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Gran Canaria Spain
29 May - 3 June, 2022

TELECOM Paris

INSTITUT POLYTECHNIQUE DE PARIS

3D Simulation for Disaster Management: Toward a new approach

Design genesis of an autonomous post-disaster response system

Context: disasters

- **Disaster** means **chaotic scenario**
- Lives in danger means **time matters**
- Chance to survive strongly decreases after 72 h

Problematic and our proposal

- **Intervention in (large) devastated areas**
  - Global (and fast): covering an area asap
    - Rapid mapping
  - Detecting victims
    - Use of EM from personal objects
    - GPR
  - Shall handle hostile environments

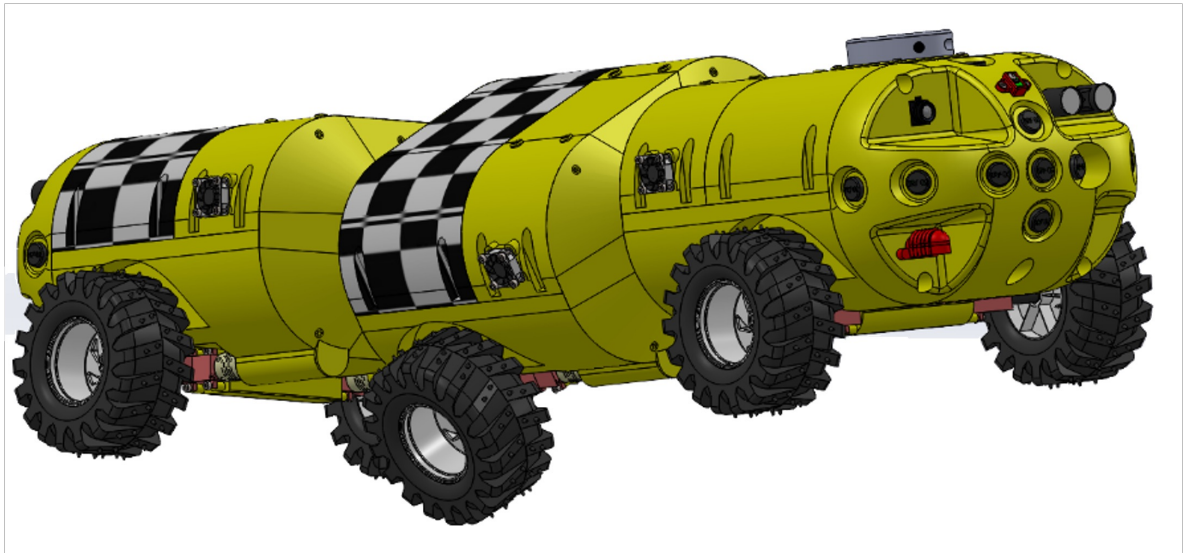
- **Our idea: designing a rover with a mission-configurable payload**
  - Autonomous - Resilient to communication loss
  - Mapping
  - Optical and IR images
  - Electromagnetic features (radars, including GPR)

TECHNISCHE UNIVERSITÄT CHEMNITZ

Prof. Madhu Chandra

Let’s welcome ArcTurius!

- **Modular**
- **Customizable payload**
  - Configurable slots for custom sensor
- **Embedded power: from 1 to 3 kWh**
- **Weight: 10 kg for classical configuration, up to 15 kg**

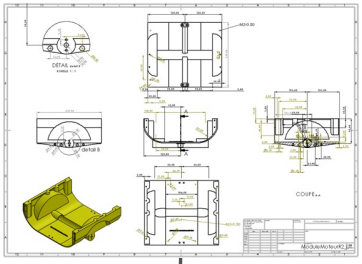


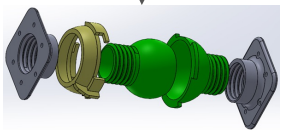
ArcTurius: typical sensors

- **Inertial unit**
  - 6 and 9 DOF accelerometer
- **Temperature, pressure, humidity**
  - Internal (LiPo, motors), external (environment)
- **Magnetometer**
- **Surroundings capture** (LIDAR, Sonar, camera, etc.)
- **Wheel rotation control for better traction control**
  - 3592 ticks per wheel revolution, 2 encoders per wheel
- **Power consumption tracking**
- **Attitude (anti-overturn control)**

