LARA Tutorial

7. *Programming Strategies for Runtime Adaptivity*

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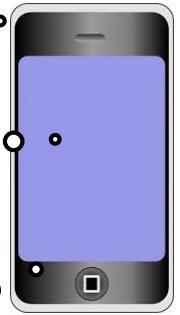
ANTAREX 10^{18}

SPeCS
Special-Purpose Computing Systems, languages and tools

Runtime Adaptation

Collision Detection?
- Fast detection
- Image quality/size

Device failure?
- Security measures
- Swap device



Low fuel/battery?
- Turn off devices
- Reduce image size

Image processing algorithm?
- Background noise
- Processing window
- Quality Requirement

Speedup process?
- Code Specialization
- Runtime compiler optimizations

Runtime Adaptation (2)

- Offline solution: compile-time specialization
  - Multiple versions generated offline – offline profiling information
  - Runtime selection
  - Impracticable in some situations

- Runtime compiler optimizations and code generation
  - Possible improvements – use of runtime information
  - Avoid code explosion
  - May impose unacceptable overhead

Runtime Adaptation in LARA

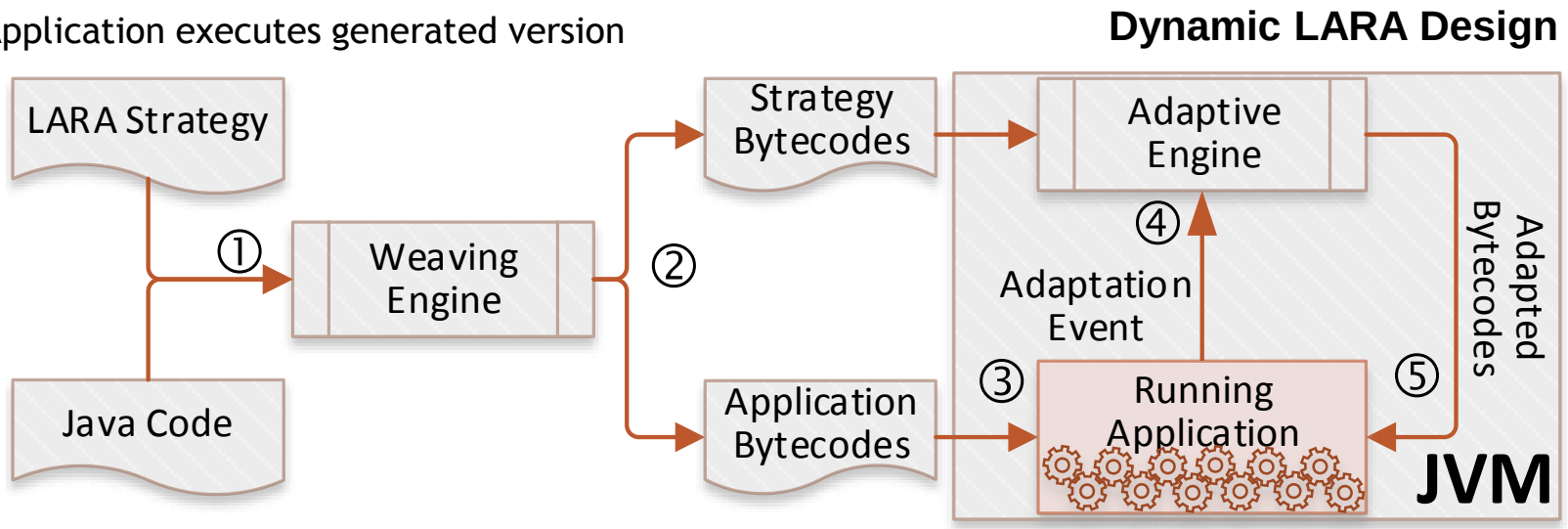
- LARA approach with runtime extensions
  - Access runtime information
  - Runtime strategy execution

- Adaptation based on:
  - Parameter tuning
  - Algorithm selection: based on predefined versions
  - Algorithm specialization:
    - selection between implementations
    - template-based code generation

- Triggered by:
  - Information attainable: when available/updated
  - Events: low battery, camera adjustment
  - Periodic adaptation: every 10 seconds, every 10 calls to a specific function

Runtime Adaptation Design

1. Target application + LARA strategies
2. Adapted application + Template-based generators
3. Application executed in the JVM
4. **Event**: generate specialized code
   - Strategy + Templates + Input
5. Application executes generated version

