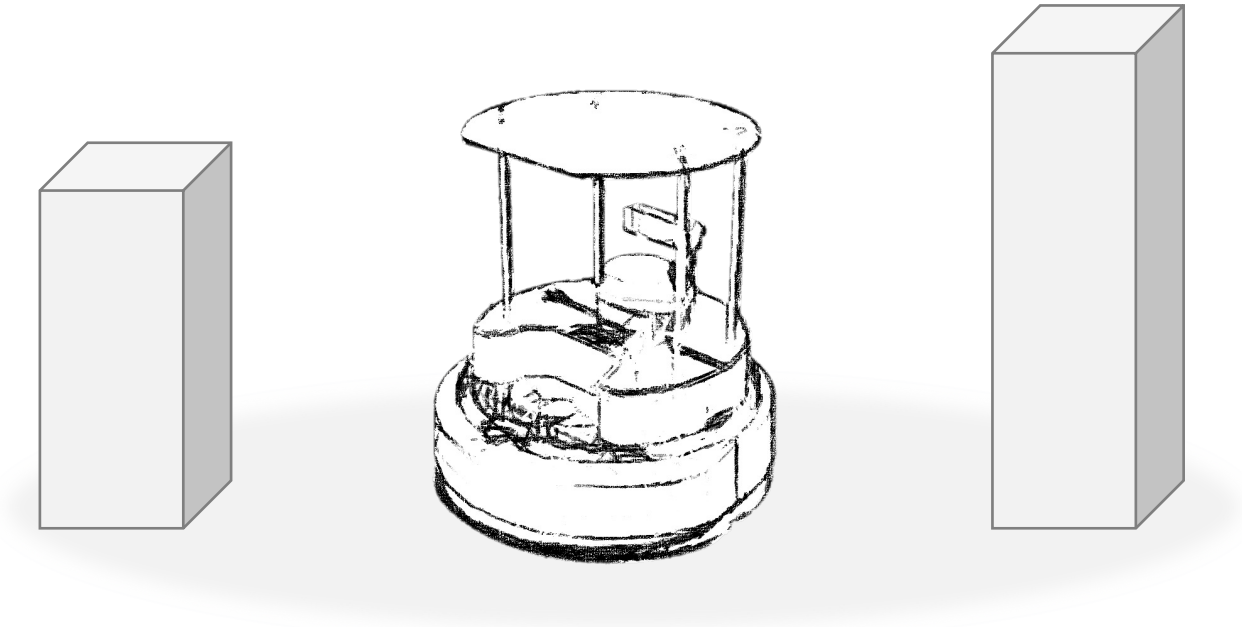
Is it a Bug?
Understanding Physical Unit Mismatches in Robotic Systems

Paulo Canelas

with Trenton Tabor, John-Paul Ore, Alcides Fonseca, Claire Le Goues, and Christopher S. Timperley

International Conference in Robotics and Automation (ICRA) 2024.

Robot code abounds with variables that are quantified using physical units



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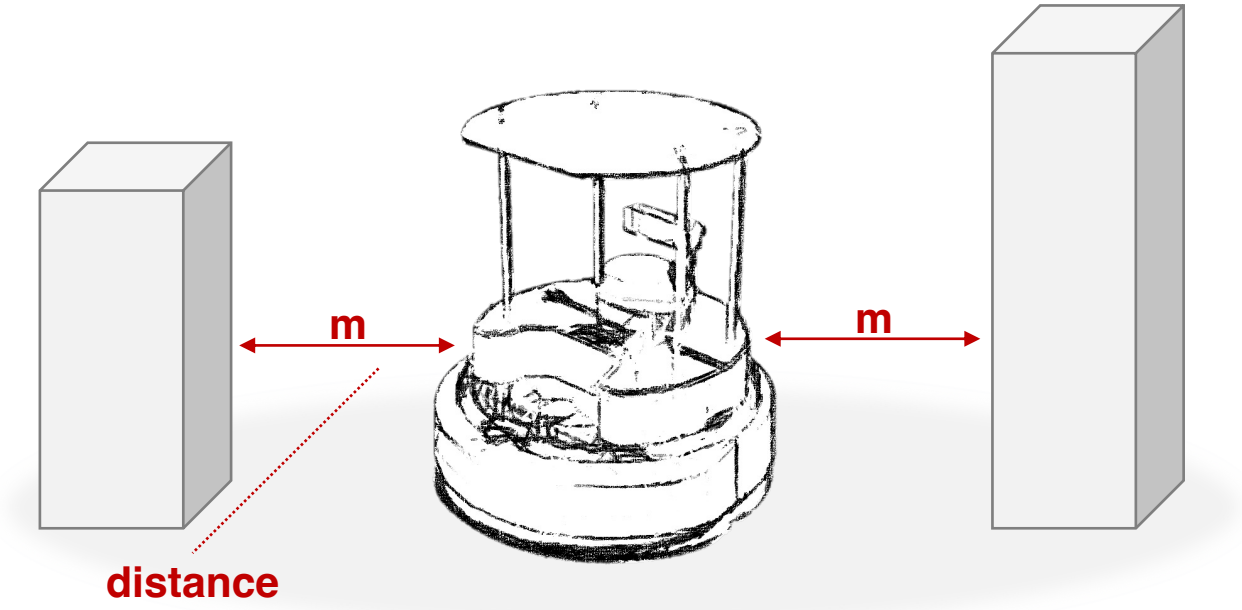

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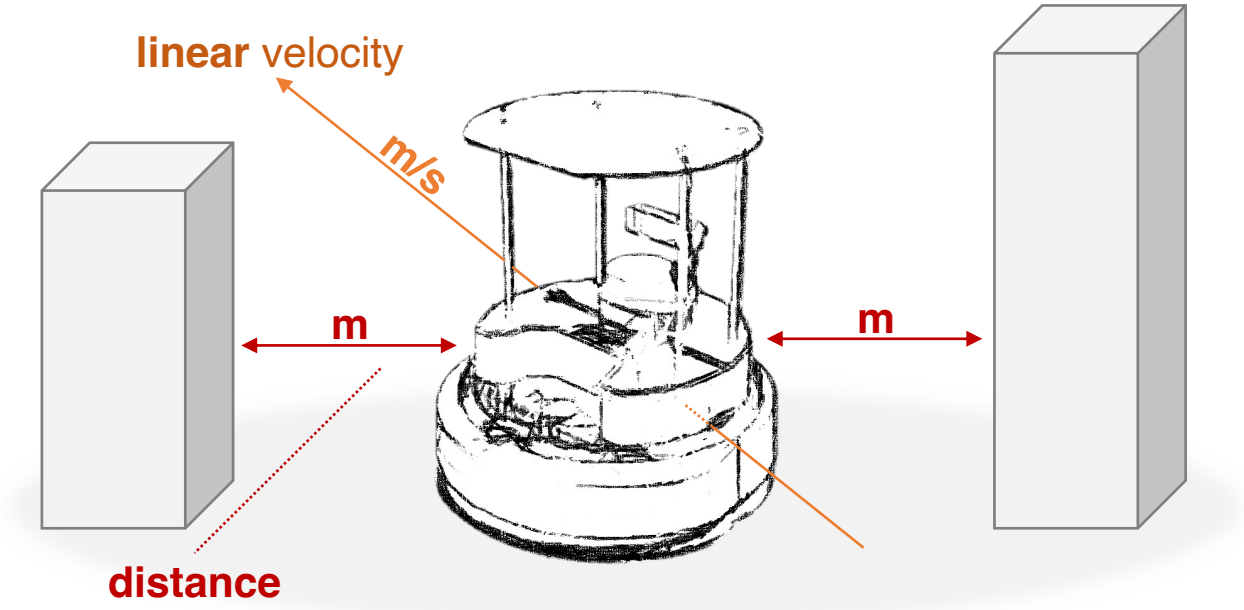

