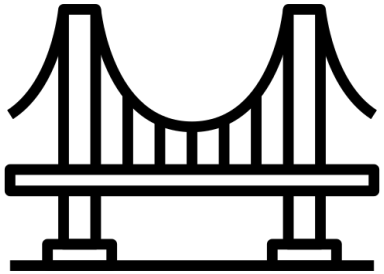
Translated Code Performance

1. Running the unoptimized code on Gemmini takes **2x** more cycles than the translated code
2. The compiler was built in < **200 LOC**

Future Work

1. Adding support for other instructions in Gemmini
2. Building the translator for other open-source accelerators
3. Optimizing the Metalift’s search to take into account the performance of the code on the accelerator

Future Work



Cost Model

- https://metalift.pages.dev/docs/tutorial/
- https://github.com/ucb-bar/gemmini

Contact: sahilbhatia@berkeley.edu