Sensor-Based Online Hand Gesture Recognition on Multi-Core DSPs

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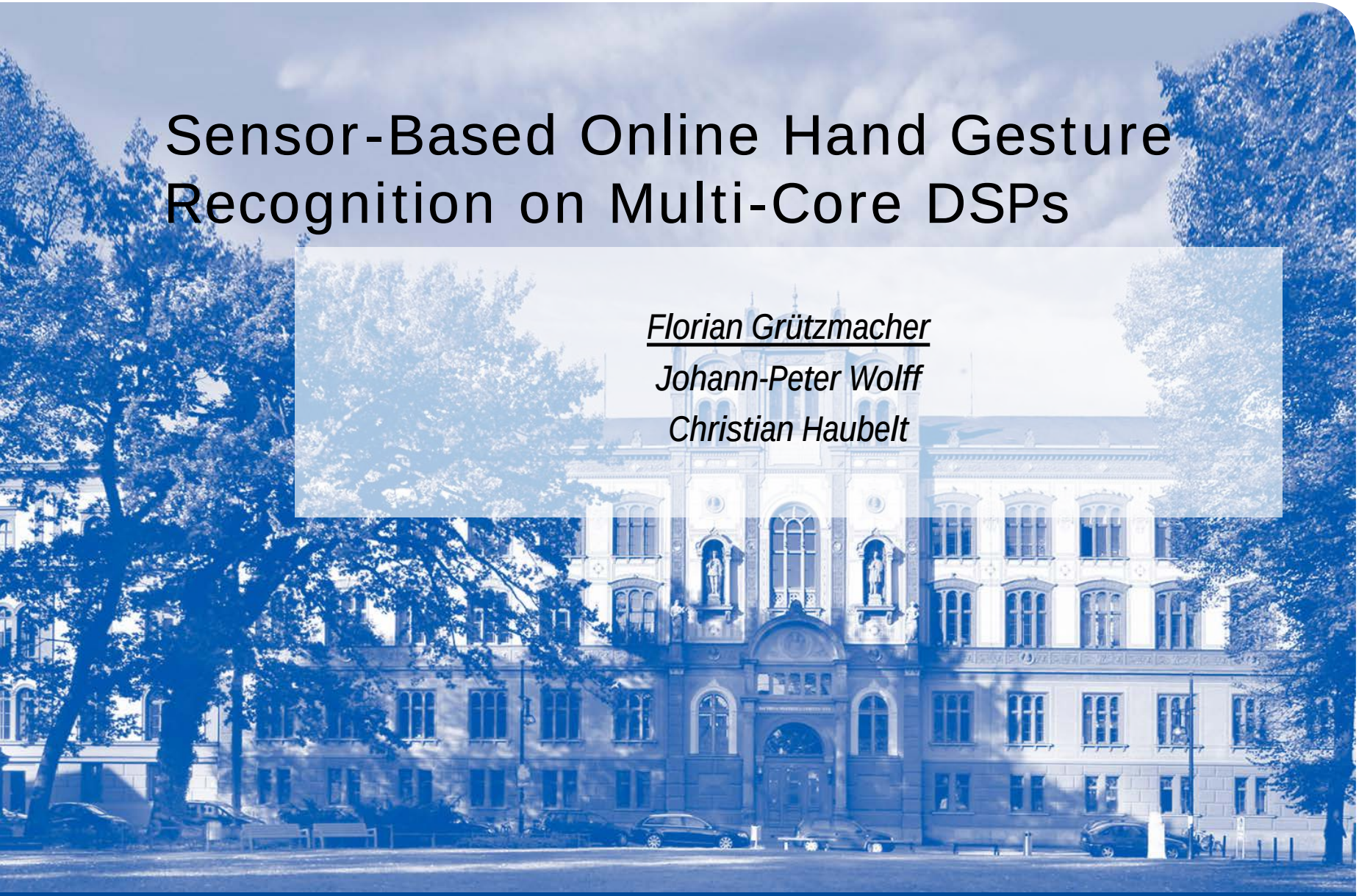
Christian Haubelt



Motivation

- Goal: energy efficient online gesture recognition
- Platform: mobile platforms
- Way: exploiting existing resources

Sources: [IDB] [SMO]

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- Mobile platforms have heterogeneous multi-core architectures
- Digital Signal Processors (DSPs) suitable for streaming applications
- First step: model-based design for homogeneous multi-core DSPs