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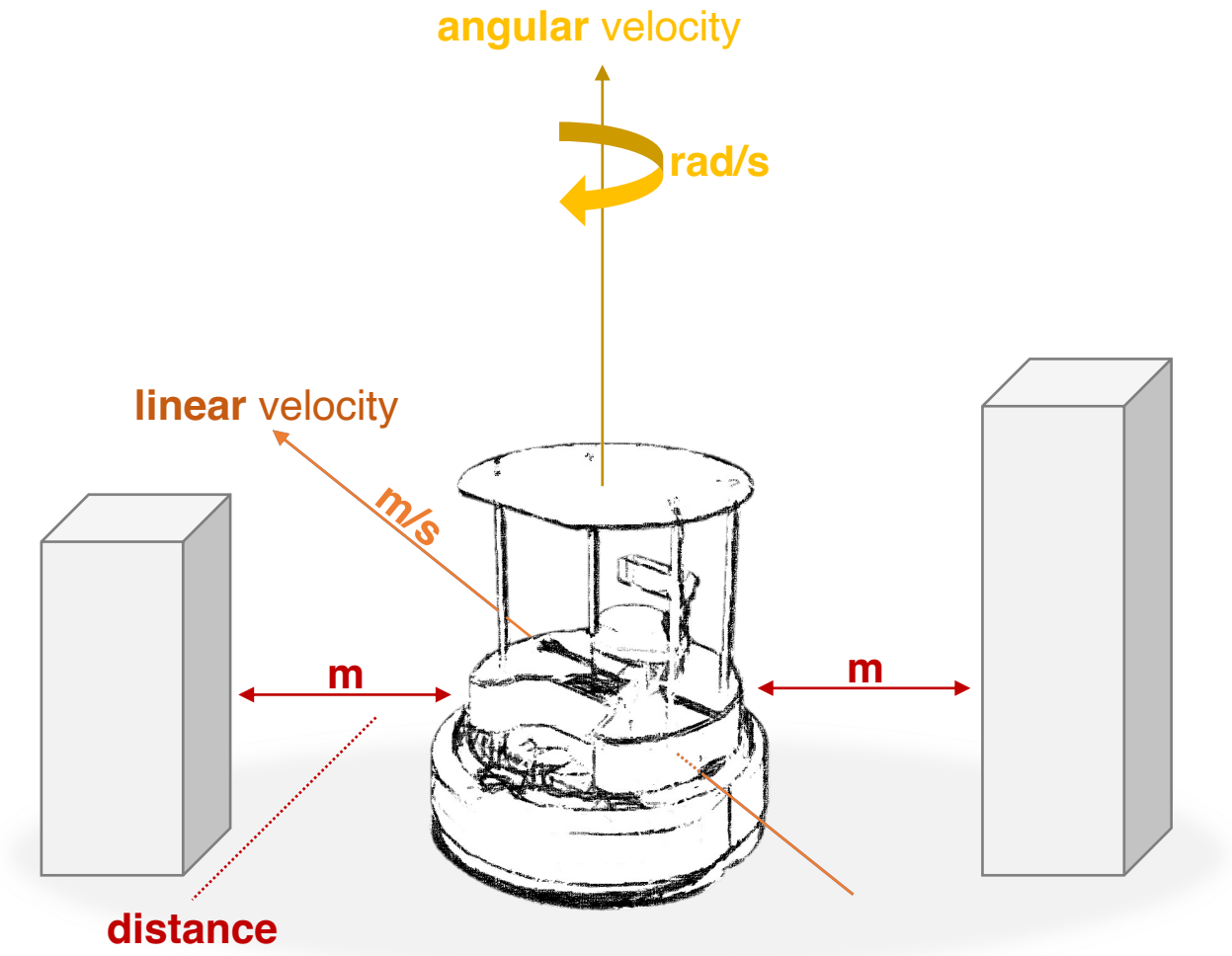

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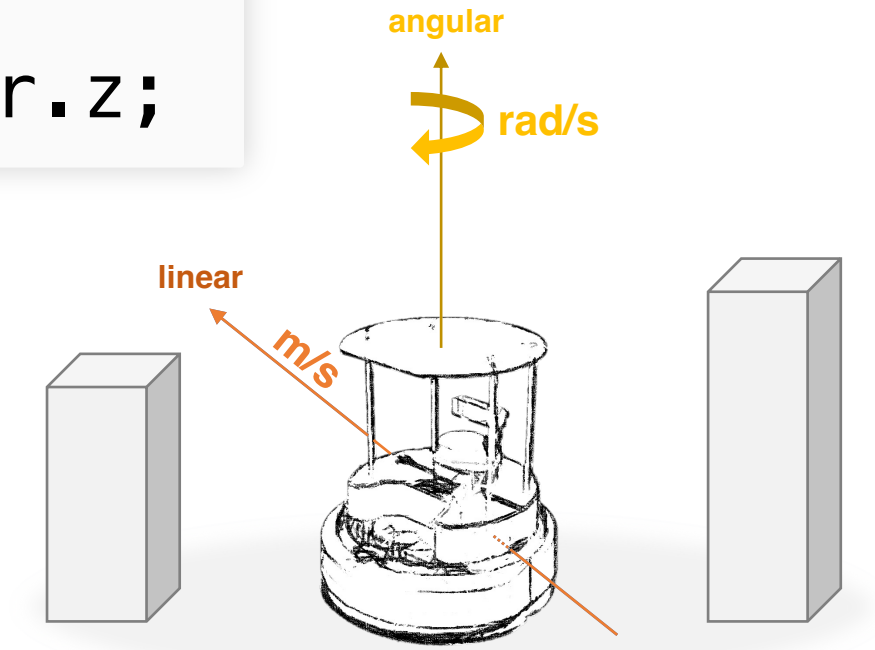

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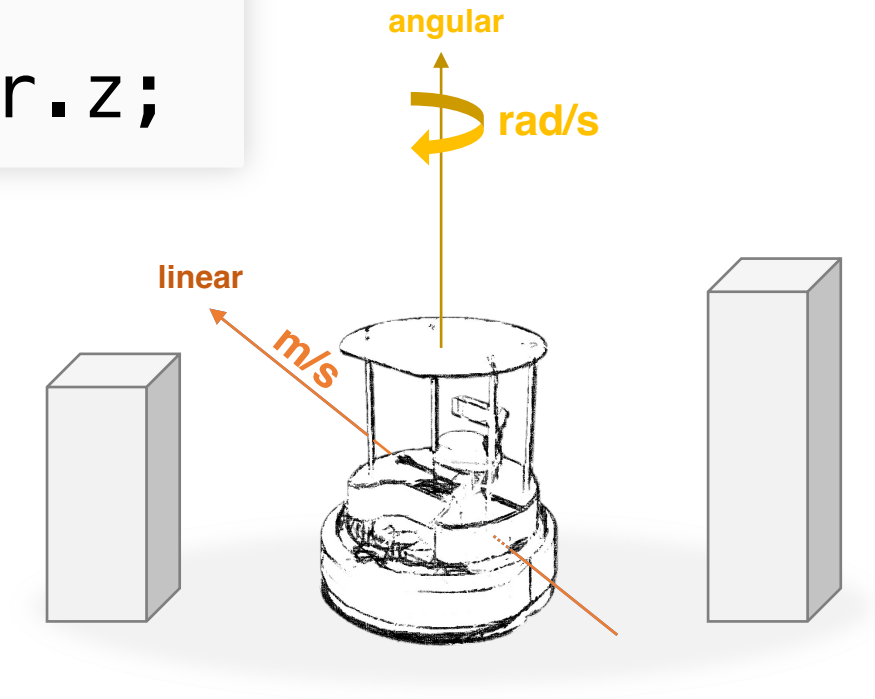

