ASSESSMENT OF THE CAPABILITIES FOR CONTROLLING AND TRANSMITTING DATA BETWEEN A MOBILE ROBOT AND AN OPERATOR

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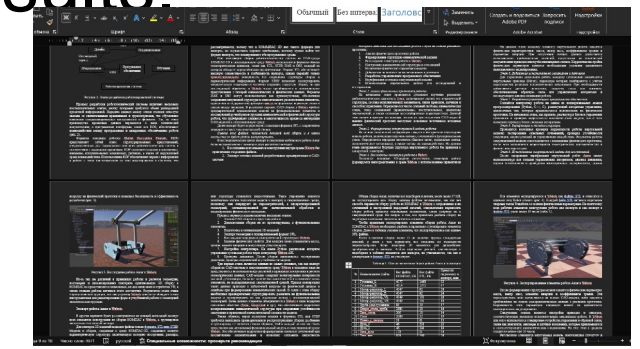
Problems in the development and debugging of mobile service robot control systems

- Design development, the role of graphical debugging tools for the control system

- The impossibility of precisely repeating experiments and reproducing the operating conditions of mobile robots

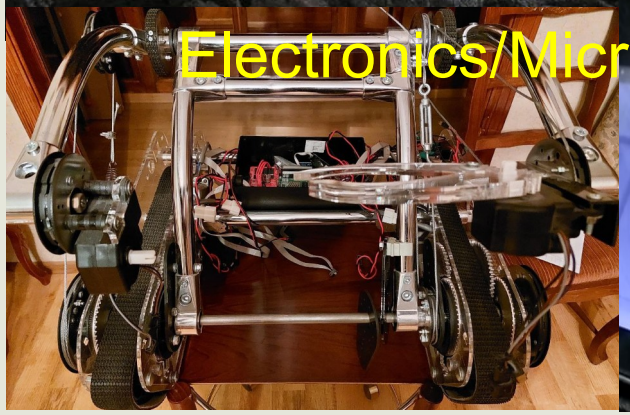
- Modeling methodology and export from CAD to Webots

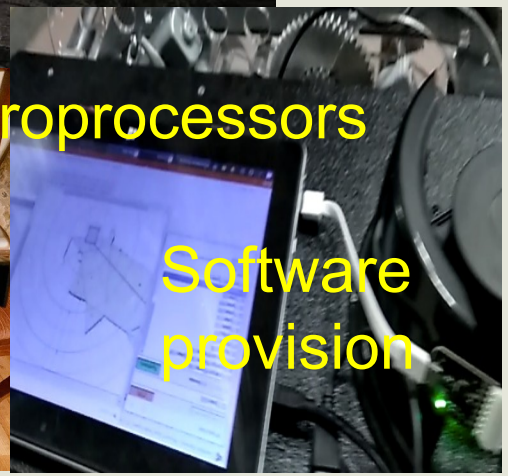
- Recreating the Amur robot using the built-in tools of the Webots environment.
- Problems with exporting robot models to Webots and their solutions.
- Simulation results.



Lack of repeatability of conditions during software debugging





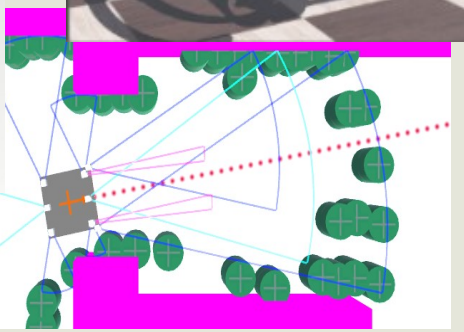


Who is to blame
sensor failures
and management?

