



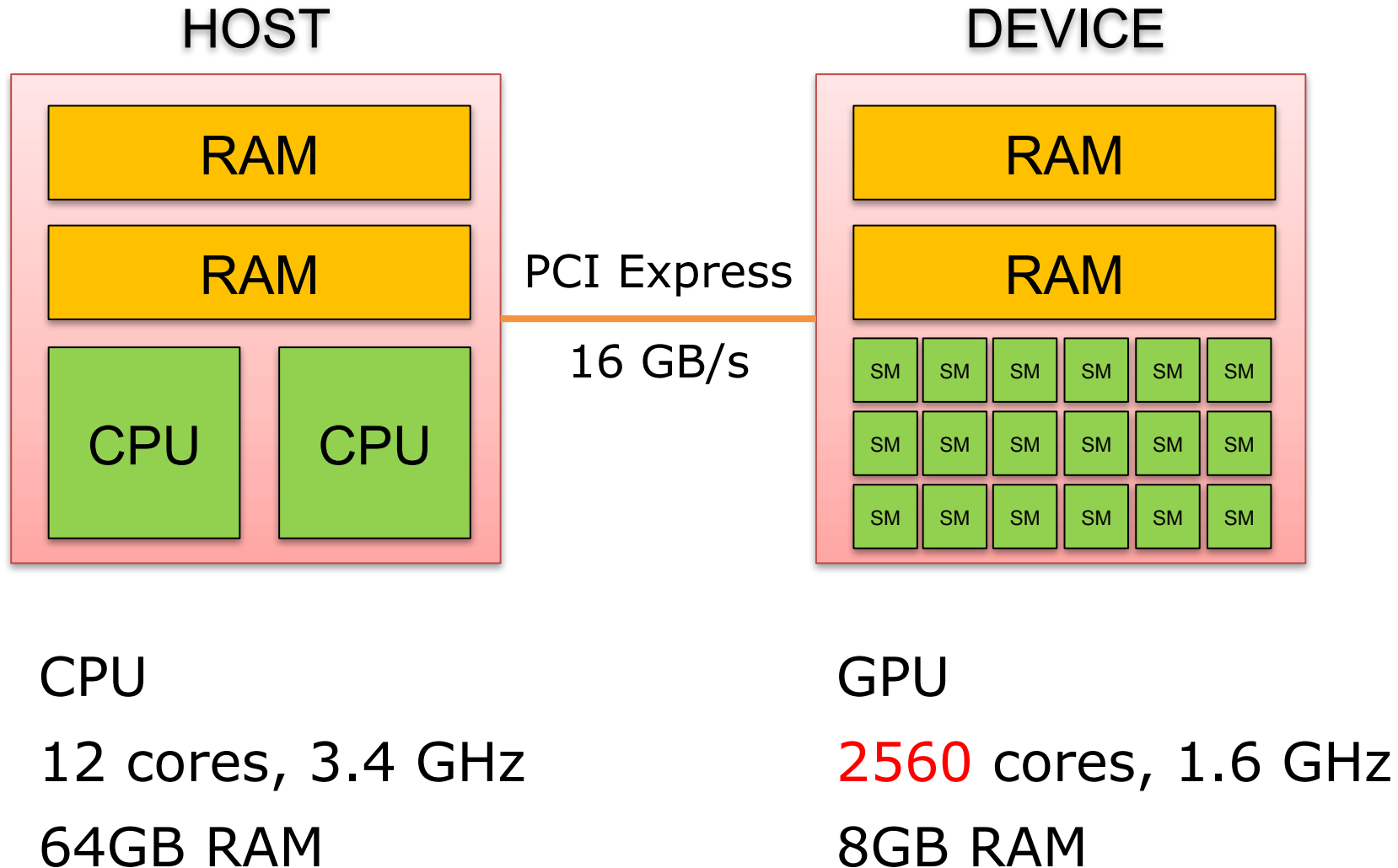
# **Parallel Computing for Mobile Robots (MA-INF 4226)**