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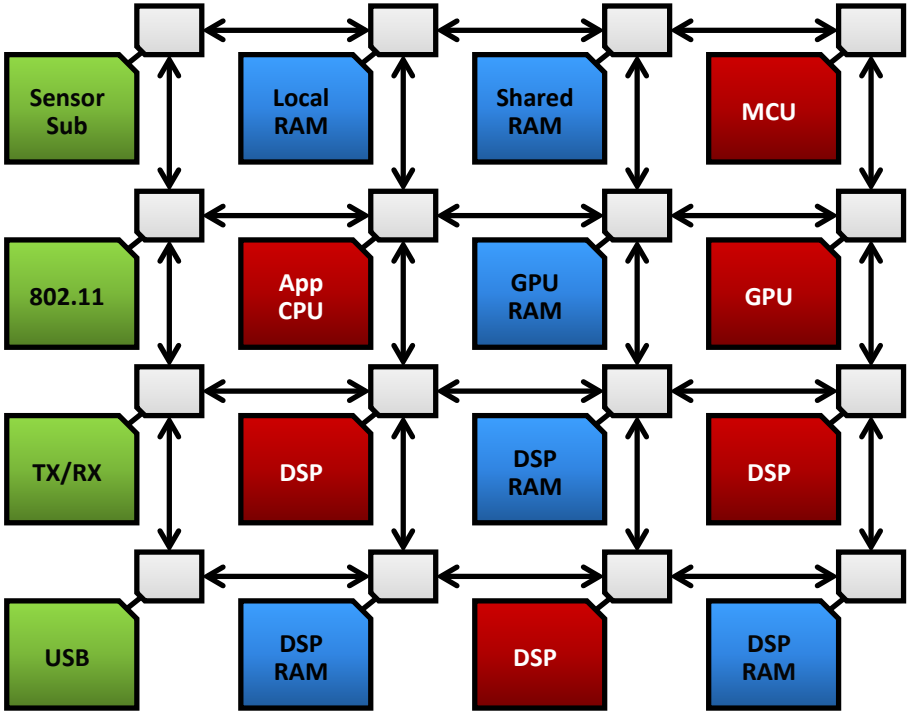

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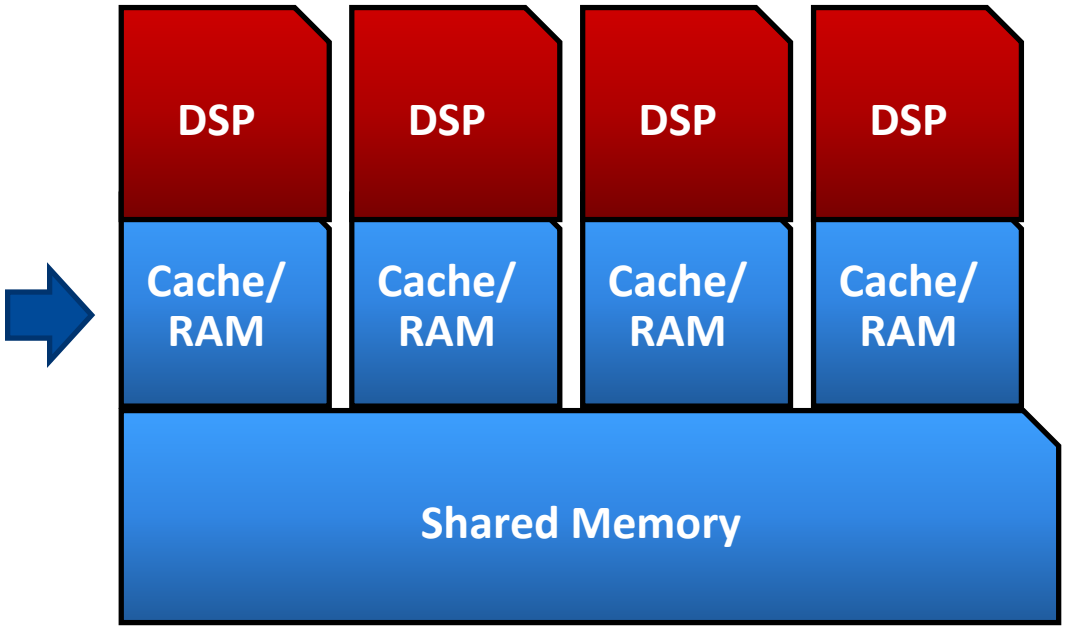

