Automatic parallelization of nested loop programs with data dependent behavior

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Outline

- Application domain
- Case-study radio application
- State-of-the-art
- Parallelization approach
- Buffers with overlapping windows
- Access pattern types
- Multiprocessor compiler
- Conclusions

Application domain

Real-time stream processing car-infotainment systems

Advanced radios contain multiple processors

Case-study radio application

```
mode=0;
while(1){
   in=input();
   switch(mode){
      case 0: {
       detect(in, out mode@);}
      case 1: {
       decode(in, out mode@, out o1);
       process1(o1, out o2);
       process2(o2);}
   }
}
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Case-study radio application

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Note:

- A while-loop instead of a bounded for-loop, not in single assignment form
- Variable “in” is read multiple times
- Variable “mode” is written for both case 0 and 1
  - Multiple writing functions for “mode”
  - Conditional update
- Conditional execution of functions

State-of-the-art

- Parallelization approaches
  - Decoupled SoftWare Pipeling (Princeton)
    - Derives parallelism based on a control dataflow graph
  - Compaan (Leiden)
    - Derives maximum parallelism based upon exact data dependence analysis
  - Daniel Cordes (Dortmund)
    - Derives parallelism based upon data dependence analysis and control flow
  - *No support for data dependent behavior* (while-loops, if-statements)
- Temporal analysis models
  - Most end-2-end throughput analysis techniques have difficulties with input data dependent behavior

Parallelization approach

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mode=0;
while(1){
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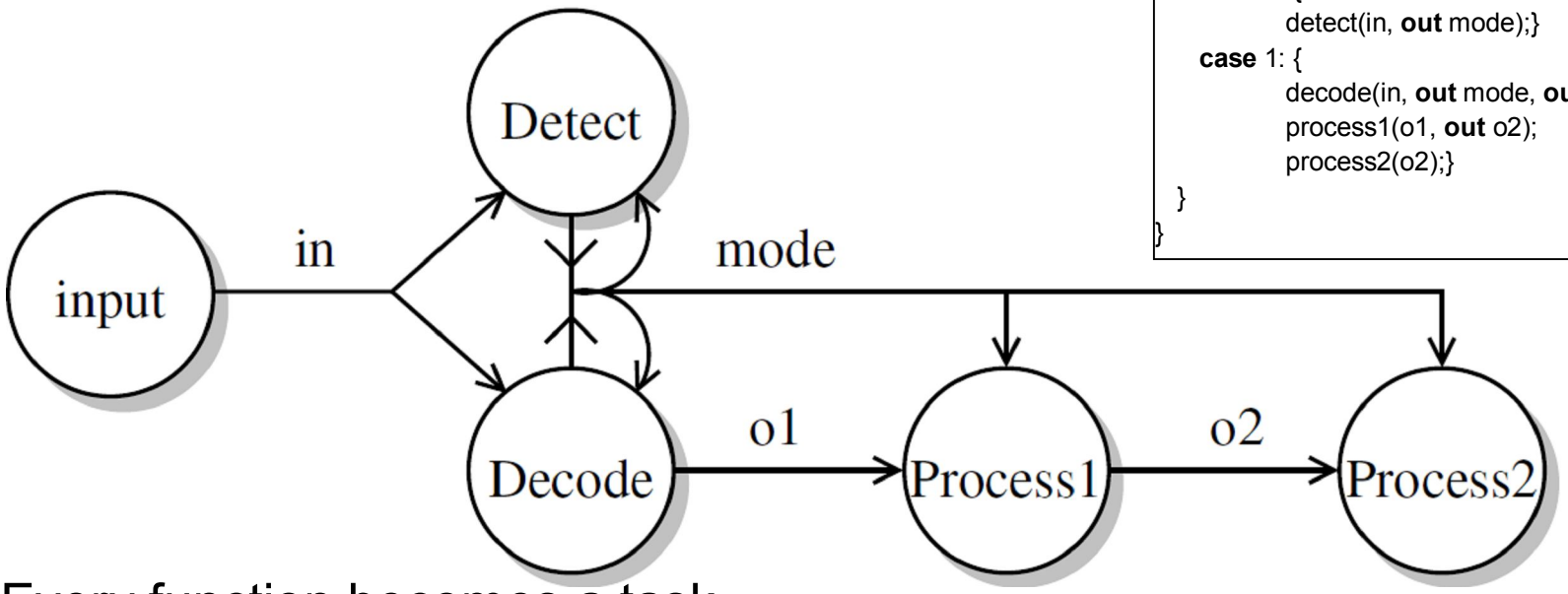