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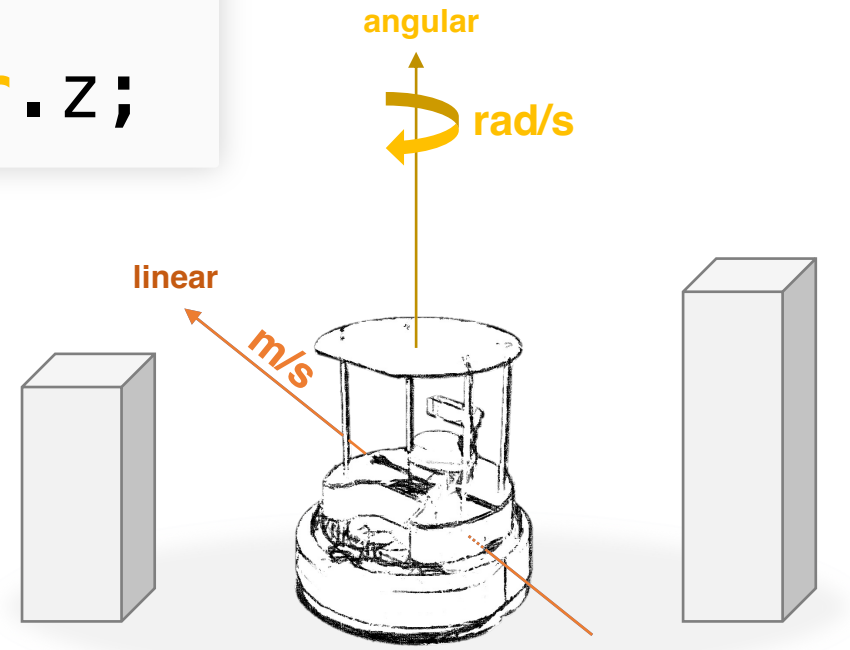

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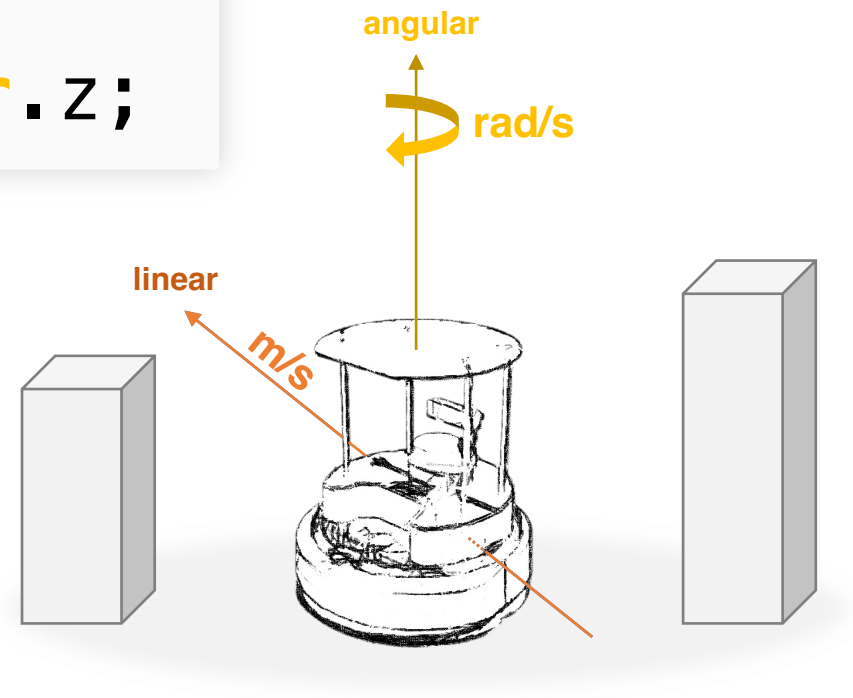

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We found that in the robotics domain, developers perform **both** **unintentional** and **intentional** unit mismatches

Methodology

The large codebase makes it challenging to manually search for unit mismatches

turtlebot_example_node.cpp

data > FrenchVanilla > src > turtlebot_example > src > turtlebot_example_node.cpp

```
28      err_x=x_t-X;
29      err_y=y_t-Y;
30      err_d=sqrt(err_x*err_x+err_y+err_y);
31      err_yaw=t-yaw_degrees;
32      //if(err_yaw<0)err_yaw=err_yaw+360;
33
34      if(err_x>0.1||err_y>0.1)
35      {vel_x=0.3;ang_z=0.0;}//ROS_INFO("1..S=%d",state);}
36      else if(err_yaw>2)
37      {ang_z=0.15;vel_x=0.0;}//ROS_INFO("2..S=%d",state);}
38      else
39      {
40          state=(state+1)%8;
41          ang_z=0.0;vel_x=0.0;
42          ROS_INFO("3..S=%d",state);
43      }
44
45  }
46
47  //Callback function for the Position topic
48  void pose_callback(const geometry_msgs::PoseWithCovarianceStamped& msg)
49  {
50      //This function is called when a new pose message is received
51
52      X = msg.pose.pose.position.x; // Robot X psotition
53      Y = msg.pose.pose.position.y; // Robot Y psotition
54      double Yaw = tf::getYaw(msg.pose.pose.orientation); // Robot Yaw
```

Phys uses names and ROS assumptions to infer the physical units and detect unit mismatches

```
vth = (dt == 0) ? 0 : dth / dt;
```

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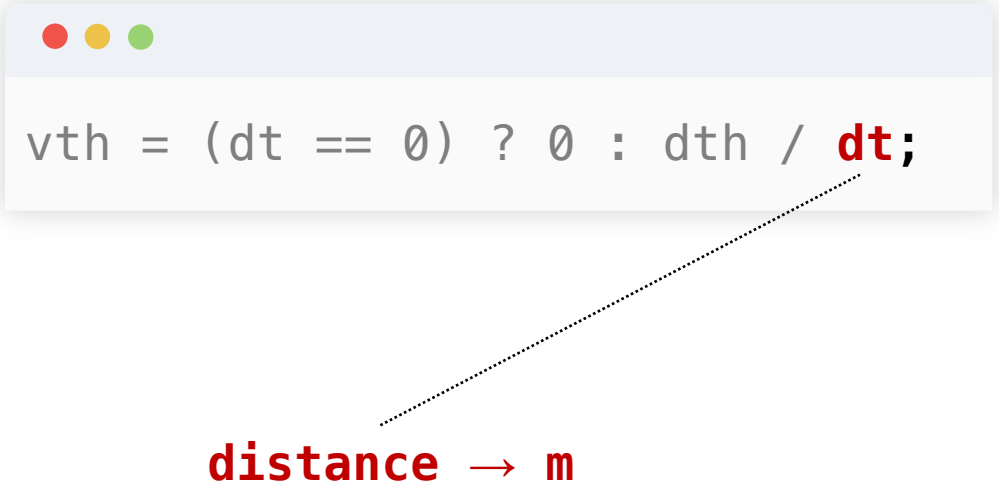