Agenda

- Basics
- Concept
- Experimental Setup
- Results
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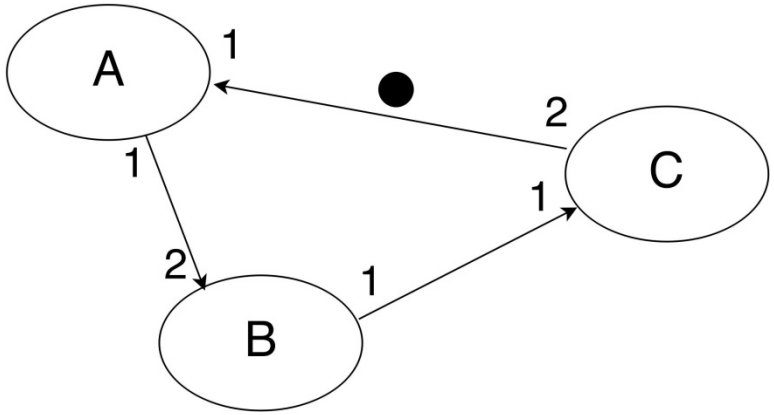
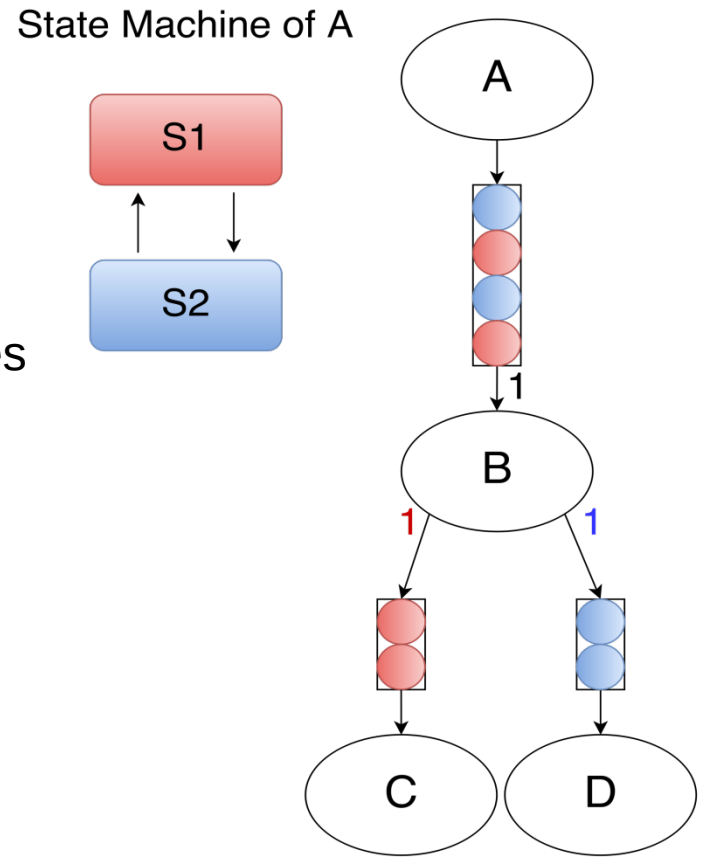
Synchronuous Data Flow Graphs

- Actors represent operations
- Edges represent directed dataflow
- Tokens represent units of data
- Actors can ‚fire‘ if data is available
- Static consumption and production rates specify firing behavior



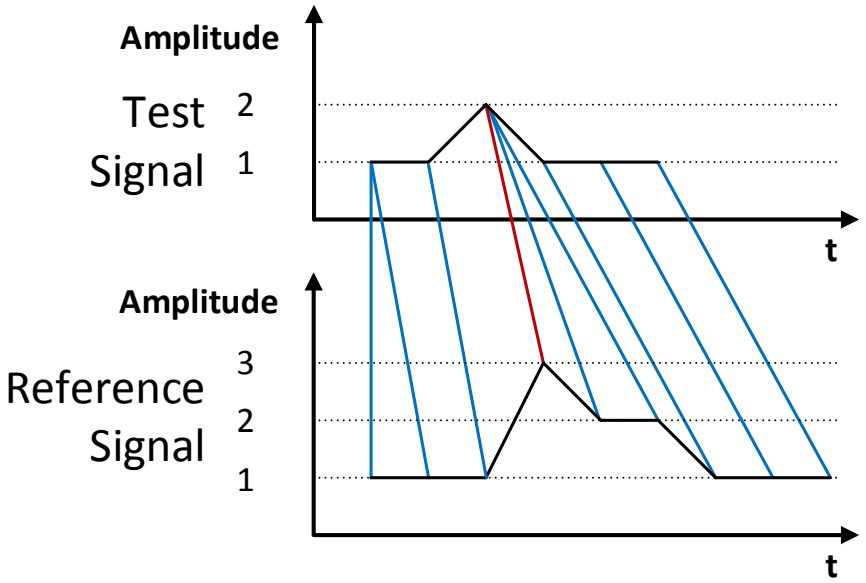
Synchronuous Data Flow Extension – Token Coloring