**Digital twins: CAD models,
2D/3D primitives**





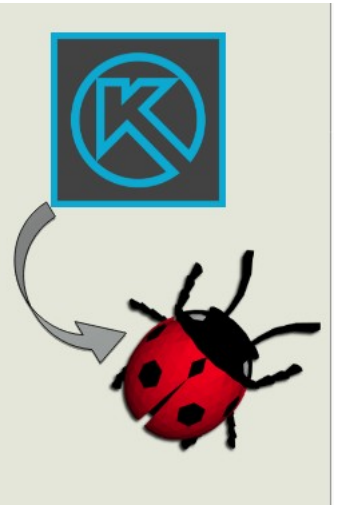


**Aristotelian mechanics
or Lagrange equations?**

Combining fundamentally different stages of mobile robot modeling

The goal is a digital twin: to create a methodology for designing mobile service robots that involves transitioning from the stage of creating a detailed robot design in a CAD system to the stage of developing and testing control algorithms in the Webots virtual environment. It is necessary to find the simplest way to quickly transfer the developed CAD robot assemblies to the virtual environment while preserving: the kinematics of the design, the mass and size parameters, and the physical characteristics of the sensor system.

The object of development is mobile robots of the Amur series, which are: service platforms with a tracked propulsion system, manipulators, and various sensors.

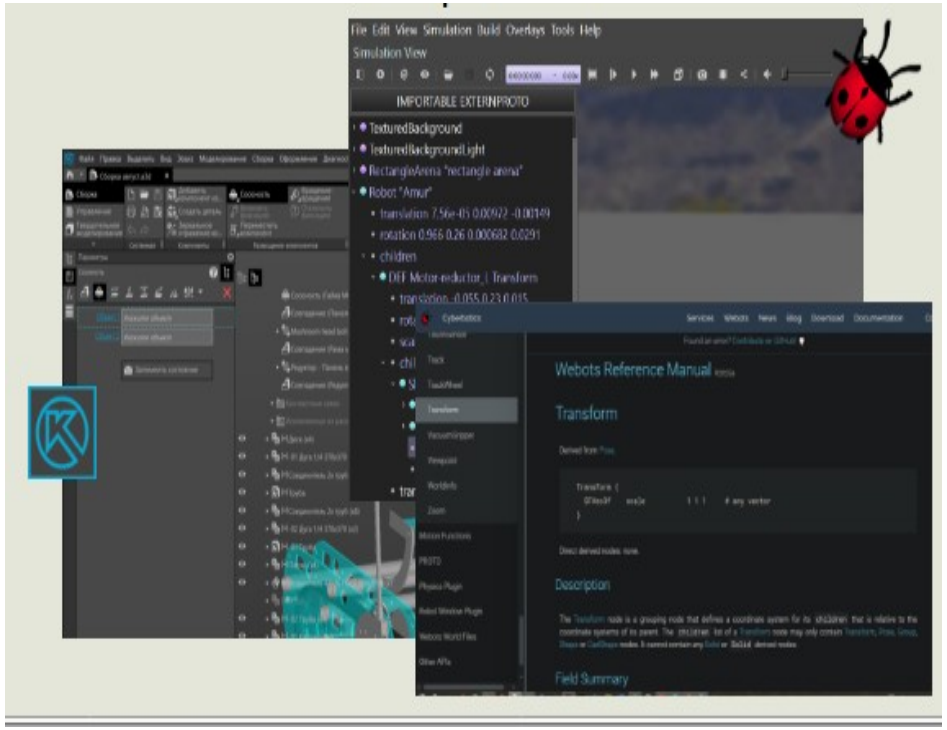


Combining fundamentally different stages of mobile robot modeling

CAD and simulation environments use fundamentally different approaches:
- CAD is a parametric solid geometry model of a robot;
- Webots uses polygonal models + explicit kinematics and physics.