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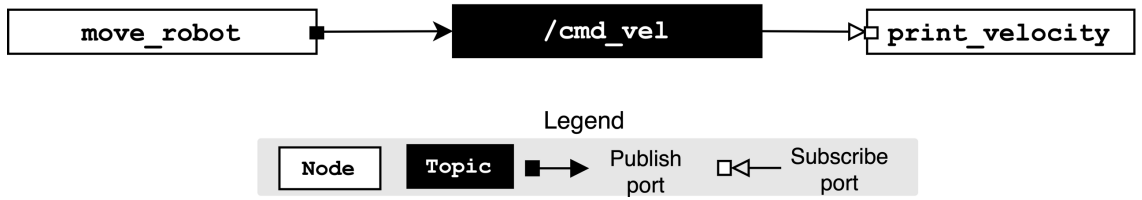

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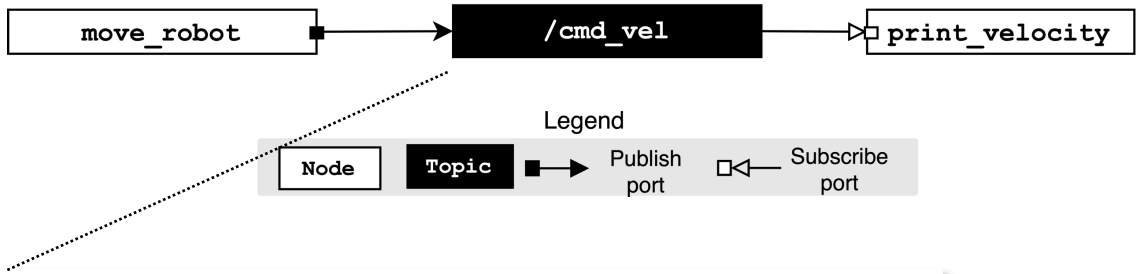


geometry_msgs/Twist Message

File: geometry_msgs/Twist.msg

Raw Message Definition

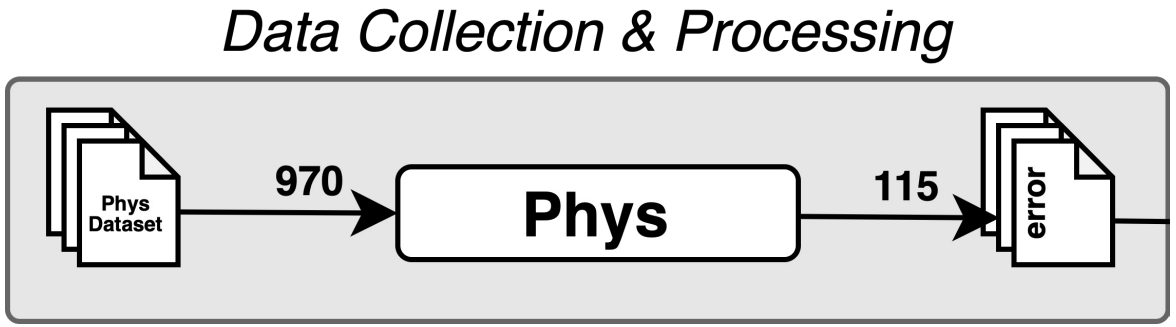
```
# This expresses velocity in free space broken into its linear and angular parts.
Vector3  linear
Vector3  angular
```

Compact Message Definition

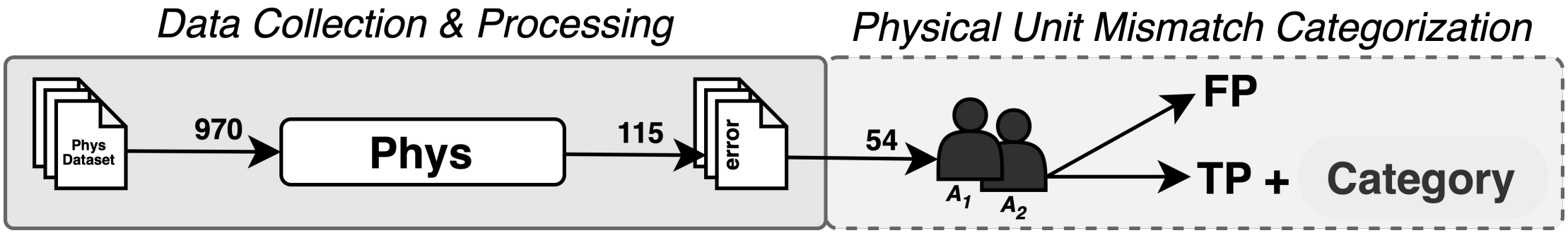
```
geometry_msgs/Vector3 linear
geometry_msgs/Vector3 angular
```

autogenerated on Wed, 02 Mar 2022 00:06:53

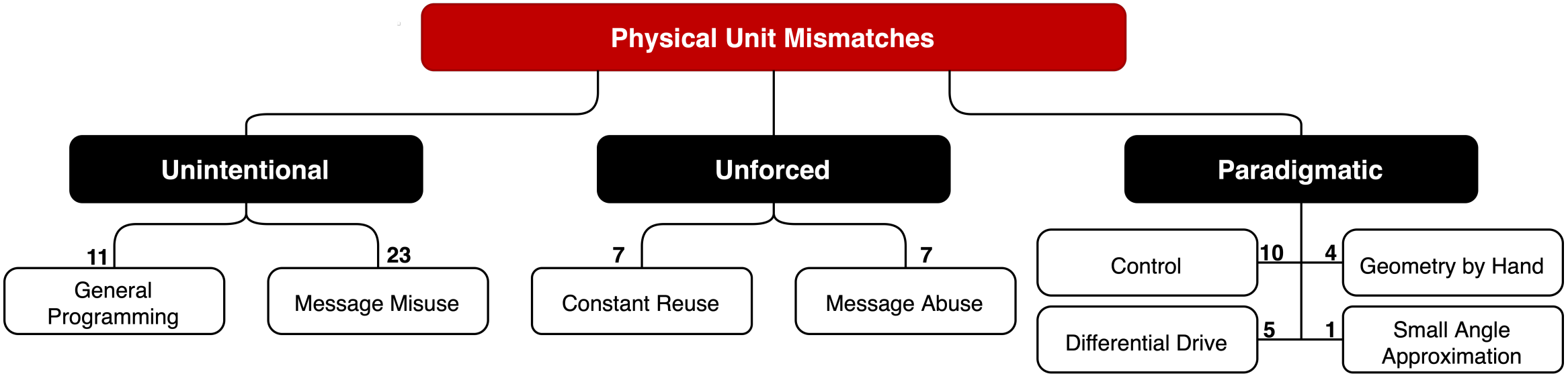
We executed Phys on its dataset and obtained 115 files with errors



