Demo: Policy-based Discovery and Patching of Logic Bugs in Robotic Vehicles

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Video 1: https://youtu.be/nhmKE03-bnR  Video 2: https://youtu.be/g1ZBPW1kYTs

This demo is based on PGFUZZ [1], a policy-guided fuzzer that discovers logic bugs in a robotic vehicle (RV), and PGPATCH [2], a policy-guided logic bug patching for the RV. Logic bugs cause deviations in the RVs’ behavior from the developer’s expectations but do not cause the program to stop execution. Discovering and patching logic bugs is challenging as there is no (i) clear definition of an RV’s “correct behavior” and (ii) methodology to find and fix them.

Discovering Logic Bugs. We address these challenges with PGFUZZ. It (1) takes, as input, a policy (expressed with temporal logic) that describes the RV’s expected behaviors, (2) finds inputs related to the policy via static and dynamic analysis, and (3) mutates the identified inputs based on distance metrics measuring “how close” the RV’s state is to a violation.

For instance, ArduPilot documentation states that the following two conditions must hold to deploy a parachute. C1: the vehicle must not be in the FLIP or ACRO flight modes, and C2: the barometer must show that the vehicle is not climbing. Based on these requirements, we express a policy in temporal logic: C1{Parachute = on} → C2{Mode ≠ FLIP/ACRO} ∧ (ALTt ≤ ALTt−1)} where t and ALT represent time and altitude, □ denotes “always”, and ∧ represents “and”.

PGFUZZ first discovers that flight mode, throttle, and parachute inputs are related to the parachute policy via a combination of static and dynamic analysis. PGFUZZ then mutates the inputs based on propositional and global distances to violate the parachute policy. Particularly, when the global distance is a negative value, the RV violates the policy. As shown in Figure 1, the global distance becomes negative when the propositional distances are positive. Hence, PGFUZZ aims to maximize the propositional distances (P1 = P3). As a result, PGFUZZ discovers that ArduPilot improperly checks the two requirements (C1 and C2). The policy violation causes the RV to deploy the parachute when its flight mode is ACRO/FLIP, making the RV crash on the ground (Figure 2).

We ran PGFUZZ for two days for each RV control program (ArduPilot, PX4, and Paparazzi) to evaluate them against 56 policies. PGFUZZ discovered 156 previously unknown bugs.

Fixing Logic bugs. The root cause of the parachute policy violation is that the RV does not check the preconditions specified in the policy. This bug can be fixed by inserting an “if statement” using the policy as a guide (Listing 1). PGPATCH (1) takes, as input, an existing policy that was used to discover the logic bug through PGFUZZ and bug-triggering inputs that PGFUZZ finds, (2) maps the policy’s

Listing 1: A patch (at lines 2 and 3) for the parachute bug.

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