- Tokens can be colored
- Actors with deterministic finite state machines
- State specifies color of produced tokens
- Production rate depends on token color
- Used to model distribution of token streams



Dynamic Time Warping (DTW)

- Distance between two signals
- Non-linear warping of time axis
- Signals can have different length
- Complexity: $O(N * M)$



local distance = 0
local distance = 1

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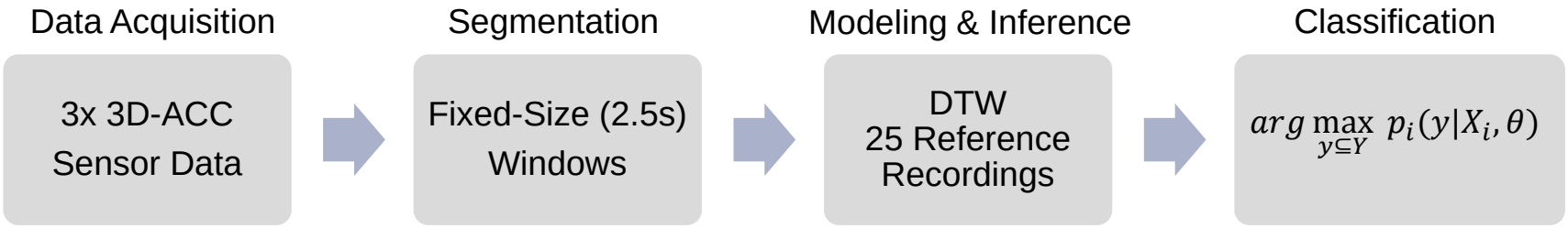
Activity Recognition Chain of our System



- Template-based gesture recognition on sliding windows
- Exploiting thread-level parallelism

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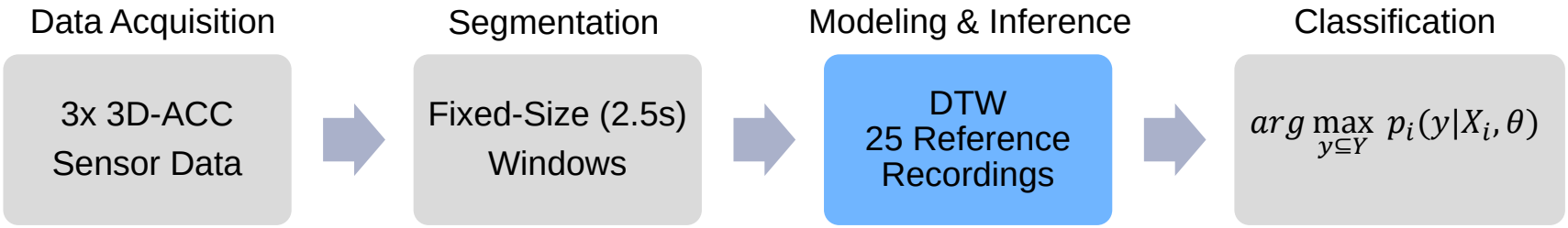
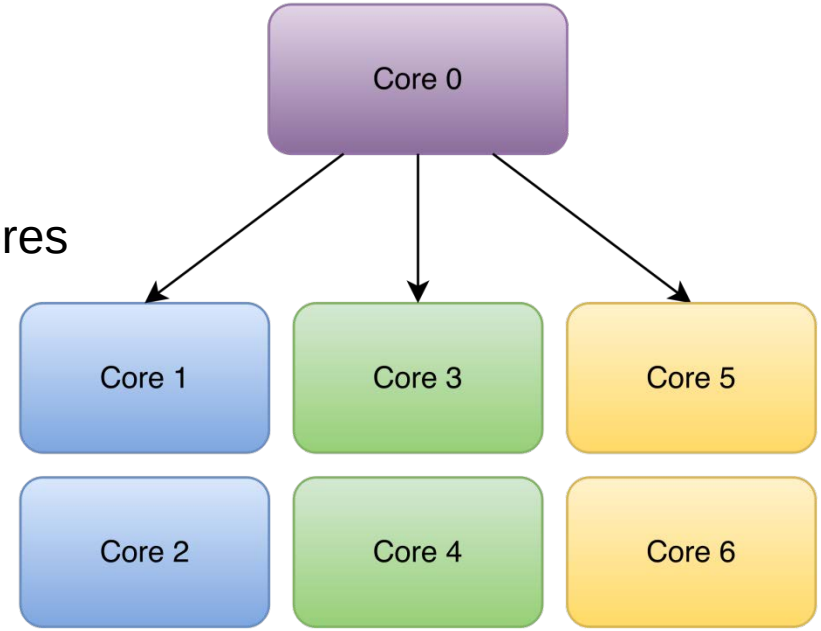