We manually analyzed 180 errors, validated with two authors and created a taxonomy



We encountered three high-level categories and eight sub-categories of unit mismatches



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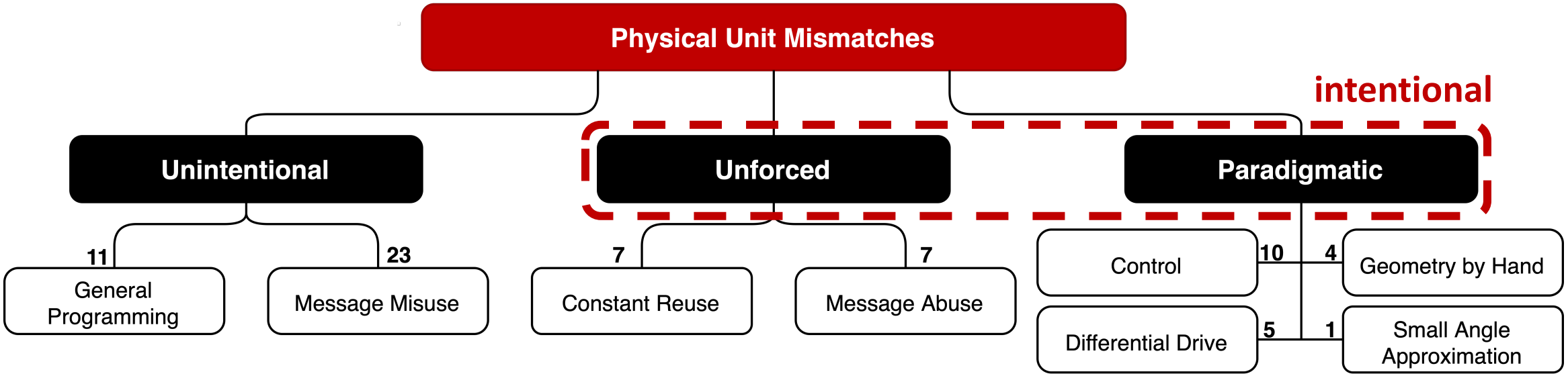

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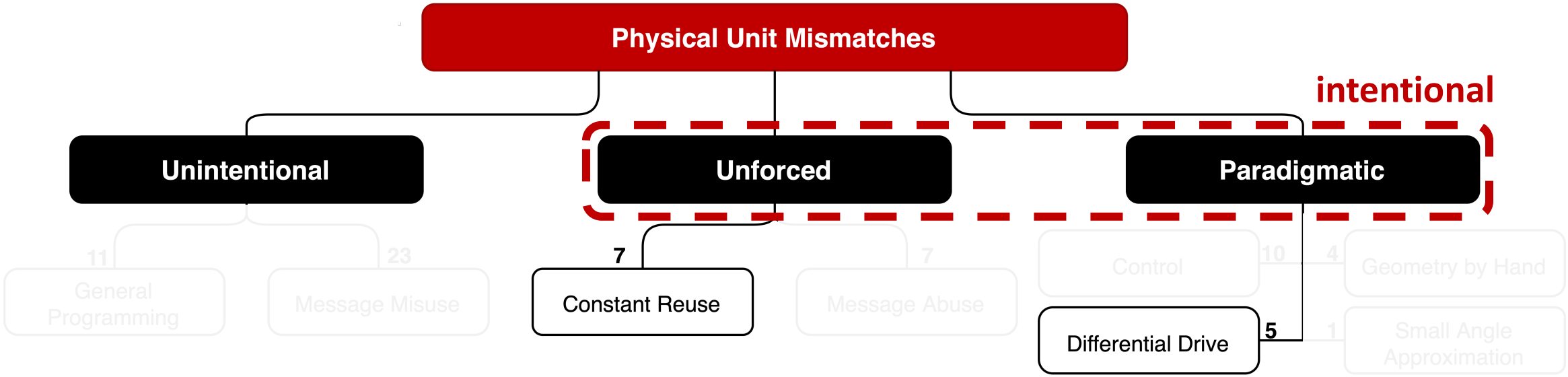

Unforced Unit Mismatches

Developers reuse constants and errors to perform calculations and comparisons

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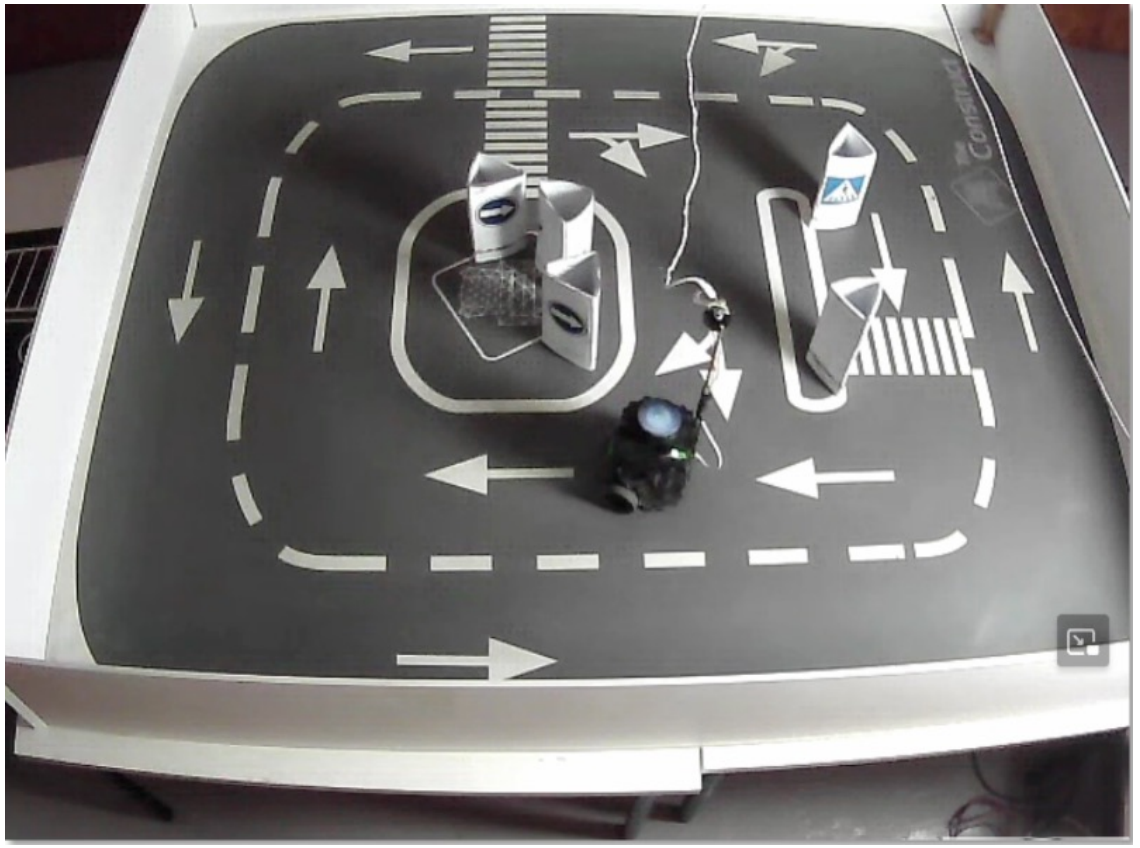

