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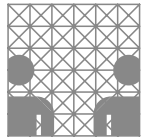

Bipedal Locomotion

Oberseminar TAMS

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Technical Aspects of Multimodal Systems

07. Januar 2020

Today I want to give you an overview of my work in the last year. It is like an update for my talk last year.

Reminder of my thesis topic:

- Bipedal walking
- Holonomic
- Low Cost hardware
- Integration with
  - falling
  - stand up
  - pathplanning
  - odometry

Table of Contents

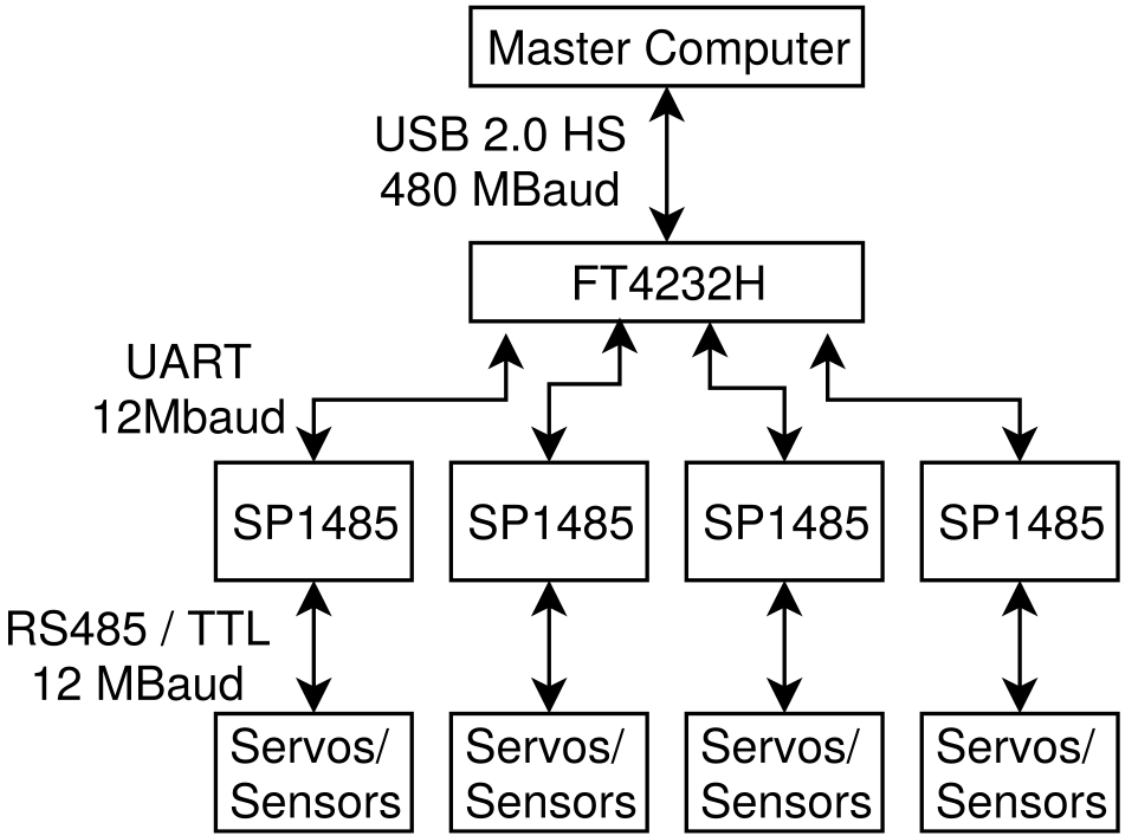
Hardware

- I had most of the necessary hardware for my thesis finished
- This year I mostly worked on improving and publishing

Servo Control

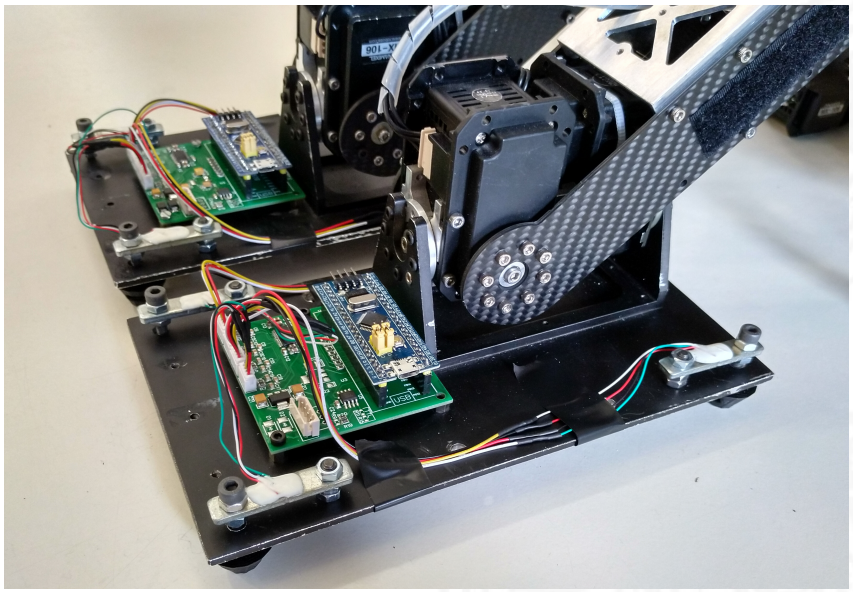
- Further work on the QUADDXL approache, presented last year
- Using a single USB-to-Serial-Chip to have four bus systems
- The goal was to reach 1kHz update cycle on the 20 Dynamixel servos
- My prototype reached 1,373 Hz (compared to current best of ca. 200Hz)
- I wrote a paper which I presented at the RoboCup Symposium
- Currently a student (Jasper) is integrating it into the robot
- Additional work was done by a student (Tobias) to create a FPGA version
  - Will probably be continued a independent study