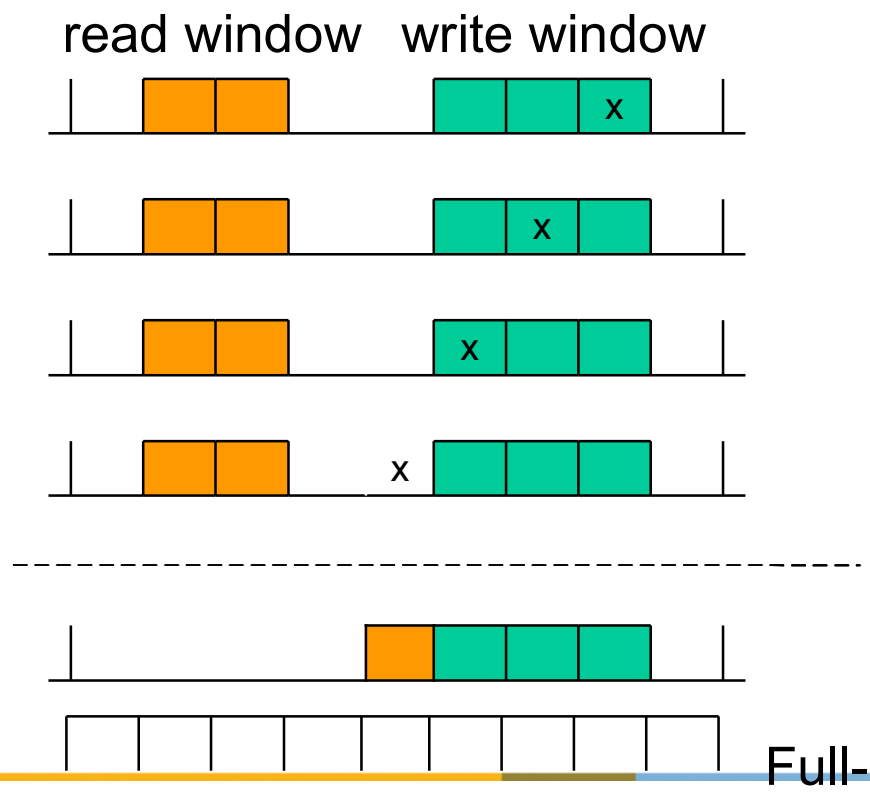


- Every function becomes a task
- A shared variable is replaced by a buffer with overlapping windows
  - Buffers support multiple readers
  - Buffers can have multiple mutual exclusive writers
    - That writes are mutual exclusive is explicit in the NLP but not in the task-graph
- A corresponding CSDF model can be derived
  - Guarantee throughput for real-time constraint
- Less restrictive form of single assignment required

Buffers with overlapping windows

- Read and write windows may overlap
  - Each written value can be read immediately, instead of at the moment that it falls outside the write window
