UGV: Stability Test on Uneven Soft Terrain [1]

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Purpose

The purpose of this test is to evaluate the stability and terrain-handling performance of an unmanned ground vehicle (UGV) operating in agricultural field conditions. Specifically, this test examines the robot's ability to traverse uneven, soft, grassy terrain without toppling over, slipping off course, or losing control when operating autonomously or being manipulated. The test also provides insights into the effectiveness of the robot's wheels or tracks in maintaining traction and balance during bi-directional motion.

Test Facility

The test shall be conducted on an outdoor terrain representative of a typical agricultural field featuring soft soil and patchy grass cover. The terrain shall be naturally uneven, without artificial smoothing and with a slope of no more than 10 degrees. The robot can perform the test either autonomously or via tele-operation (i.e. direct human control). The setup for this test is shown in Figure 1.

A straight test path shall be marked out with the following requirements:

- Path width: 1.5 times the robot's maximum width.
- Path length: At least 10 times the length of the robot's maximum length.
- The boundaries of the path shall be visually marked or delimited with stakes or tape.
- No obstacles (rocks, holes, etc.) shall be intentionally introduced, but natural surface irregularities shall remain.

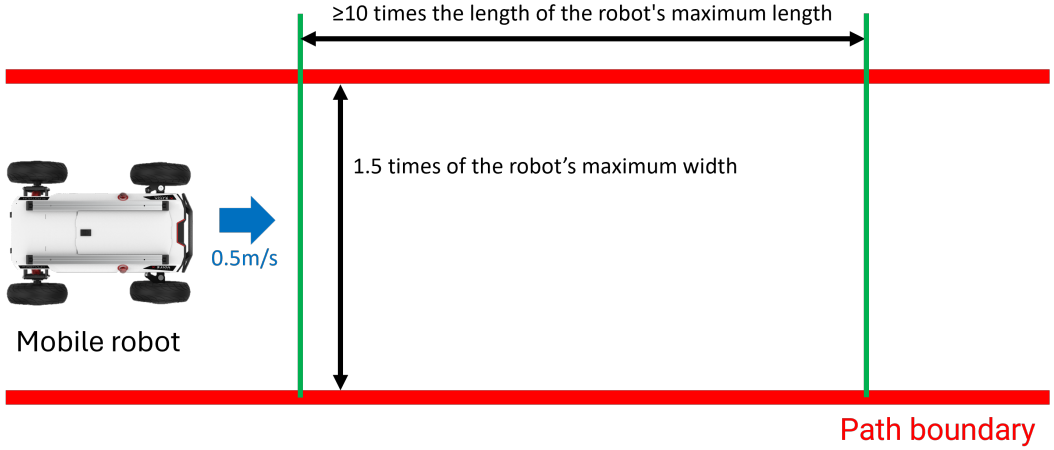

Figure 1. Test area for UGV.

Test Procedure

This test consists of one test configuration and multiple consecutive trials under the same environmental conditions. Each trial follows the steps below:

1. The UGV, configured with its standard payload, is positioned at one end of the test path and aligned along the path direction. Trial start time is marked.
2. The robot moves forward along the centerline of the path at a constant speed of 0.5 m/s for 10 seconds.
3. After 10 seconds, the robot stops for 1 second.
4. The robot then reverses direction (if the robot can drive in reverse) or make a U-turn (if the robot cannot reverse) within 5 seconds and moves backward along the path at the same speed for 10 seconds, followed by another 1 second stop.
5. Steps 2–4 are repeated in a continuous loop until either:
   - The robot topples over or visibly loses stability (e.g., significant tilt, fall [2]), or
   - The robot deviates laterally beyond the path boundary.
6. Trial end time is marked.

Evaluation Criteria and Error Conditions

Trials are evaluated based on the number of successful cycles and duration of each trial (difference between trial start and end times).

A trial is considered failed if any of the following errors occur:

a. The UGV topples over or tips significantly.
b. The UGV deviates beyond the defined path boundaries.
c. The UGV cannot complete one bi-directional cycle due to terrain-induced immobilization.

Conditions

The following test conditions shall be recorded and included in the test report:

- Robot and path sizes.
- Terrain conditions (soil softness, grass cover density, moisture if relevant).
- Terrain gradient (%).
- Observed behavior in each segment (stability, wheel/track slippage, yaw drift).
- Robot configuration and payload details.
- Start and end time of each trial.

Test Result

The following shall be recorded and included in the test report:

- Number of successful cycles (forward + backward).
- Overall duration of test (in seconds).
- Average duration of cycle and standard deviation (in seconds).

- Reason for test termination (e.g. error a, b or c).

The final stability performance shall be declared as the maximum number of successful full bi-directional cycles before failure.

References

1. BS ISO 18646-1_2016
2. BS EN ISO 16231-2:2015