Servo Control



Foot Pressure

- Worked a bit further on foot pressure sensors
- Able to read them with 700Hz
- Further improvements will be investigated by students
  - Replacing microcontroller for better update rate
  - 3D printing foot base for nicer integration



Falling Protection

- The robot was often damaged when falling
- Mostly broken gears due to the impact
- Flexible 3D printed bumpers were added on the torso
- Flexible 3D printed SEAs were added to the shoulders
- Most of the work was done by the RoboCup team

Dynamic Stack Decider - DSD

- Lightweight behavior framework
- Flexible like a behavior tree and simple like a FSM
- I already wrote a paper in 2018 for a workshop at IROS which was canceled
- 2019 I co-authored a new paper which is in second phase of peer review for *Journal of Intelligent & Robotic Systems*
- Some improvements were made
  - Better rqt plugin
  - Creation by Domain Specific Language
- Currently in use for the master project

Hardware Control Manager - HCM

- Allows to handle bipedal robot like wheeled ones
- Seven functions
  - Hardware error
  - Manual stop
  - Falling
  - Standing up
  - Joint mutex
  - Semantic state
- This year updated to new DSD version
- I'm currently writing the paper
- Probably will submit it in a journal

Quintic Walk

- Holonomic bipedal walk engine in cartesian space
- Parameters influence position of quintic spline points
- I implemented and presented the first version in 2018
  - Was still completely open loop
- This year I improved it
  - Complete refactoring of the code base
  - Common spline engine interface also used in kick and stand up
  - Faster speed change
  - PID torso control to improve pitch stability
  - Stopping when unstable
  - Phase reset
  - BioIK balance goal did not work
- Won the push recovery challenge in this years RoboCup
- A bit more testing and evaluation for the stability features is needed
- Learning of parameters in simulation would still be necessary
- Paper planed for this years CLAWAR

Video

Inverse Kinematics

- Walk engine computes goals in Cartesian space
- Need to be transformed into joint space by IK
- Currently BioIK (gradient method) is used
- Takes up a lot of computing power
  - ca. 1,5 cores at 200Hz control cycle
- Since no additional BioIK goals are used, I tried other approaches
- Analytic solution not easy since first three joint axis don't cross
- FastIK does not find a solution
- KDL and TrackIK work in the MoveIt! demo, but not in my code

Path Planning

- The walk engine takes velocities as input
- To be able to go to a specific location, path planning is necessary
- Due to the HCM we can handle the robot as if it has wheels
- Therefore I used the standard ROS package *move_base*
- After some initial problems it worked well
- Biggest problem was the odometry

Live Demo

RViz live demo

Odometry

- Originally I computed the odometry just by using the walk engine
- One transformation tracked where the support foot is in the world
  - After each step the goal of the step was added to this vector
- This one was combined with the current goal of the torso in relation to the support foot to get the odometry
- The error was bigger than expected due to servos in the knees not reaching the goal position
- This lead to problems with the path planning
- I wrote a new odometry, which uses the actual joint feedback
- The error was largely minimized
- A more in depth evaluation has to be done

Deep Quintic

- I want to improve the walking with RL
- My idea is to use reward shaping similar to Deep Mimic
- Normally this is done by using mocap data
- The Wolfgang kinematic is very different from humans
- Instead of using mocap, use Quintic Walk data
- Train using PPO
- Original my idea was to use RoboSchool
  - Deprecated and not longer supported
  - Multiple other problems with code base
- DeepMimic code base not usable
- Decided on PyBullet
- As validation I tried to let the robot learn to stand still
  - Active stable standing is actually interesting for push recovery
- Currently not working, I don't know why

Live Demo

PyBullet environment demo

Current State

- Robot ✓
- Robot model ✓
- Train environment (PyBullet) (✓)
- Learn algorithm (stable baselines PPO2) (✓)
- Policy network (same as Deep Mimic) (✓)
- Reward function ✗
- Real world training / evaluation ✗
  - Make robot able to withstand many falls ✓
  - HCM to stand up automatically ✓
  - Celing cam + april tag to get data ✓
  - Pathplanning to provide command velocities ✓
  - Evaluation script that provides random navigation goals and records results ✗

Further Papers

- Unrelated to this I co-authored two more papers in 2019
- Position Estimation on Image-Based Heat Map Input using Particle Filters in Cartesian Space
  - Main author Niklas
  - Published at IEEE MFI
- An Open Source Vision Pipeline Approach for RoboCup Humanoid Soccer
  - Main author Niklas
  - Published at RoboCup Symposium
- Ask me about it if you are interested

Questions?