  - Prevents deadlock in case of cyclic dependencies
- Multiple reading and writing tasks
- Array size as buffer capacity, sufficient for deadlock freedom



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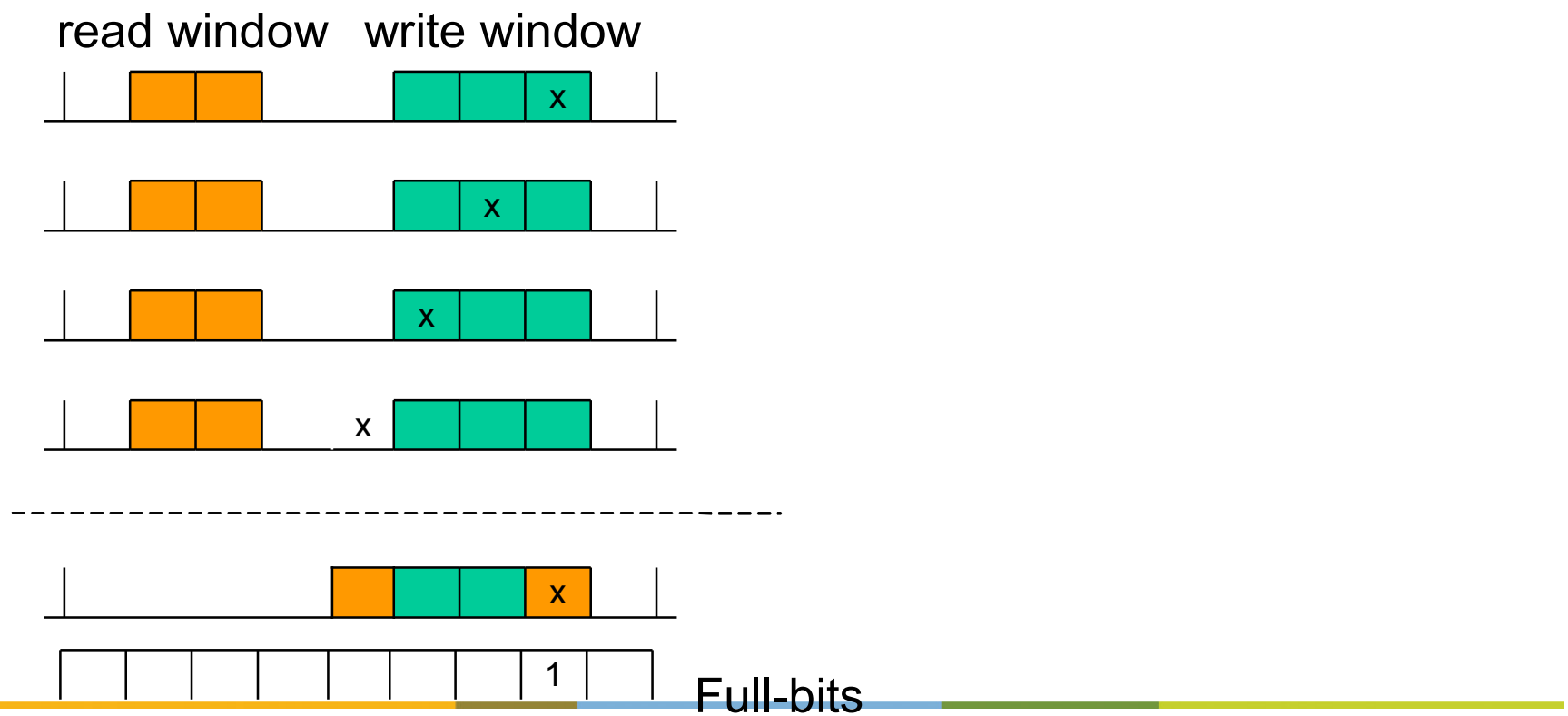
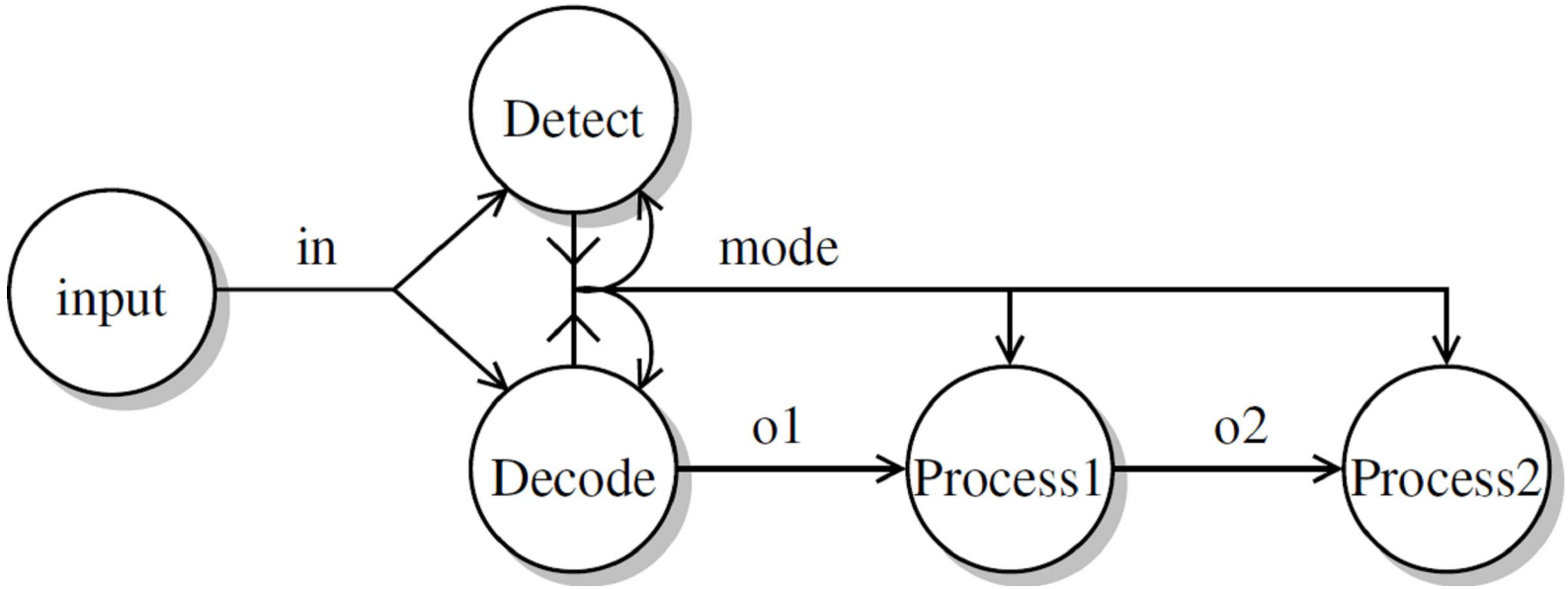


Access pattern types

- Access type indicates that there is FIFO access for variable, such that FIFO buffer can be used
  - Results in smaller buffers
  - Allows acquires and releases inside the switch statements



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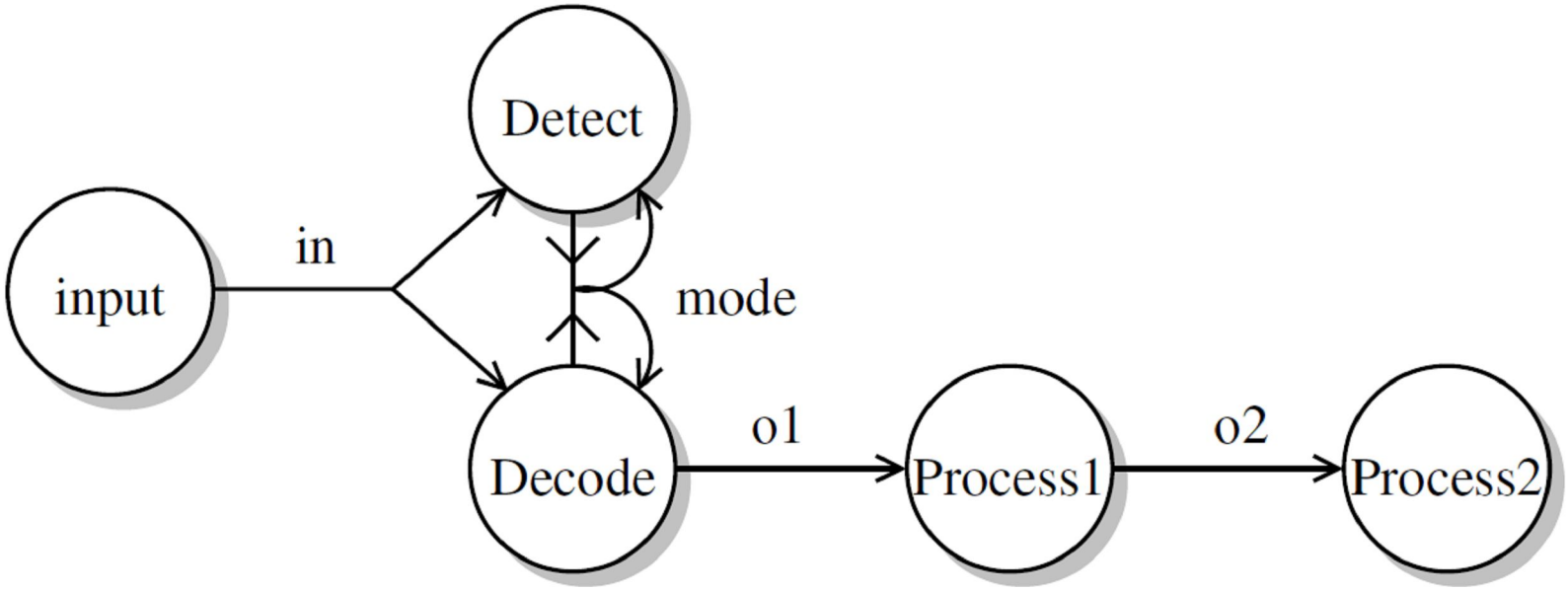