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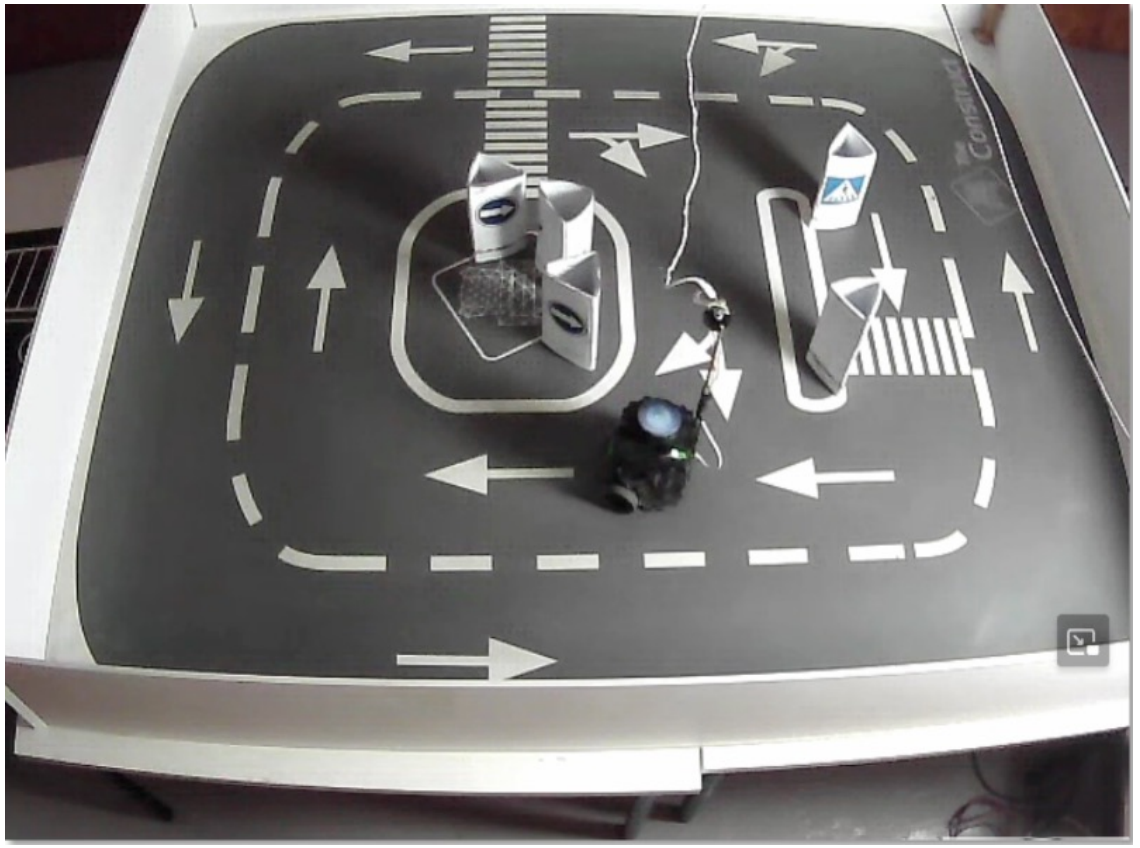

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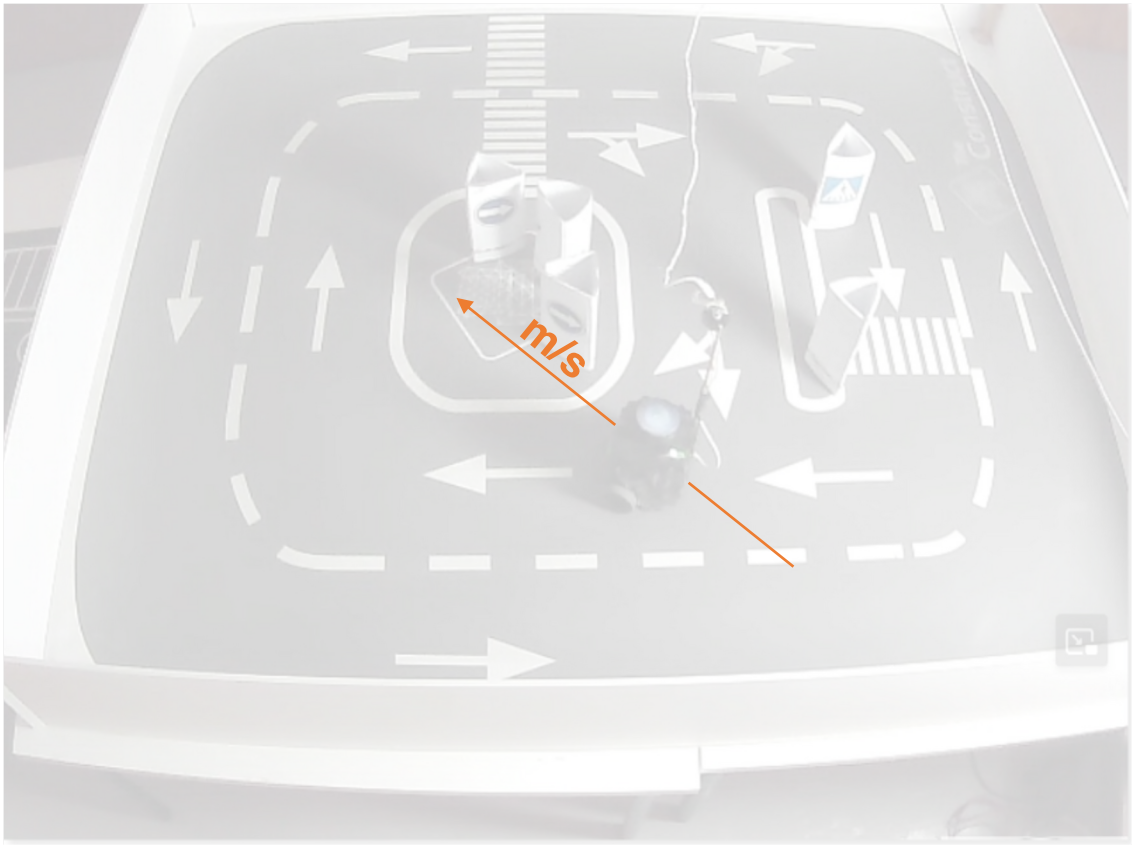