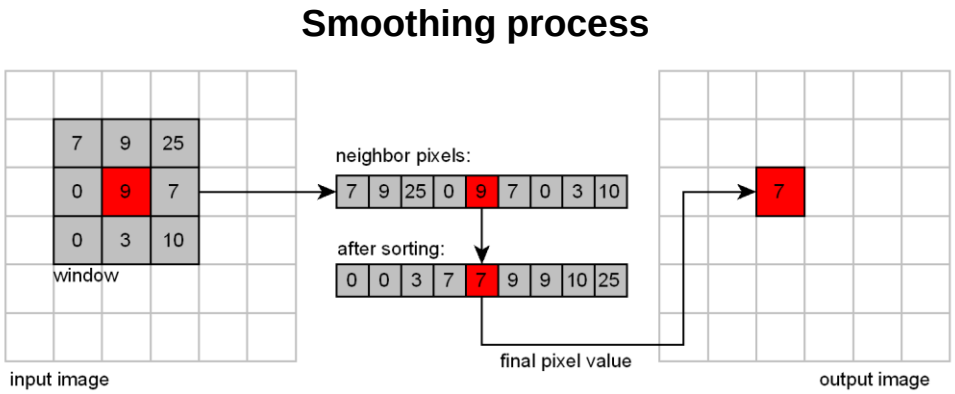


Experimental Setup

- Experiments with program specialization
- Environment
  - Ubuntu 13.10
  - Intel® Core™ i5 @ 3,20GHz * 4
  - 8GB RAM
  - Oracle JRE 1.8.0 11 Virtual Machine
- Benchmark
  - Median smooth filter (Hipr2[1])
  - Sobel (UTDSP[2])

[1] Hipr2 Library: http://homepages.inf.ed.ac.uk/rbf/HIPR2/
[2] UTDSP Benchmark Suite: http://www.eecg.toronto.edu/~corinna/DSP/infrastructure/UTDSP.html

Experimental Results: Median Smooth



✓Specialization Opportunity

1. Select best sorting algorithm
   - Window size
   - Values range (gray image: [0:255])
2. Apply compiler optimizations
   - Window size

Experimental Results: LARA Example

```
1  aspectdef BestMedianImpl
2    medianCall: select fcall{"median"} end
3    kernel: select method{"smooth"}.param{"kernelSize"} end
4    apply dynamic to medianCall::kernel
5      var bestMedian;
6      switch($param.value){
7        case 3:    bestMedian = "sorting_net"; break;
8        //...
9        case 7:    bestMedian = "counting_sort"; break;
10     }
11
12     run generator($fcall, bestMedian, $param.value);
13   end
14 end
15
```

According to *kernelSize*...

...select the best sorting template...

... and generate code based on *kernelSize*

Every call to smooth!

Experimental Results: LARA Example (2)

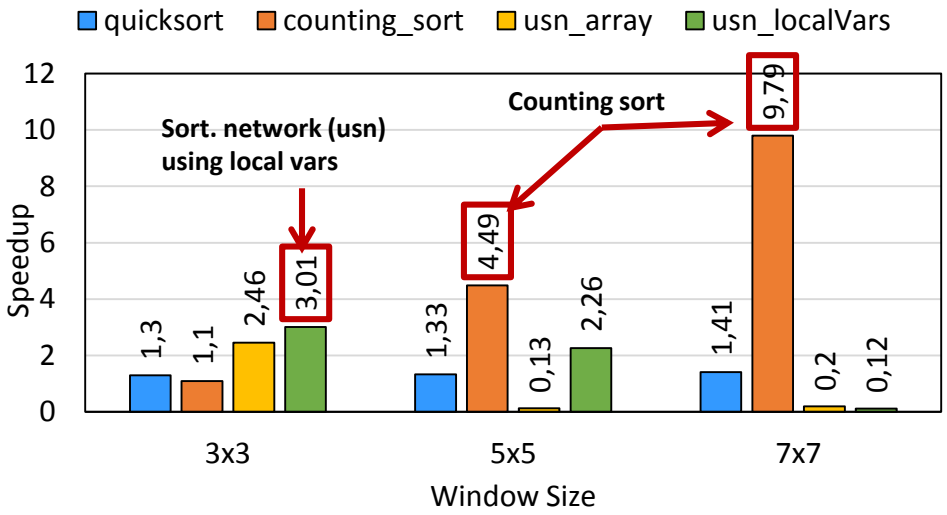
- Periodic adaptability

```
1  aspectdef BestMedianImpl
2    medianCall: select fcall{"median"} end
3    kernel: select method{"smooth"}.param{"kernelSize"} end
4    apply every 10 sec dynamic to medianCall::kernel
5      … // same as before
6    end
7  end
8
```

now we execute every 10 sec

Experimental Results: Median Calculation

- Speedups over original library implementation (Hipr2*)
- Adaptation allows changing to the best version



