The Power of The Dark Side:

Using Cast Shadows for Visually-Guided Touching

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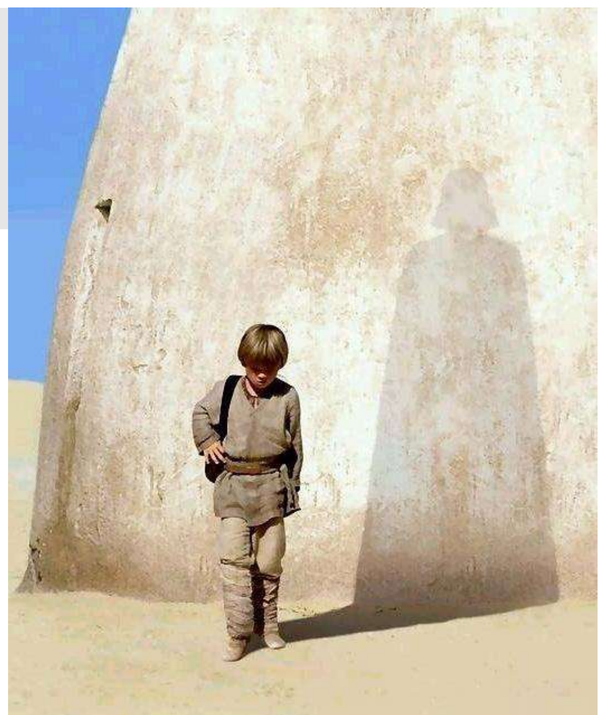
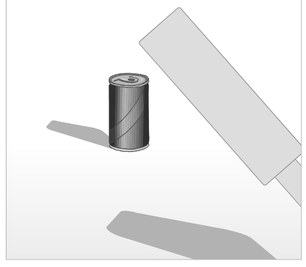


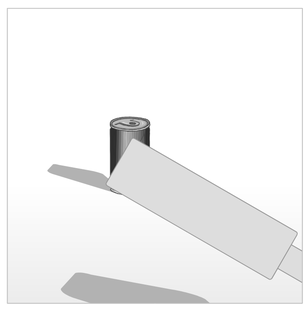
Shadows can be very revealing!

MOTIVATION AND GOALS

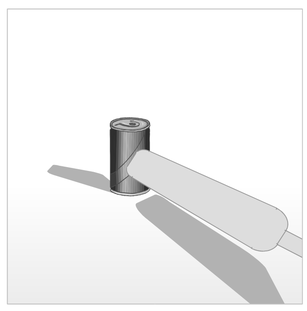
- In computer vision, shadows are generally treated as a nuisance, but that doesn't mean roboticists should do the same.
- We show that the cast shadow of a robot arm on a surface can be detected by a camera and used to derive a time-to-contact estimate.
- We achieve 3D control of a robot arm relative to an unmodelled surface by integrating shadow information with 2D visual cues.
- This method is complementary to stereo vision in scenarios with reflections and low-texture surfaces.
- We show that reflections can be detected and used in the same way as cast shadows.



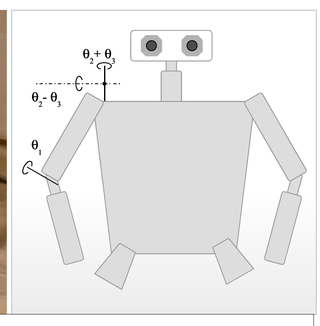
Robot sees target, arm, and arm's shadow



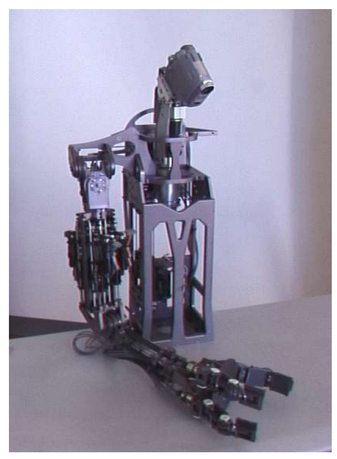
Robot moves to reduce visual error between arm and target