- Template-based gesture recognition on sliding windows
- Exploiting thread-level parallelism

Hybrid Parallelization Approach - Hy-DTW

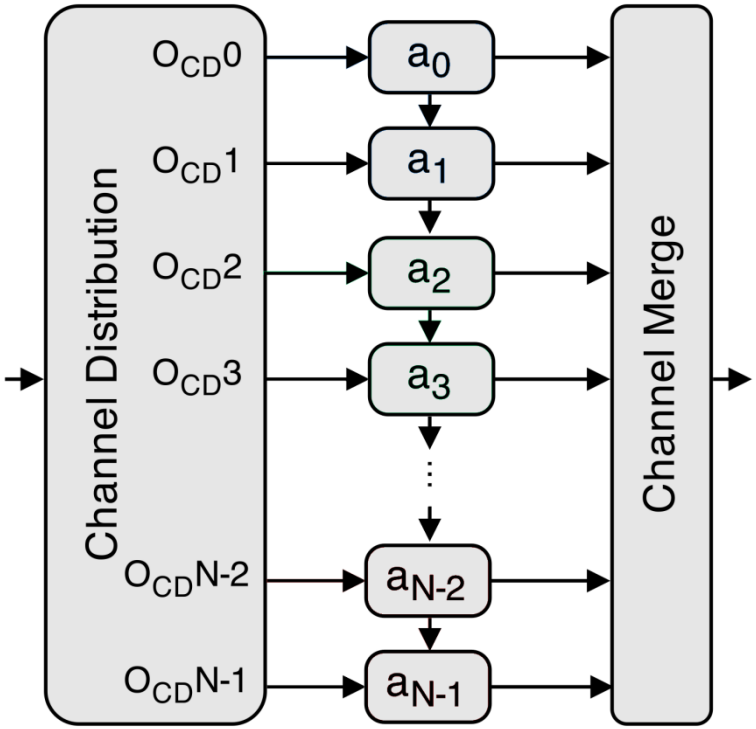
- Exploiting two types of parallelism:
  - Multiple reference recordings simultaneously
  - Consecutive sliding windows in parallel
- Initiator – Worker structure
- Tiles are logical subgroups of worker cores
- A single tile per sliding window
- Reference recordings are distributed
- Number of tiles specifies configuration



Example: 3 tiles

Hybrid Parallelization Approach - Hy-DTW

- Tiles composed of multiple actors
- Parallelization captured only by changing production/consumption rate
- a_x is DTW for reference recording x
- Multiple cores by independent channels



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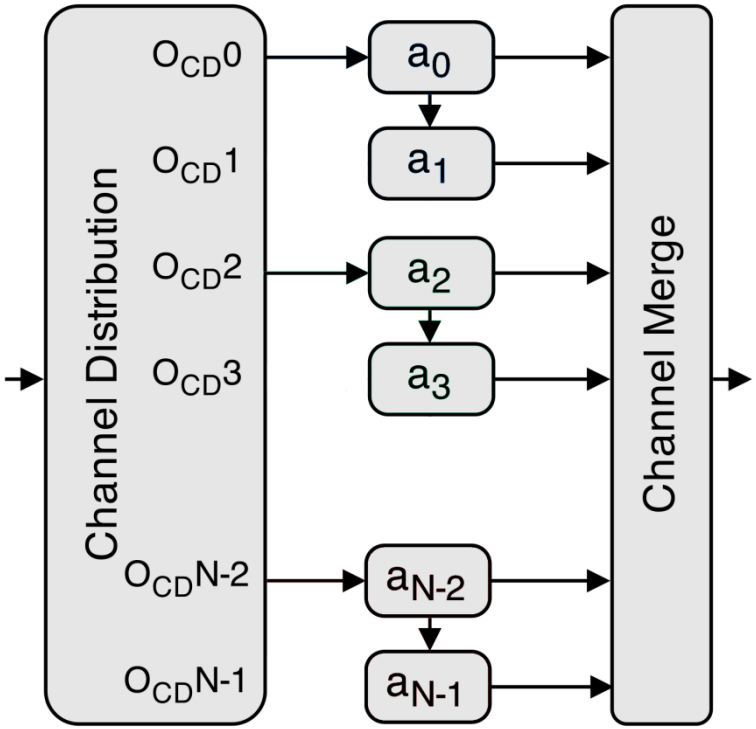