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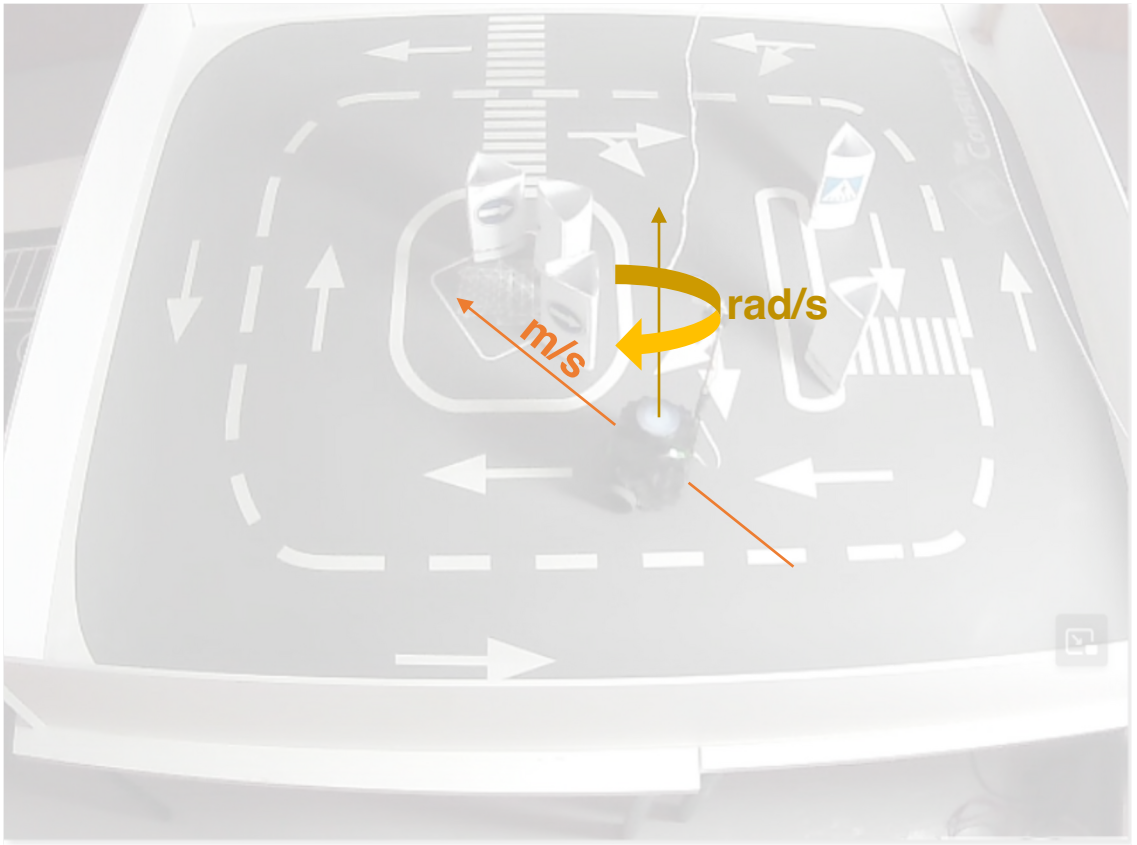

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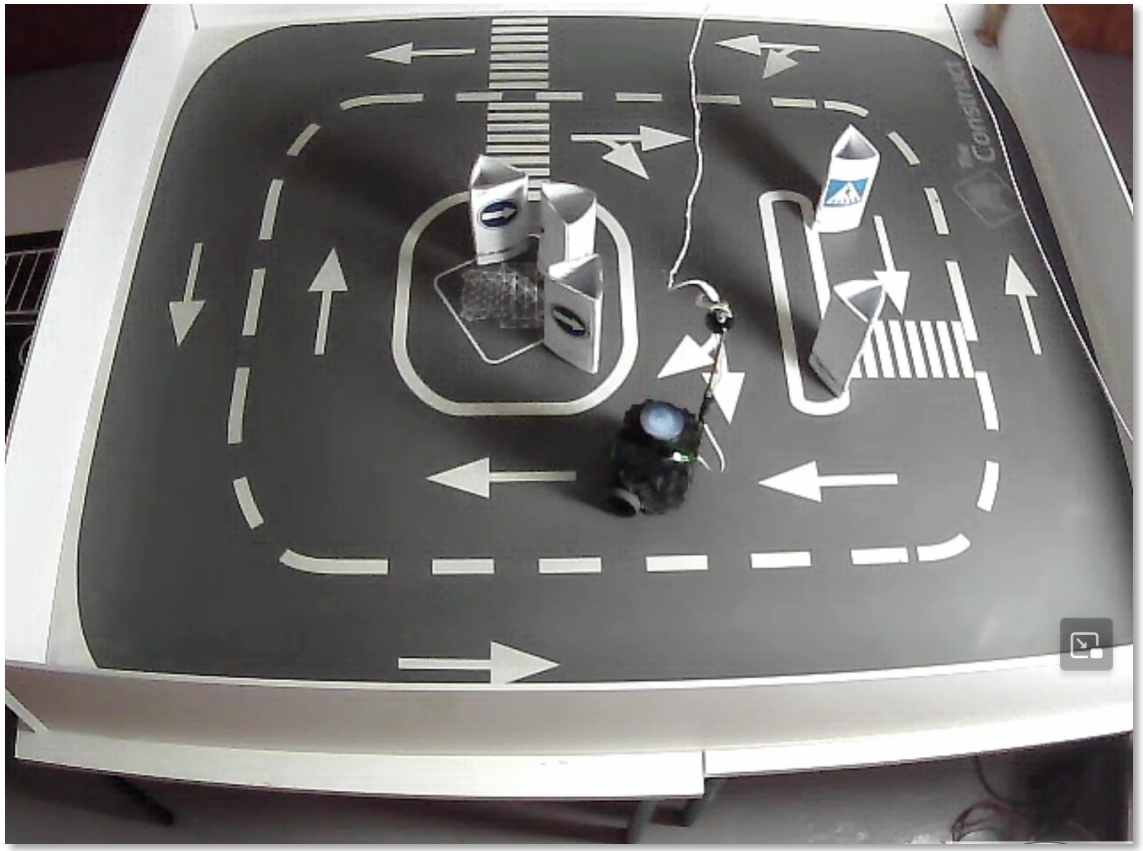

Paradigmatic Unit Mismatches

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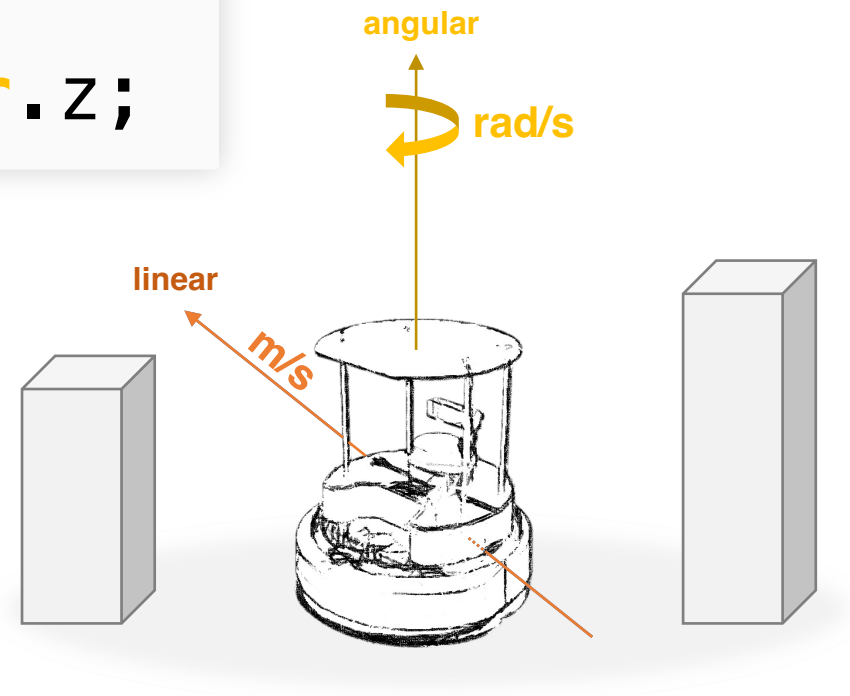