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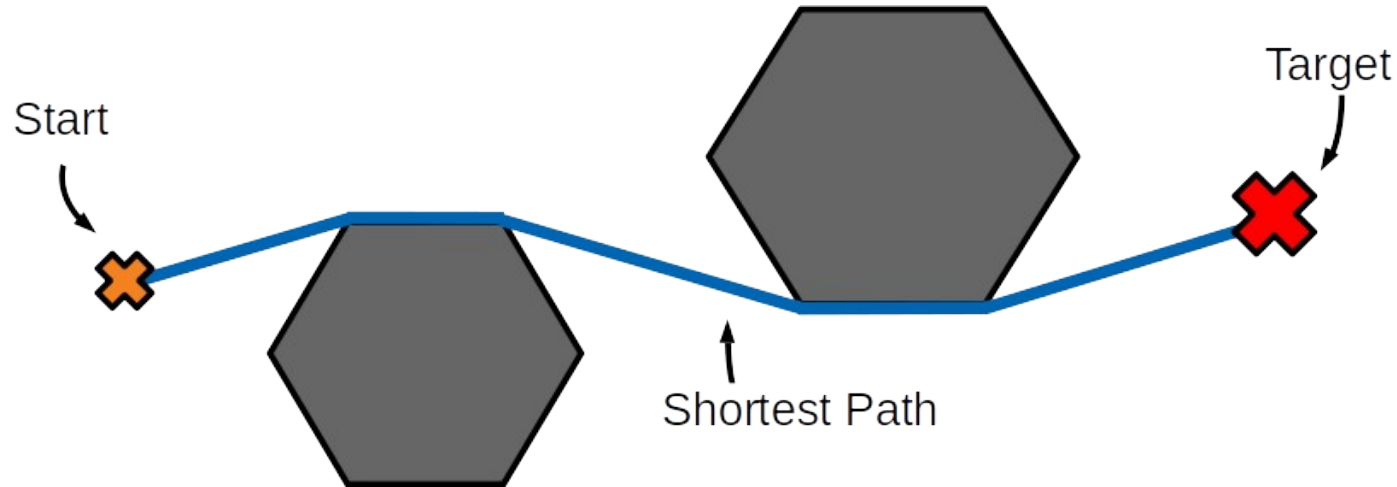
Humanoid Robots Lab, University of Bonn

# Parallel Computing with a GPU



# Lab Overview

- Learn parallel programming with CUDA framework
- Learn about shortest path planning
- Accelerate shortest path planning using parallel computing



# Agenda

- CUDA Tutorial
- Profiling: Measure and understand speed of data transfers and memory access
- Parallelization of basic algorithms (vector addition, max finding)
- Parallelization of path finding with Visibility Graph and A\*

# Workflow

- Small groups of 2 or 3 people
- Assignments communicated by email
- Communication by email, zoom and in person meetings for your questions possible
- Test code on our lab computers through remote access
- Submission of assignments via git before deadlines
  - <https://gitlab.igg.uni-bonn.de>
- Final oral exam with questions related to the tasks

# CUDA-Basics

- CUDA extends C++
- Supports kernels with `__global__` prefix
- Kernels called from host, executed on device
- Number of blocks and threads per block specified on call
- Can be three-dimensional

```
__global__ void processData(double *x, uint64_t n) {  
    int startIdx = blockIdx.x * blockDim.x + threadIdx.x;  
    for (uint64_t i = startIdx; i < n; i += blockDim.x * gridDim.x)  
        x[i] *= 2;  
}
```

```
processData<<<NUM_BLOCKS, THREADS_PER_BLOCK>>>(data, N);
```

# Memory Management

- CUDA provides its own memory allocation functions
- `cudaMalloc` → allocate memory on device
- `cudaMallocHost` → allocate memory on host
- `cudaMallocManaged` → automatically managed memory
- `cudaMemcpy` to copy between device and host
- More details:  
[https://docs.nvidia.com/cuda/cuda-runtime-api/group\\_\\_CU\\_DART\\_\\_MEMORY.html](https://docs.nvidia.com/cuda/cuda-runtime-api/group__CU_DART__MEMORY.html)

# Compilation

- nvcc compiler: `nvcc -std=c++11 main.cu other.cpp -o main`
- For your tasks: Provide compilation instructions / makefile
- Use of CMake possible

```
cmake_minimum_required(VERSION 3.24)
set(CMAKE_CXX_STANDARD 14)
set(CMAKE_CUDA_ARCHITECTURES native)
set(CMAKE_CUDA_SEPARABLE_COMPILATION ON)
project(CudaLab VERSION 0.1 LANGUAGES CXX CUDA)
find_package(CUDAToolkit)
include_directories(${CUDAToolkit_INCLUDE_DIRS})
add_executable(main main.cu)
```



# Next steps

- Registration in BASIS until 25th April
- Send email to [dawood@cs.uni-bonn.de](mailto:dawood@cs.uni-bonn.de)
  - gsg account, gitlab account, group preferences...
- Notification and instructions from our side
- First assignment after registration
- Check out CUDA C++-Guide:  
<https://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html>