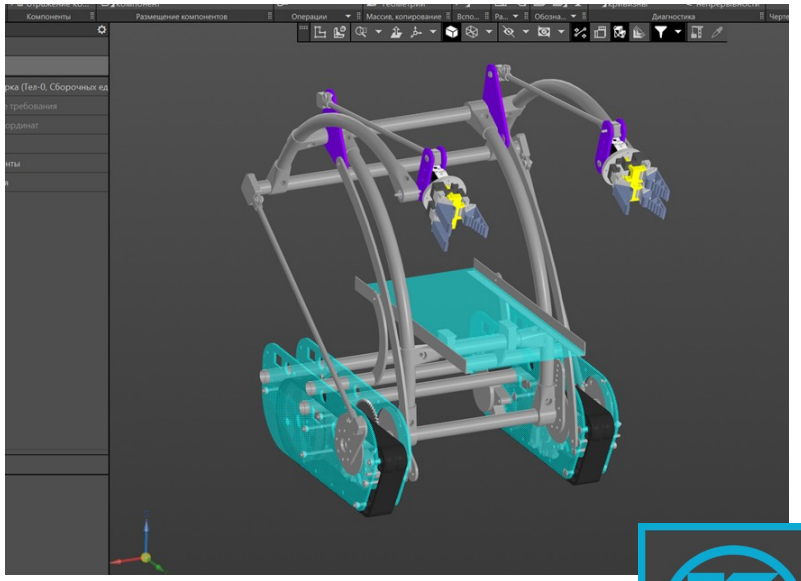
When exporting the model:
- the assembly structure is lost, dependencies disappear,
- data on drives and constraints is missing..

☞ As a result, the model essentially has to be reassembled from scratch.



Transition from the KOMPAS system to Webots

The design of the service robot was developed in the KOMPAS-3D system. The created CAD assembly is not originally intended for simulation.

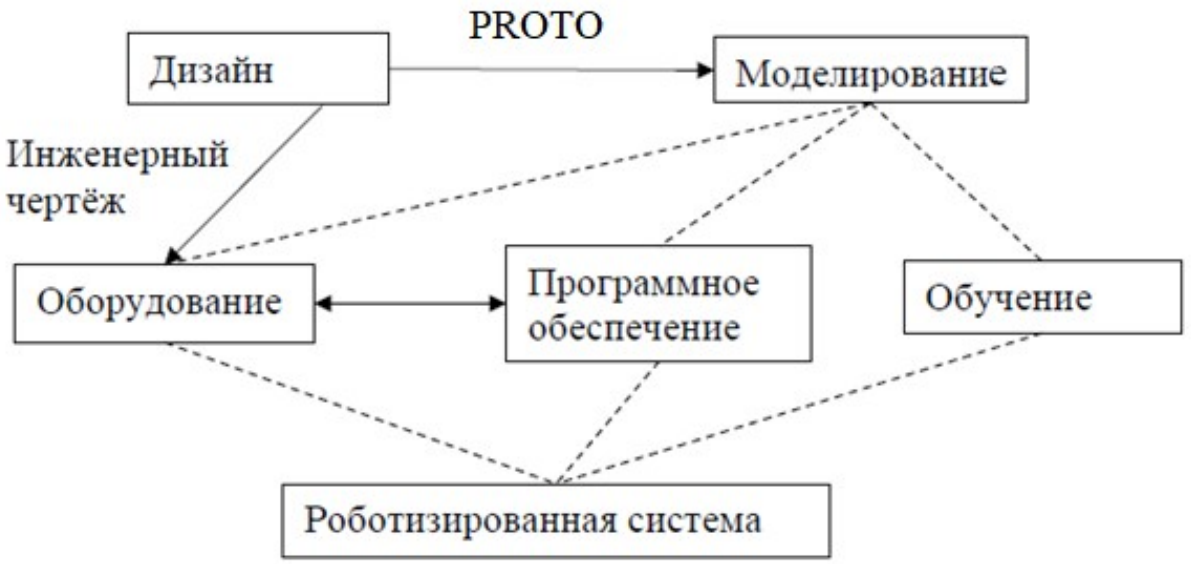


To transition to Webots, it is necessary to:
- Analyze the developed model;
- Optimize its structure;
- Recreate the kinematic and physical model in the Webots virtual environment.

The key requirement is: do not create the model from scratch, but use the original CAD assembly.