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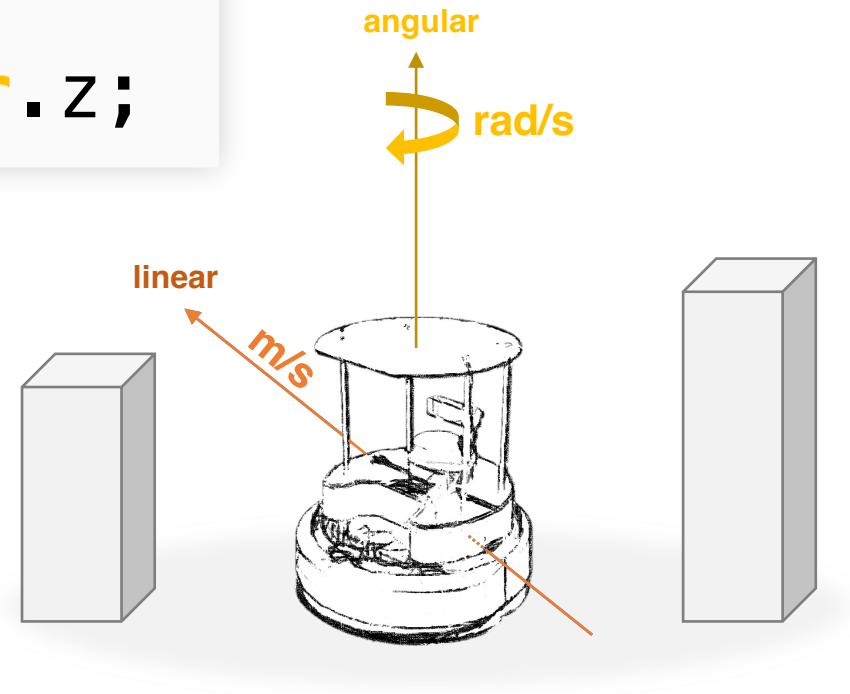
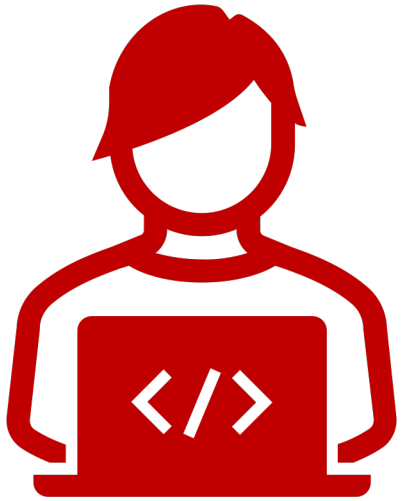


By understanding how robot developers introduce physical unit mismatches we can…



Inform the teaching of robots software development to avoid unforced unit mismatches

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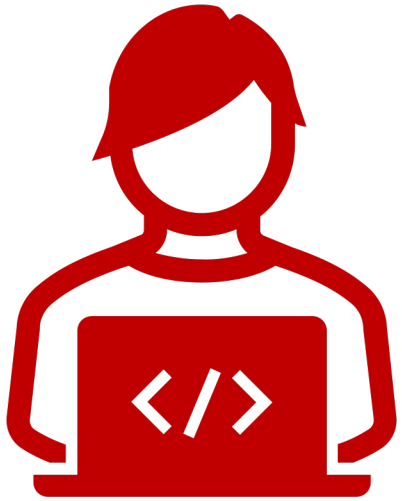

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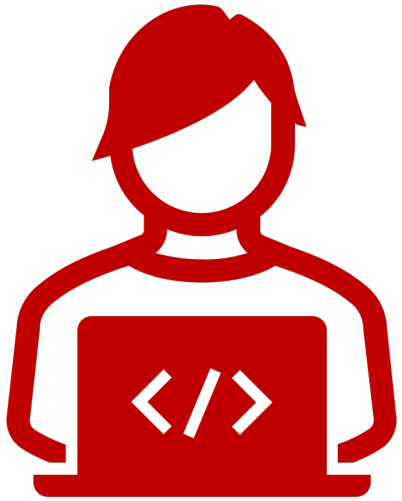

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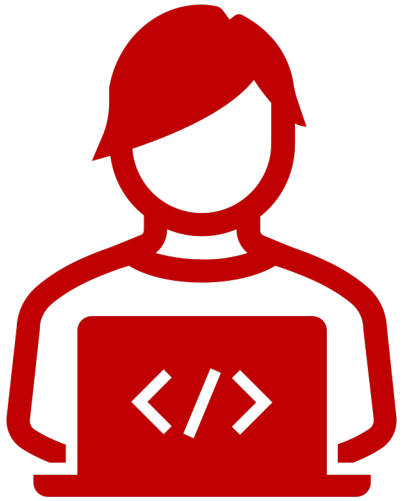

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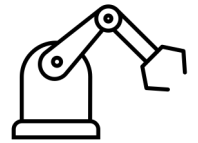

Context-dependent Analysis

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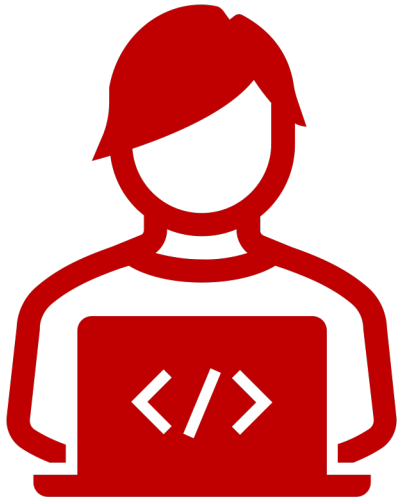

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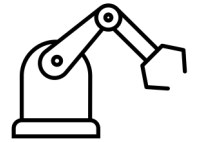

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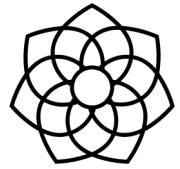

Domain-specific patterns

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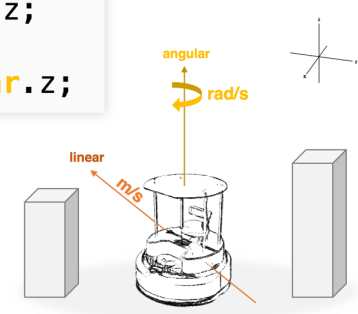

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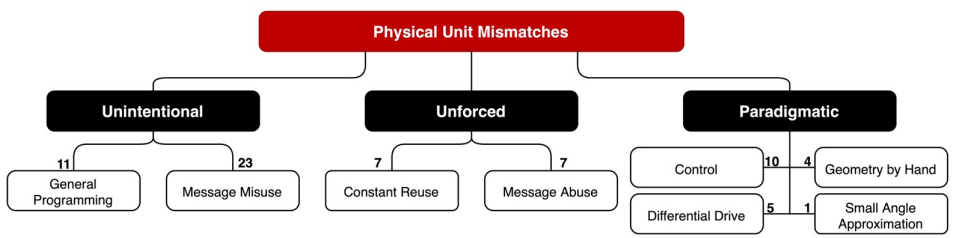

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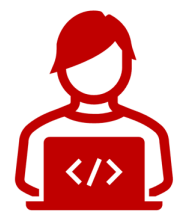

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