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Robots Using Environment Objects as Tools The 'MacGyver' Paradigm for Mobile Manipulation

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***Abstract*—Mobile manipulators and humanoid robots should have the ability to use objects in their environments. Previous work has shown significant advantages to robots that can remove objects that interfere with their goal. We propose the next step. Just like the fictional character 'MacGyver,' robots should construct simple machines and tools from arbitrary objects. This video presents our progress in developing and validating 'MacGyver' skills in a simulated rescue mission.**

Mobile Manipulators and Humanoid Robots have the distinct capacity for both motion *and* manipulation. While often used independently, we previously introduced the domain of Navigation Among Movable Obstacles (NAMO) [1] which allowed robots to use manipulation to move obstacles out of the way and assist navigation. Continued work includes the first NAMO implementation, onboard perception and research on manipulation in clutter [2]–[4]. However, in all these cases *environment objects were treated as obstacles*. We now take the next step by giving robots the capability to *use environment objects* and complete task-level missions.

Just like the fictional character 'MacGyver' who uses arbitrary environment objects to construct simple machines, we propose that robots should also take advantage of objects that they find. For instance, robots could use a random board as a lever, a bridge or a wedge. Humans regularly benefit from their ability to use environment objects and now we present the same paradigm as a research area in robotics. Our work is primarily on planning and autonomous decision making [5]. In this video we evaluate actual robot capabilities on Golem Krang, discuss required elements, challenges and areas of research.

In this experiment, we design a complete rescue scenario with a 100kg brick object blocking entry to a room and another 100kg loaded cart. Interestingly, the loaded cart becomes a fulcrum for an arbitrary board to topple the bricks. Then the bricks, which were initially an obstacle, are used as a fulcrum for a lever to pry open the door. Finally the robot uses a wider board to create a bridge and perform the simulated rescue.

To analyze the feasibility and challenges of our new domain we use partial autonomy. Robot actions are directed by teleoperation of location, and workspace gripper position. Balance is autonomously controlled and expanded to incorporate external environment forces arising from object mass and the forces applied during each environment interaction. The importance of autonomous dynamic balance appears in two forms: First, the robot uses its entire body to lean into the two demonstrated lever actions. Furthermore it is able to comply and recover from the impulse and force applied in opening the door via Kalman filtering of experienced forces.

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Fig. 1. Humanoid robot Golem Krang uses a makeshift lever from a 2x4 and an obstacle as the fulcrum to displace a 100kg brick object.

Object Suitability: The robot must determine whether an object is suitable for a task. In bi-manual interaction, our robot keeps a consistent relationship between its arms and grippers and uses active compliance to prevent internal forces. Yet, generating internal forces and applying them to an object is a useful method for testing its tensile strength.

Utilizing Physics: Typical robots cannot move 100kg objects. Yet, Krang grasps a 2x4 board, creates a lever *and* leans into it with his entire mass. The relationship between distance and torque created by the lever makes it possible to achieve two displacements. Also, re-grasping the lever can be achieved in the air since gravity and friction ensure the board stays in a given configuration while the robot moves its grippers. Re-grasping is automated in our system.

Local Linearization: An interesting challenge in this experiment was opening the door with the lever. Due to the highly constrained space and Krang's non-holonomic motion it was essential that Krang, the fulcrum and the door be positioned precisely so that the forward motion would locally generate the greatest force/impulse on the door. Future work will reason about such linearization autonomously.

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