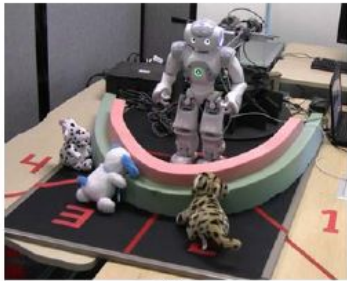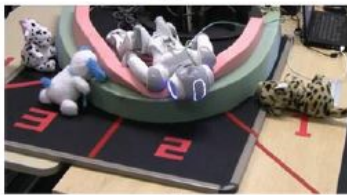# Direction-changing fall control of humanoid robots: theory and experiments

(a)

(b)

(c)

(d)

(e)

Humanoid robots are expected to share human environments in the future and it is important to ensure the safety of their operation. A serious threat to safety is the fall of such robots, which can seriously damage the robot itself as well as objects in its surrounding. Although fall is a rare event in the life of a humanoid robot, the robot must be equipped with a robust fall strategy since the consequences of fall can be catastrophic. In this paper we present a strategy to change the default fall direction of a robot, during the fall. By changing the fall direction, the robot may avoid falling on a delicate object or on a person. Our approach is based

on the key observation that the toppling motion of a robot necessarily occurs at an edge of its support area. To modify the fall direction, the robot needs to change the position and orientation of this edge vis-a-vis the prohibited directions. We achieve this through intelligent stepping as soon as the fall is predicted. We compute the optimal stepping location which results in the safest fall. Additional improvement to the fall controller is achieved through inertia shaping, which is a principled approach aimed at manipulating the robot's centroidal inertia, thereby indirectly controlling its fall direction. We describe the theory behind this approach and demonstrate our results through simulation and experiments of the Aldebaran NAO H25 robot. To our knowledge, this is the first implementation of a controller that attempts to change the fall direction of a humanoid robot.

Publications:

"Direction-changing fall control of humanoid robots: theory and experiments," A.Goswami, S.-K. Yun, U.Nagarajan, S.-H. Lee · K. Yin, S.Kalyanakrishnan, Autonomous Robots, 36(3):199-223, 2014