ArcTurius: development process

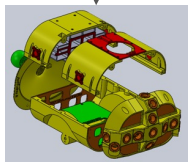
3D design



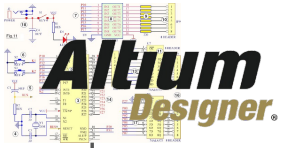


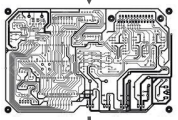
Mechanical Validation

3D Print



HW design





SW design

SysML Model

Safety verification

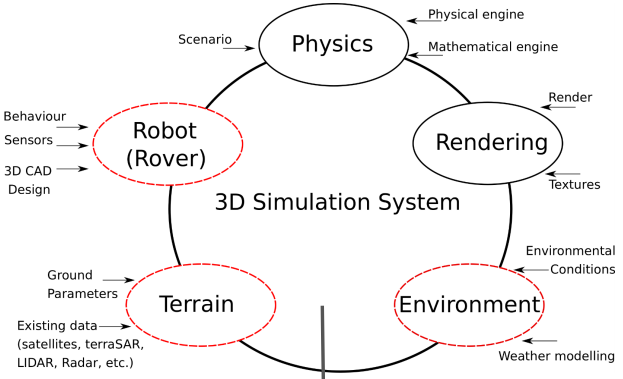
Code Generation

C/C++

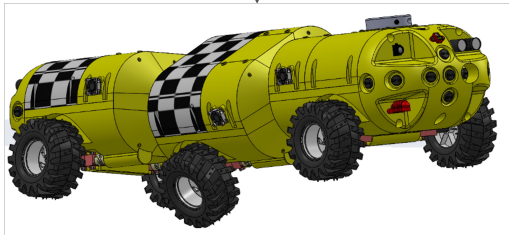
Embedded system

Supervisory SW

System Simulation

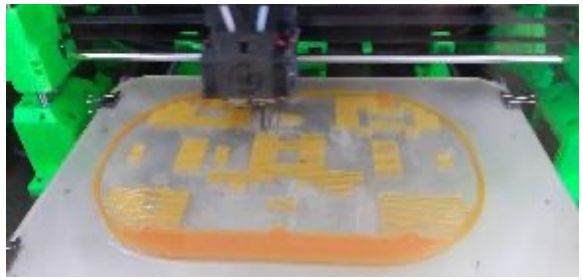


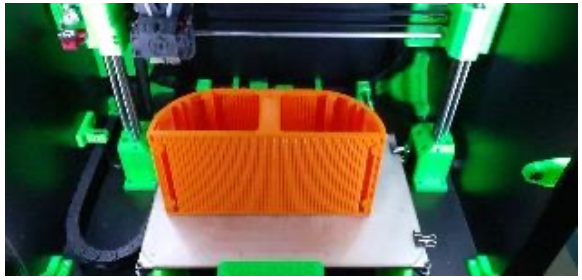
Configuration

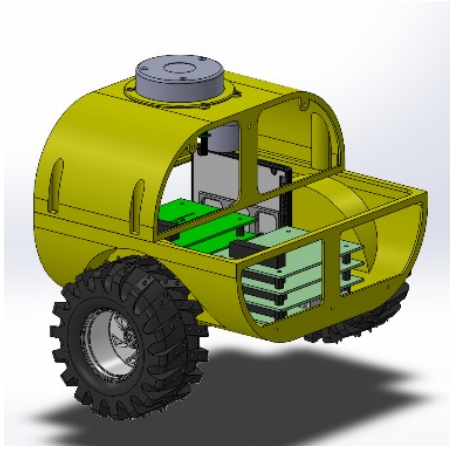


Mission-specific system

ArcTurius: 3D design and printing







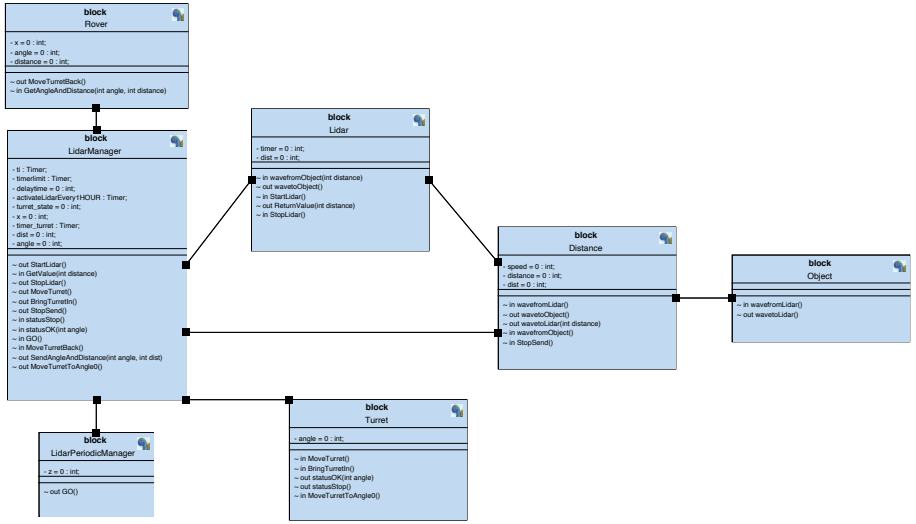
- **Prototype: PLA, PETG**
- **Final system: carbon-loaded nylon**