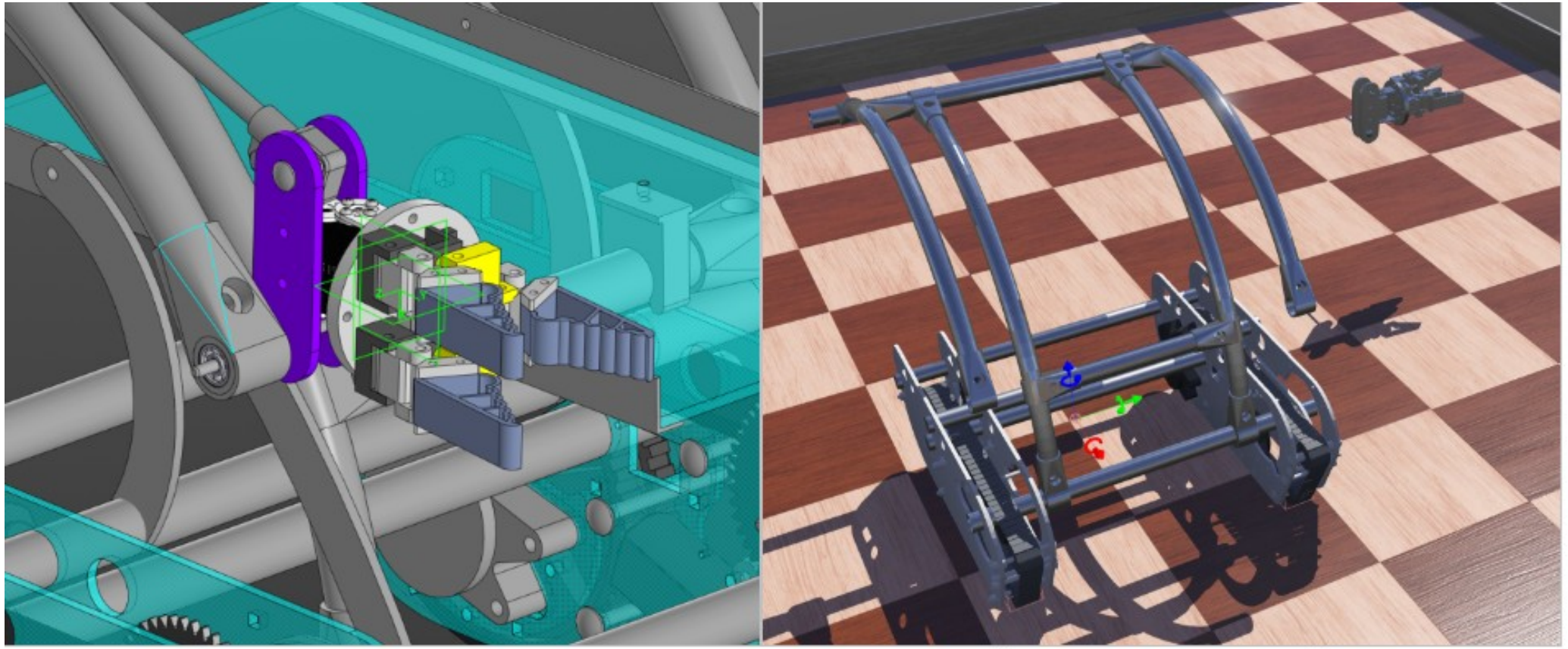
Digital twin formation

CAD → Webots integration is not just "file export", but a multi-stage process of model reconstruction.
This process includes:
- assembly decomposition,
- geometry rework,
- manual kinematic setup,
- physics setup.



In other words, a digital twin of the robot is actually created.

The emergence of problems related to defining coordinate systems.