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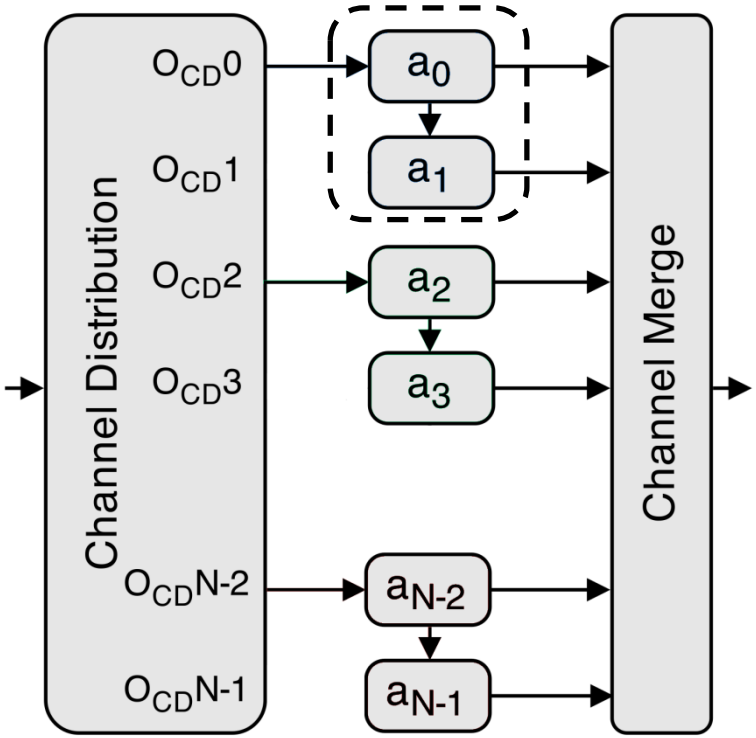

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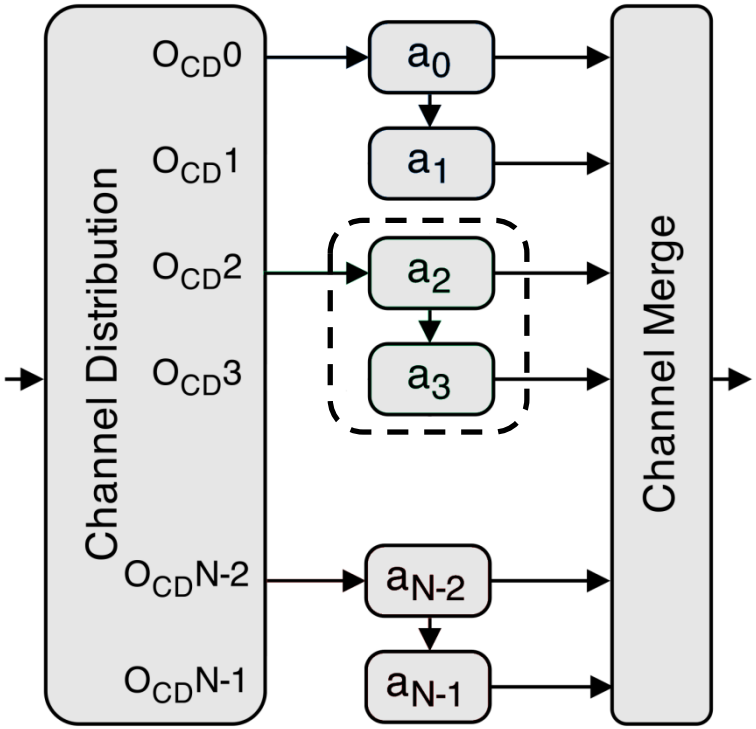