ArcTurius: software design

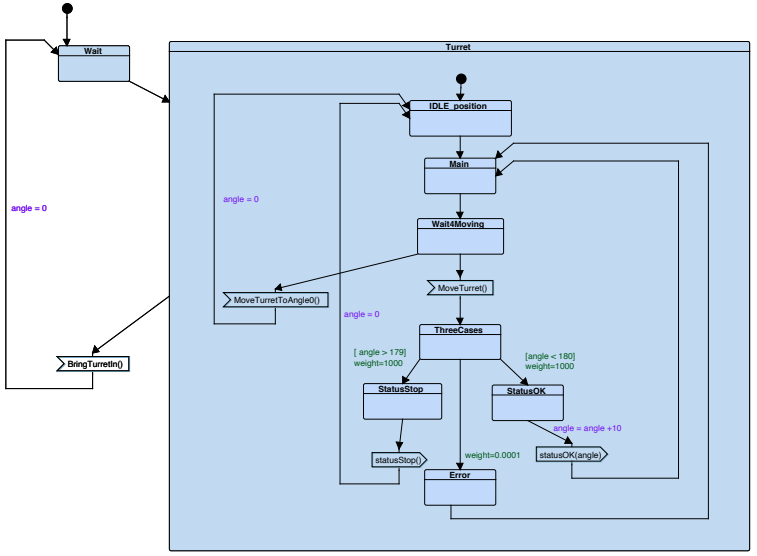
- **Objectives**
  - Designing the control software
    - Critical parts
  - Verifying safety properties
- **Our approach: using TTool**
  - Open-source
  - Well-known modeling language : SysML
  - Safety verification with a press-button approach
    - Simulation
    - Formal verification

ArcTurius: software design of the LIDAR control

- **Objectives**
  - Understanding how to **efficiently control the LIDAR**
    - Measuring distance, handling of the angle at which the scan should occur, bringing back the LIDAR turret in case of upper obstacle
  - **Verifying safety properties**: values returned by the LIDAR, liveness of the LIDAR control



Architecture



Behavior

ArcTurius: software design of the LIDAR control (Cont.)

- **How to express safety properties?**

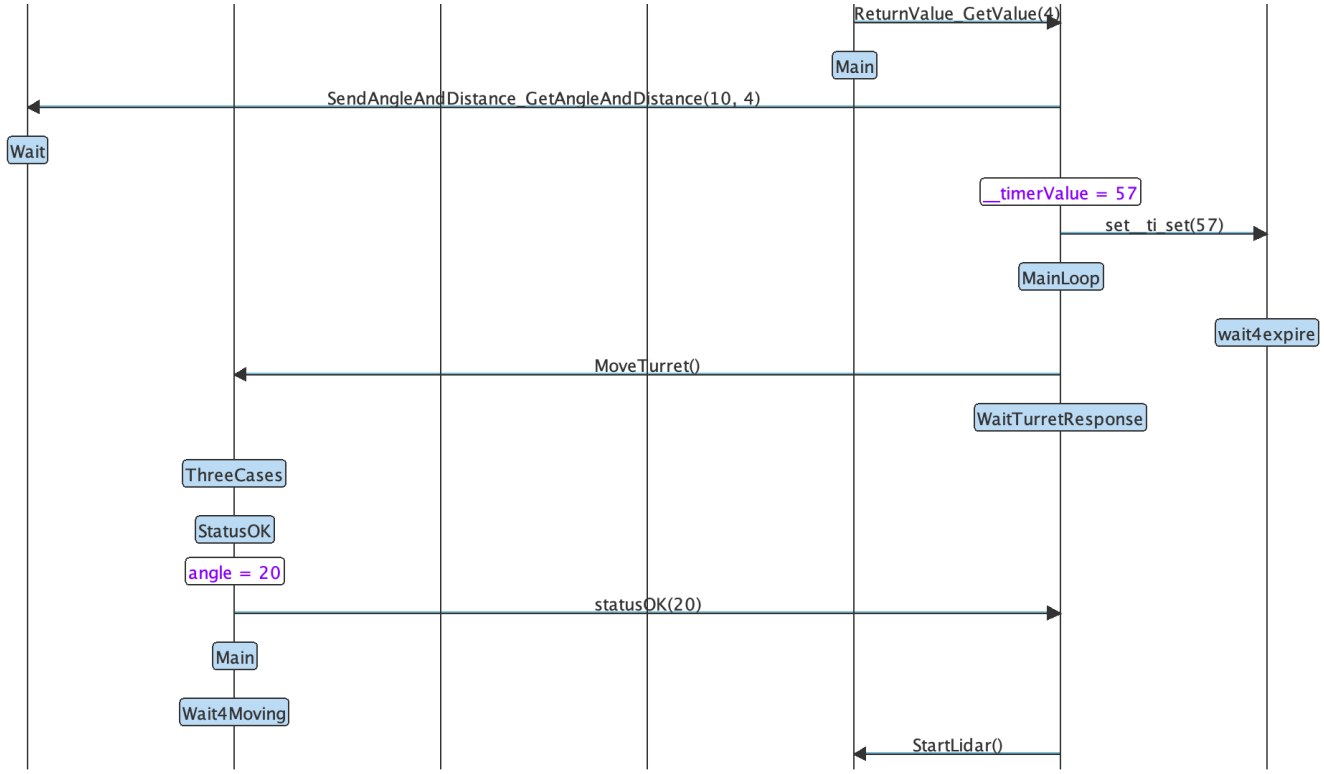
```
Safety Pragmas
A[] Lidar.dist<10
LidarPeriodicManager.Start --> LidarPeriodicManager.Start
LidarManager.Wait4Response --> LidarManager.WaitingForTurretActivation || LidarManager.MainLoop
```