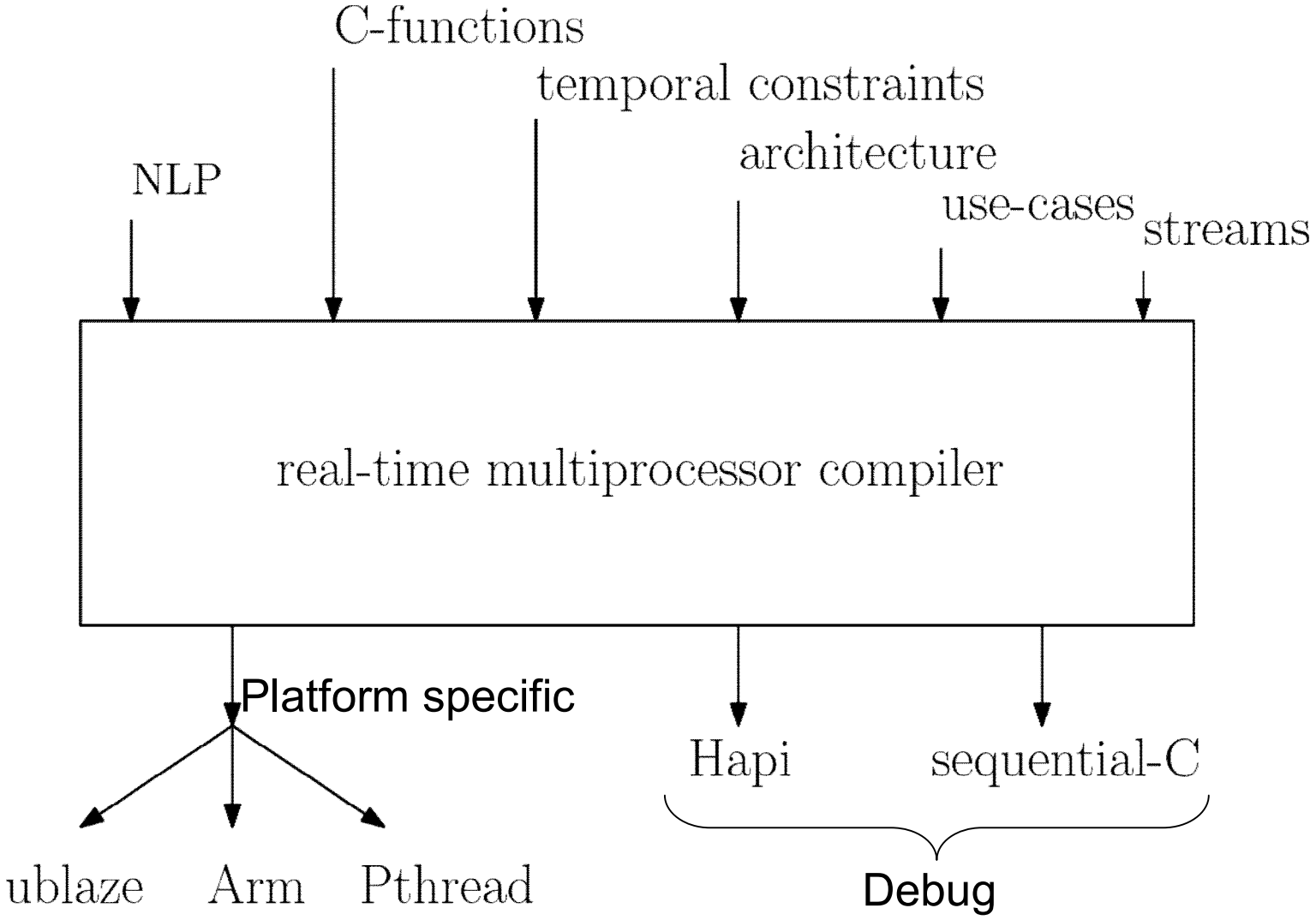
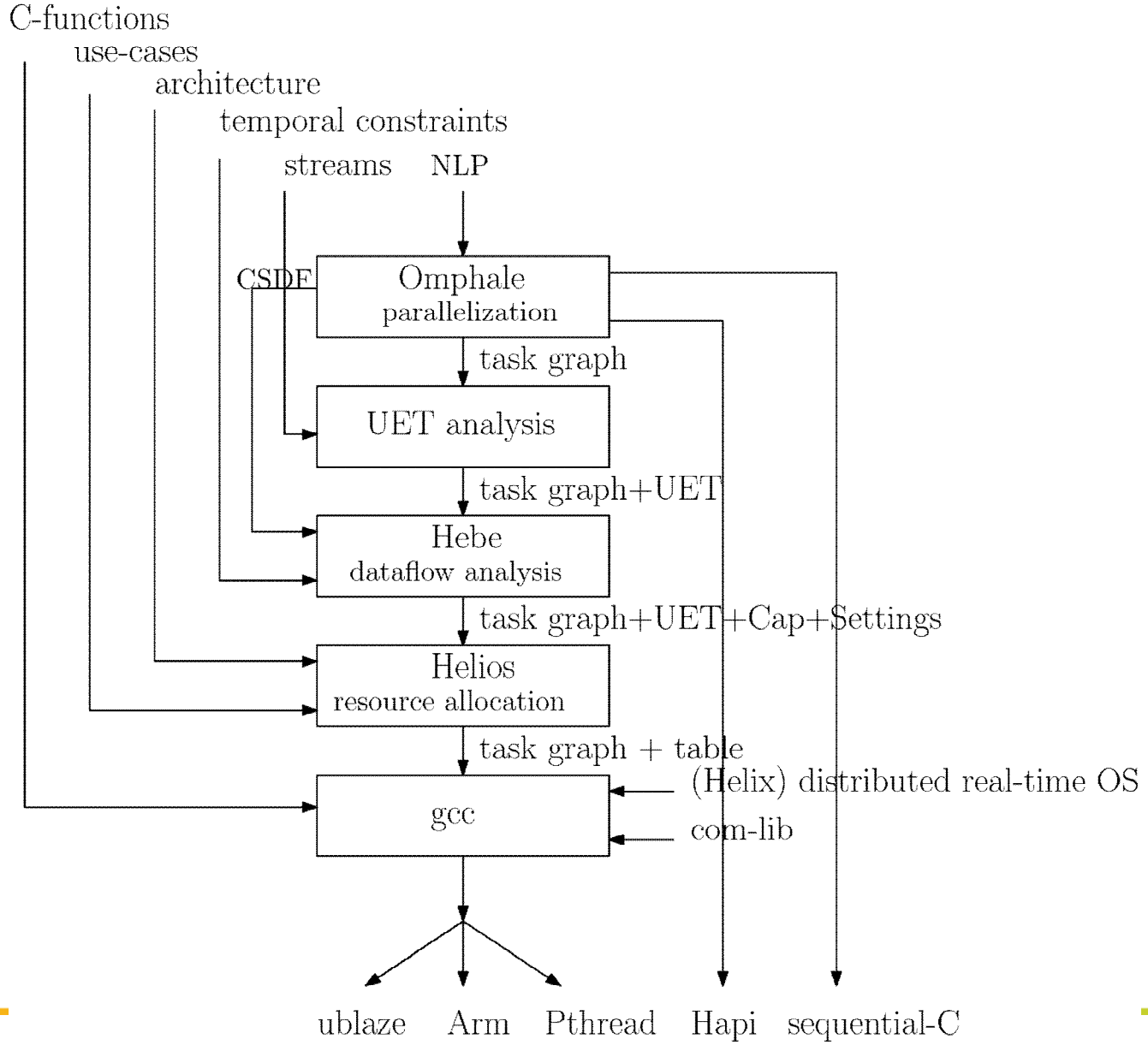


Multiprocessor compiler



Multiprocessor compiler flow



Conclusion

- Automatic parallelization
  - We can automatically extract a task graph from a data dependent NLP
    - Is (should be ☺) correct by construction
    - May contain an infinite loop for endless stream processing
    - May contain if-statements
  - Buffers with overlapping windows can be used for multiple reading and writing tasks
  - The access pattern type has been introduced
- The automatic parallelization approach is implented in a multiprocessor compiler

Questions