Различие систем координат на примере моделей захватных устройств в КОМПАС-3D (слева) и Webots (справа)

Options for the graphical representation of a mobile robot with a dual manipulator



Рис. 1. CAD-сборка (модель) мобильного робота Amur, разработанная в КОМПАС, содержит полную документацию для тиражирования

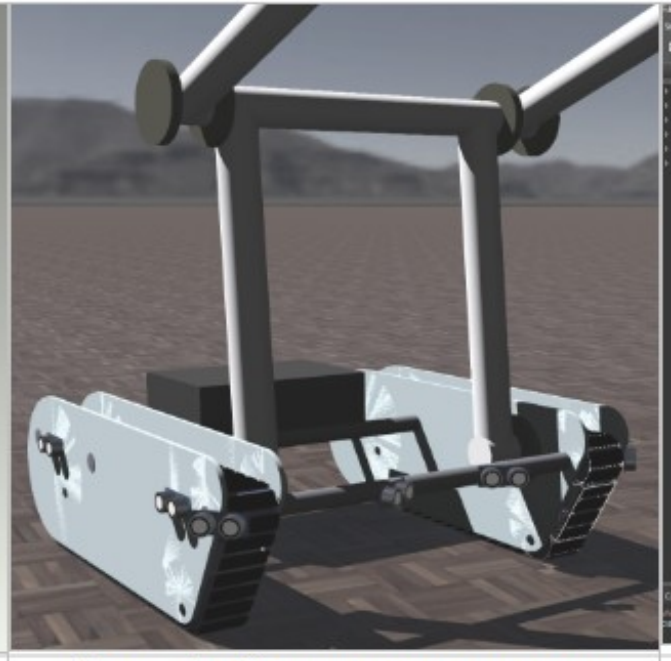


Рис. 2. Создание модели робота Amur с помощью инструментов Webots применимо для упрощенной оценки динамики

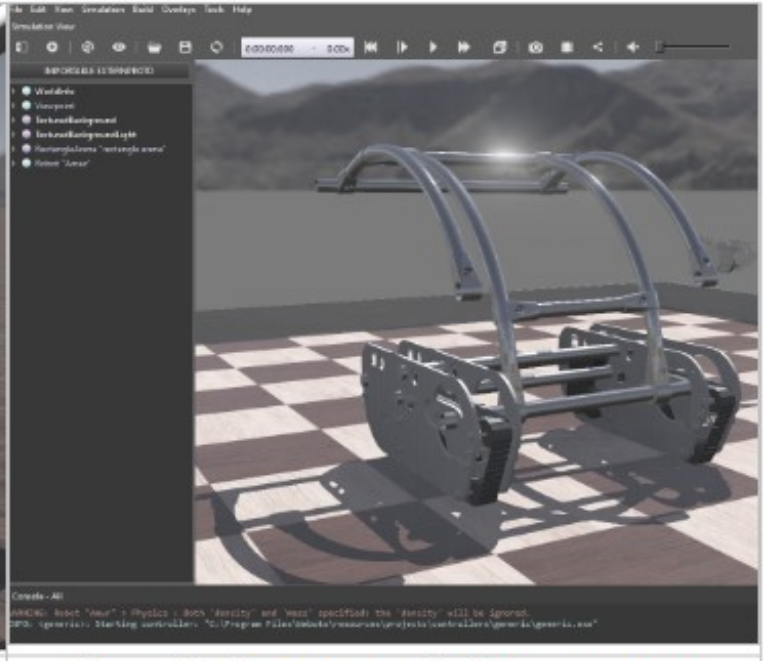


Рис. 3. Экспорт CAD-модели мобильного робота Amur после реструктуризации в Webots необходим для всестороннего тестирования кинематики и работы СУ в модели внешней среды

An example of applying the methodology for transferring CAD models to Webots.

The complete CAD assembly of the Amur robot takes up about 37 MB and includes approximately 55 parts and subassemblies (excluding standard items). Exporting the entire structure as a single file was not possible, so 20 functional modules were allocated for transfer, each exported as separate STL files.

The empirical assessment of the model's accuracy compared to the real prototype may be 7-15%.

Design time in a CAD package and in Webots

Creating a CAD model begins with agreeing on the technical specifications based on preliminary dimensional sketches, and then detailed design of the new structure takes place, which can take months. The transition to a simulation model is significantly faster — on the order of a week. Creating a model directly in Webots fundamentally results in incomparably lower quality. However, there is an advantage: the ability to quickly test the robot's dynamic capabilities without finalizing the design.