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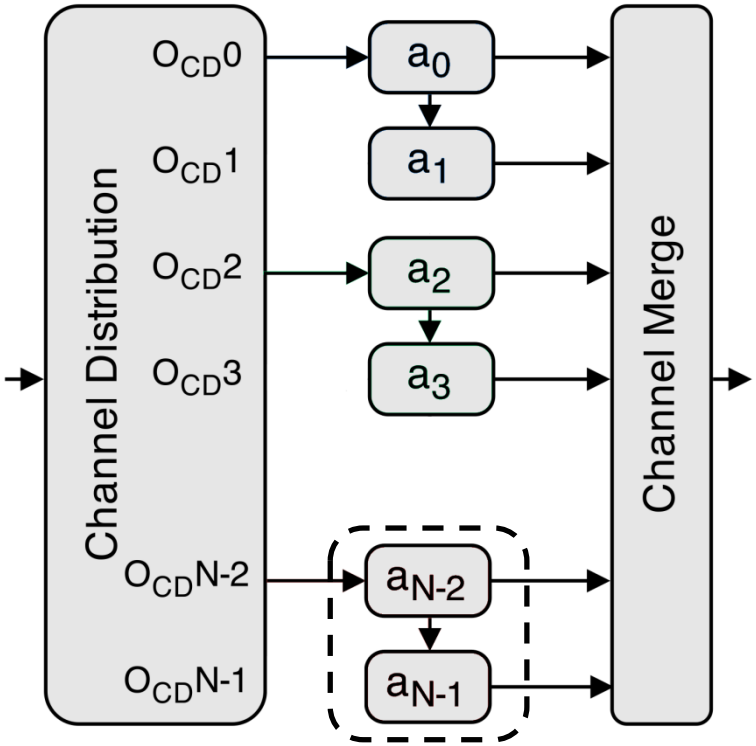
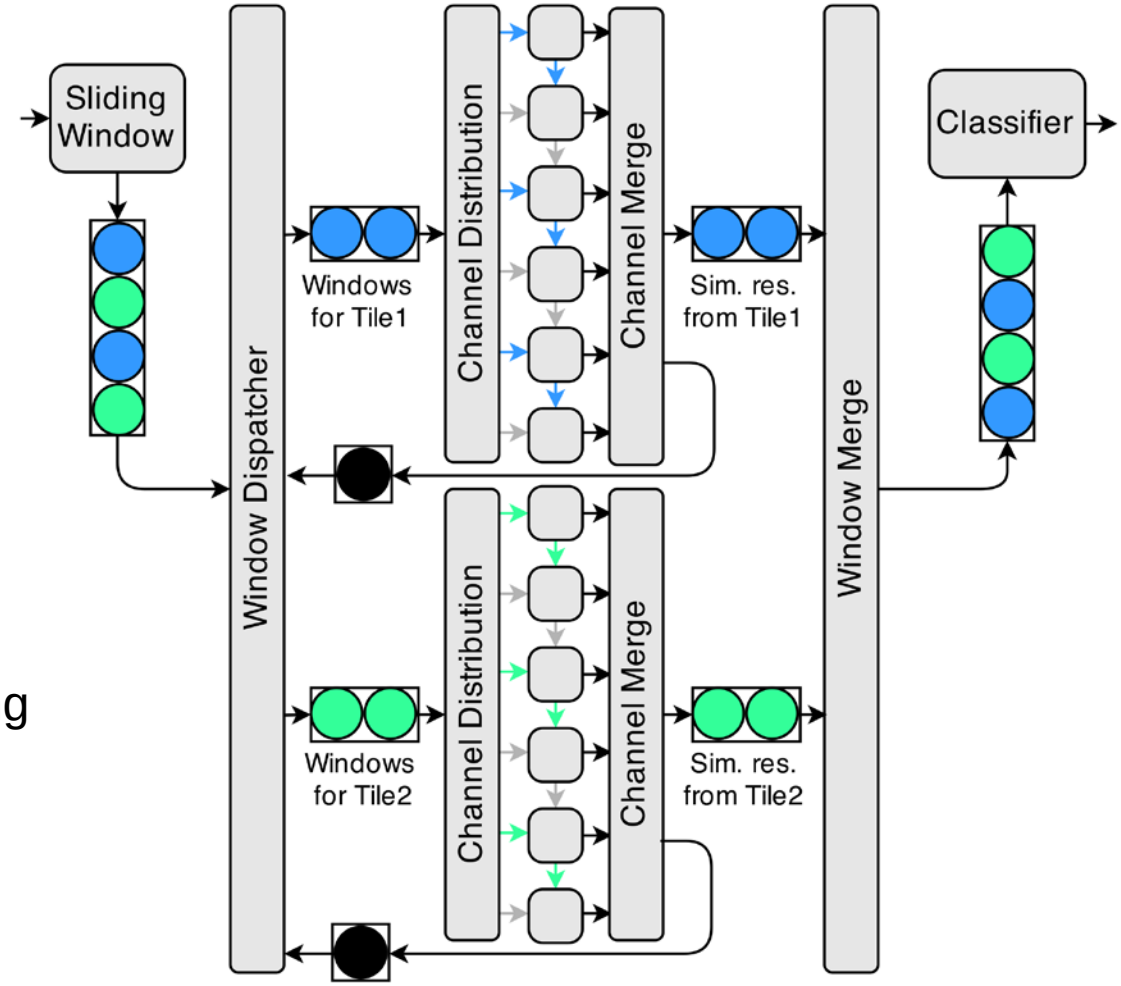