Robot moves to reduce visual error between arm's shadow and target



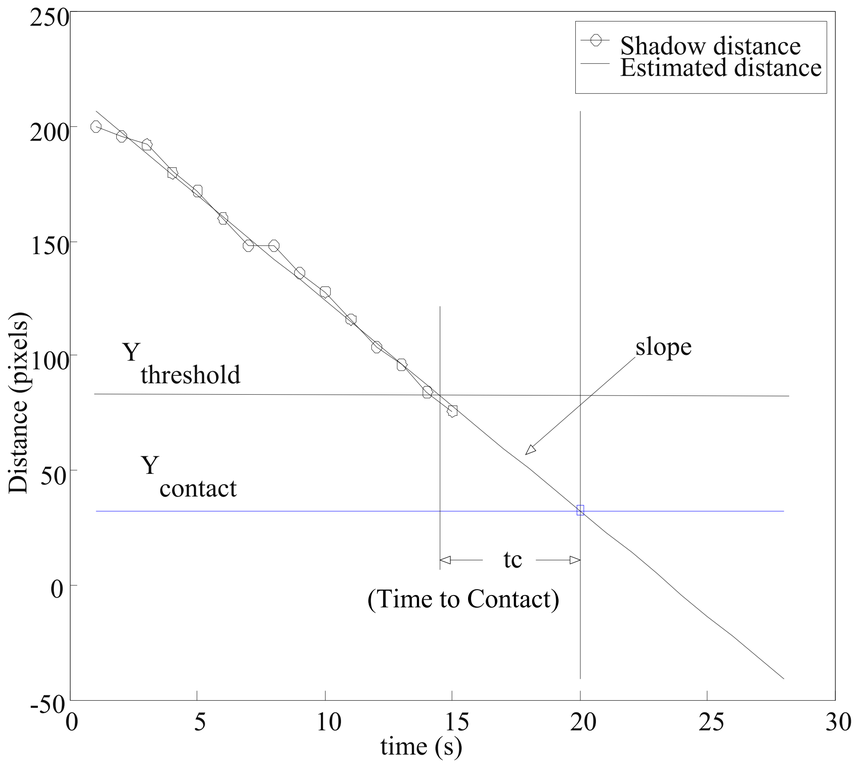
Coco: A gorilla robot



Obrero: The next generation platform

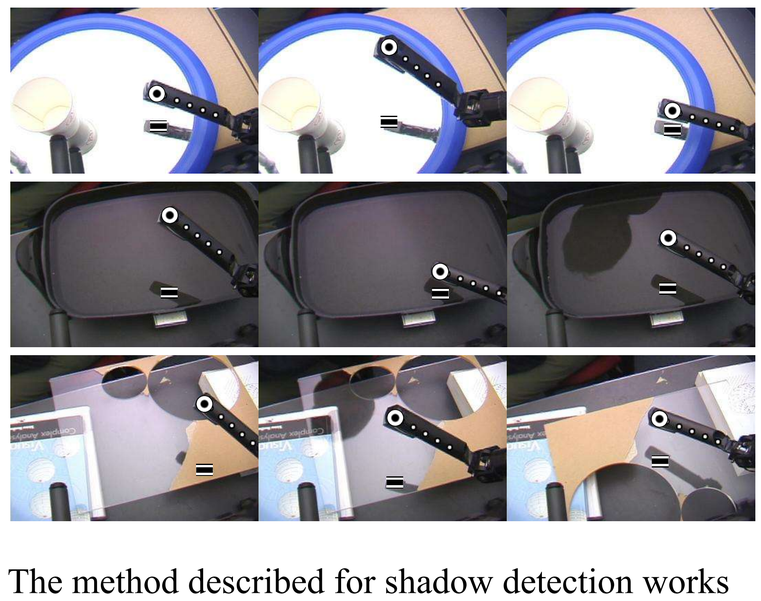
SHADOW DETECTION

- We detect shadows using their motion.
- We detect motion using both image differencing and a background model built as the arm swings into view.
- The arm itself is tracked and discounted.
- The figure on the left shows examples of detection of the arm endpoint (circle) and the arm's shadow (bar).
- The surfaces are at different distances.
- Lighting varies from ambient to strongly directional.



TIME TO CONTACT ESTIMATION

- We acquire samples of the distance between the arm and its shadow for a period of time.
- We estimate the rate of change of the distance.
- Using this information we can predict the time-to-contact assuming motion linearity (this is similar to time to collision using optic flow in navigation).
- Since the tracked points in the shadow and hand might not correspond exactly, there can be an offset in when contact occurs.
- We use a force sensor to learn this offset.



The method described for shadow detection works without change to detect reflections.

Top: mirror, Middle: water, Bottom: acrylic.