- **Verification**
  - Takes around 10 minutes
  - Reachability graph: 4 millions of states, 8.6 millions of transitions
    - Manual analysis (after minimization), automated analysis (deadlocks)

```
Safety Pragmas
✓ A[] Lidar.dist<10
✓ LidarPeriodicManager.Start --> LidarPeriodicManager.Start
✓ LidarManager.Wait4Response --> LidarManager.WaitingForTurretActivation || LidarManager.MainLoop
```

ArcTurius: software design of the LIDAR control (Cont.)

- **Handling combinatory explosion**
  - Create sub-systems
  - Simulation
    - Random
    - User-guided



ArcTurius: software design of the LIDAR control (Cont.)

- **Model-to-C code generation**

```
/* Main loop on states */
while(__currentState != STATE__STOP__STATE) {
  switch(__currentState) {
    case STATE__START__STATE:
    traceStateEntering(__myname, "__StartState");
    __currentState = STATE__Main;
    break;

    case STATE__Start:
    traceStateEntering(__myname, "Start");
    makeNewRequest(&__req0__LidarPeriodicManager, 656, SEND_SYNC_REQUEST, 0, 0, 0, 0, __params0__LidarPeriodicManager);
    __req0__LidarPeriodicManager.syncChannel = &__LidarPeriodicManager_GO__LidarManager_GO;
    __returnRequest__LidarPeriodicManager = executeOneRequest(&__list__LidarPeriodicManager, &__req0__LidarPeriodicManager);
    clearListOfRequests(&__list__LidarPeriodicManager);
    traceRequest(__myname, __returnRequest__LidarPeriodicManager);
    __currentState = STATE__Wait4AnotherStart;
    break;

    case STATE__Wait4AnotherStart:
    traceStateEntering(__myname, "Wait4AnotherStart");
    waitFor((500)*1000000, (500)*1000000);
    __currentState = STATE__Main;
    break;

    case STATE__Main:
    traceStateEntering(__myname, "Main");
    __currentState = STATE__Start;
    break;

  }
```

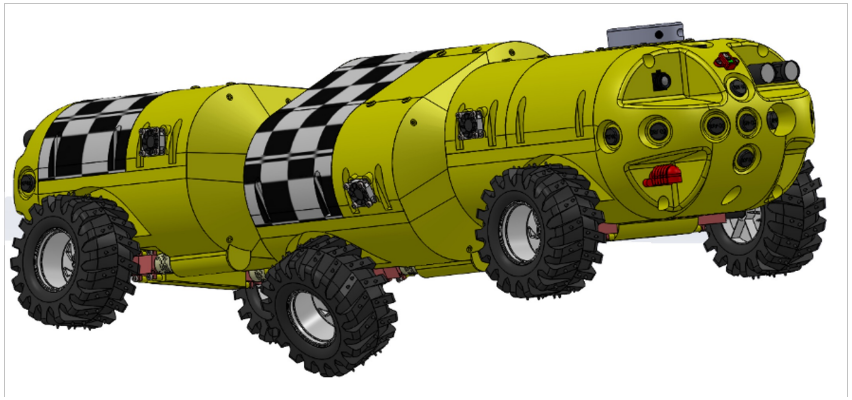
ArcTurius: supervisory software

Conclusion and perspectives

- **Objective: enhancing response to disasters**
- **ArcTurius: an almost ready-to-use rover**
  - Configurable
  - Interdisciplinary project
  - Expected to be used by operational teams to better handle risk
- **What's next?**
  - Currently: software integration, integration tests
  - Outdoor tests and global validation planned for summer 2022
- **Necessary to have a good collaboration between rescuers and researchers**

Thank you!

Any questions?



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