Hybrid Parallelization Approach - Hy-DTW

- 2 tiles
- 3 cores per tile
- Alternated distribution of sliding windows
- Modeled by token coloring



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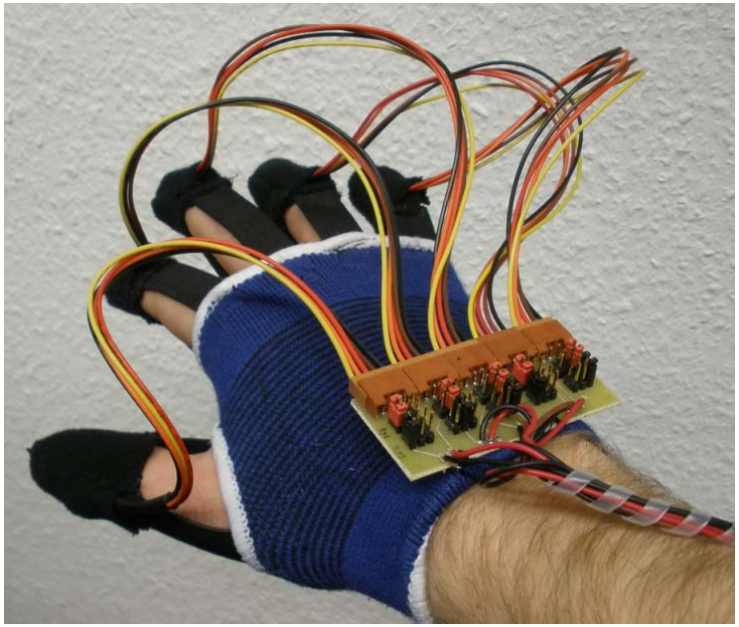
Experimental Setup



- 3 of 5 sensors were used
- 5 gestures * 5 reference recordings = 25 templates
- Single-user system
- Implemented on 8 core DSP (TMS320C6678)
- Offline tests on recorded test sequences
- Triggered sliding windows (50Hz)

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Response Time

- Measured response time processing a single sliding window
- ≈ 210,000 measured values per configuration

# Cores	Min. [ms]	Max. [ms]	Mean [ms]	σ [ms]
1	102.56	102.61	102.58	0.010
2	53.76	53.78	53.77	0.004
3	35.24	35.26	35.25	0.007
4	26.95	26.96	26.96	0.003
5	22.73	22.73	22.73	0.001
6	18.59	18.60	18.59	0.001
7	18.36	18.36	18.36	0.001

- All configurations meet real-time requirements
- Verified in experiments that no sliding windows were skipped

Recognition Performance

- Comparison of recognized gestures and ground truth sequence
  - Precision: 70.5 % (correct classifications to all recognized gestures)
  - Recall: 63.2 % (correct classifications to all performed gestures)

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Conclusions

- Configurable approach is compromise between latency and scalability
- More cores per tile or more tiles?

Attribute	More cores per tile	More tiles
Suitability	High number of reference recordings	Reference recordings can not be distributed efficiently
Drawback	Amount of reference recordings has to be balanced	Higher response time

Summary

- Configurable approach exploiting thread-level parallelism
- Extended data flow model to formally describe the approach
- Real-time performance verified
- In future:
  - Research on timed data flow models to optimize resource utilization
  - Binding actors to different resources on heterogeneous platforms

Q&A

Thank you for your attention!

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Image Sources

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