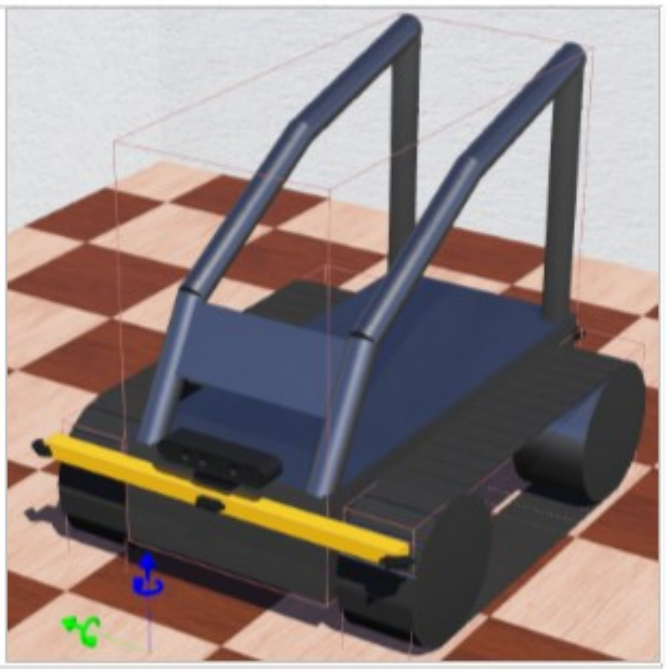
Testing using a digital twin makes it possible to eliminate solutions, that are unfeasible, for example, due to incorrect mass-and-size configurations of mobile robots with manipulators, and to develop control synergies that take into account the instability in certain relative positions of the robot and the objects being grasped.

An example of analyzing control algorithms and the transmission of sensor data flows

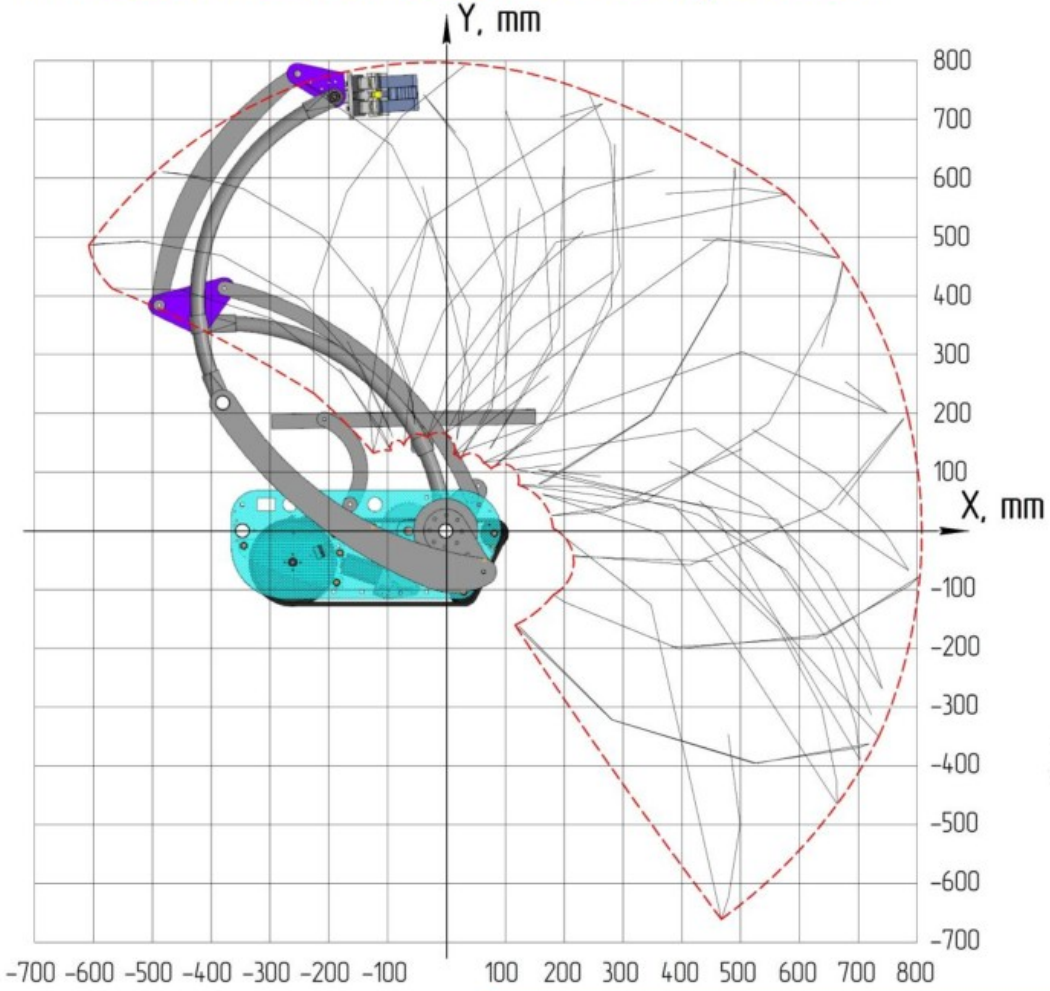
Comparing real-world experiments with a model of a mobile robot allows us to study supervisory control algorithms and the mechanisms for forming feedback in a control loop involving an operator.