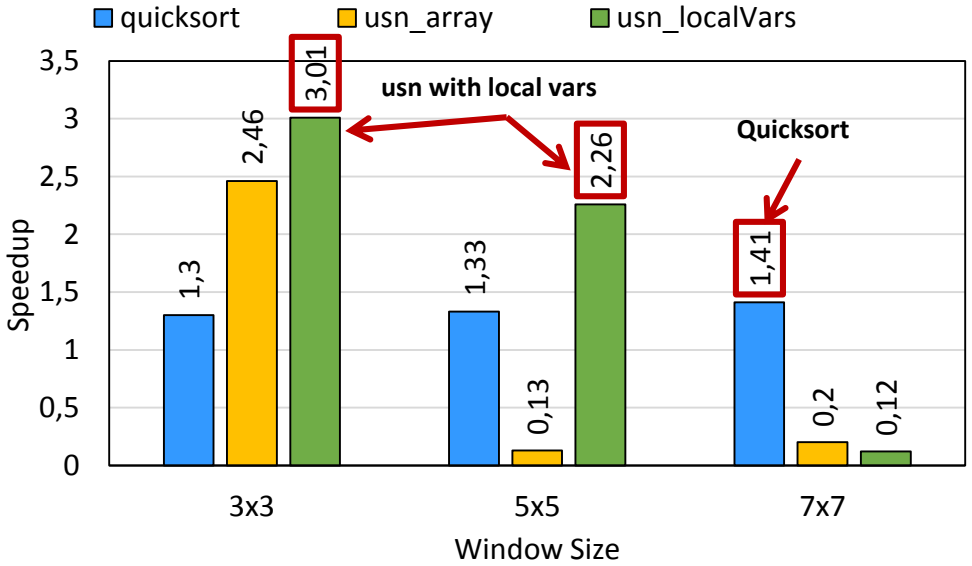
Templates:

- usn_array
  - All loops unrolled
- usn_localVars
  - All loops unrolled
  - Replace array accesses with local variables

*Hipr2, Image processing learning resources: http://homepages.inf.ed.ac.uk/rbf/HIPR2/

Experimental Results: Median Calculation

- For **input range > 256**, counting sort may not be feasible
- Strategies definition can conduct to the best speedup



Templates:

- usn_array
  - Full loop unroll
- usn_localVars
  - Full loop unroll
  - Scalar replacement

Experimental Results: Sobel

- Edge detection

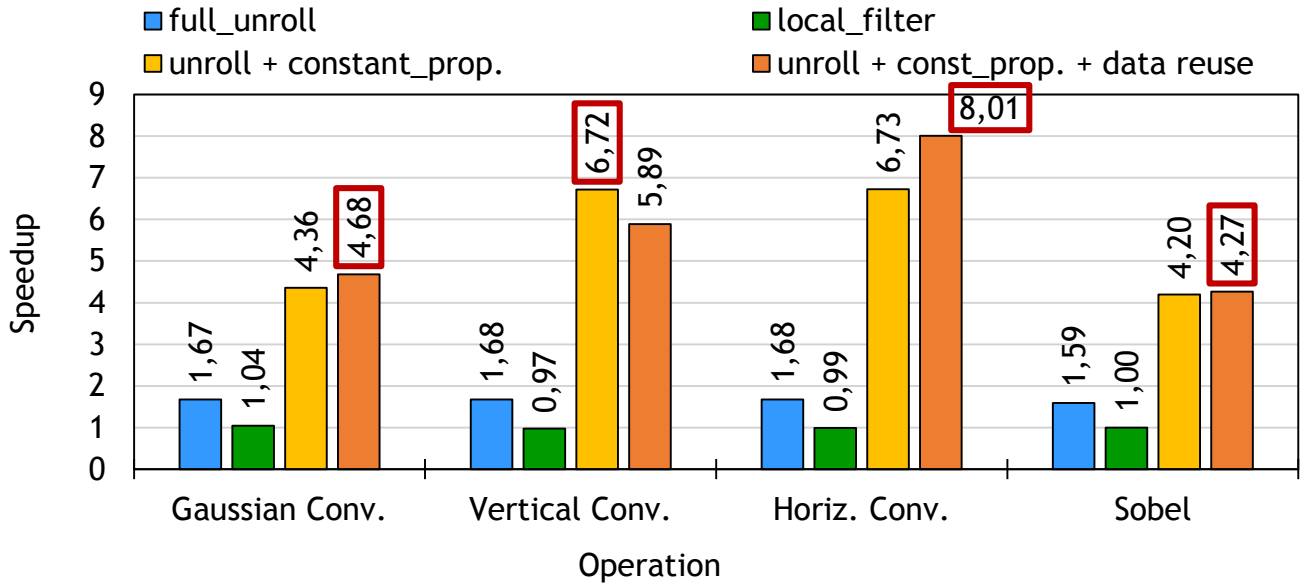
```
convolve(   gaussianCoeff); //smooth
convolve( horizontalCoeff);
convolve(   verticalCoeff);
```

✓Strategy
  - Different specialized versions for each convolution operation

- Templates:
  - full_unroll – fully unroll loops processing the coefficients array
  - local_filter - New version for each op
    - Insert coefficients array inside each new version (no loop unroll!)
  - constant_prop - Replace coefficients array accesses with corresponding constant values
  - data reuse - Reuse neighbor values in next iterations

Experimental Results: Sobel

- Speedups over the original Sobel (and convolution) version
- Example of unviable compile-time code generation
  - Coefficients array can take different values/size



Takeaway Points

- Specialization based on contextual information
  - Template-based code generation
- Adaptation: parameter, algorithm selection and specialization
- Experiments show benefits from code generation + runtime information