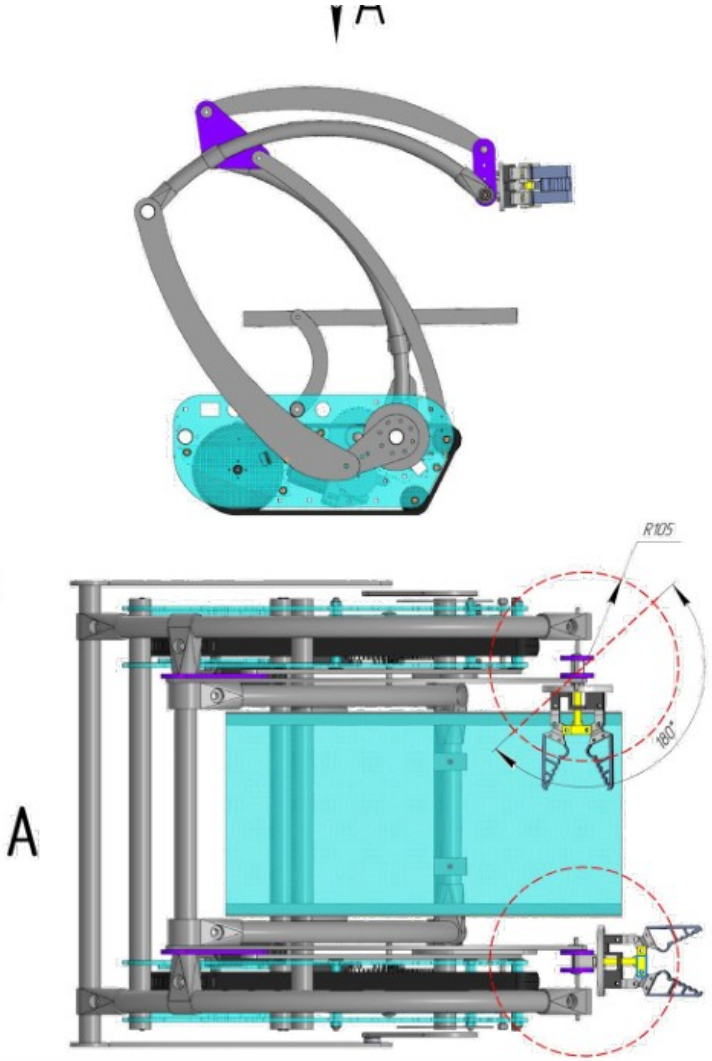






Modernization of the manipulator





Workspace of the AMUR-307 service robot manipulator

The drive of the lower link has the ability to rotate 360 degrees. This rotation mode allows the robot to perform stepping movements, which can be an additional function for overcoming obstacles during the movement of the crawler chassis.

Thank you for your attention!