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Vision-based Tactile Sensor

ABSTRACT

When a real or virtual object is picked up using a robotic arm, the strain, e.g., the pattern of deformation, on the object is unclear. Tactile sensing is key to autonomous robotic interaction with the world. This disclosure describes techniques to determine a contour map of the strain on an object being picked up by a robotic arm or other prehensile device. Per the techniques, cameras sensitive to light polarization are used to detect the polarization angle of the light being reflected off the picked-up object. The polarization angle of light reflecting off a given point on the surface is used to infer various object reactions to the gripping pressure, e.g., the contour map of the deformation of the object, etc.

KEYWORDS

- Tactile sensor
- Light polarization
- Photoelasticity
- Virtual reality
- Augmented reality
- Robot vision

BACKGROUND

When a virtual object is picked up, e.g., in a virtual or augmented reality landscape using a robotic arm, the strain, e.g., the pattern of deformation, on the object is unclear. For example, the virtual (or real) object may be fragile, e.g., an egg, which could break if the prehensile grip is even slightly too high. On the other hand, too low a prehensile grip can result in the object being dropped or remaining unpicked. In general, the amount of force applied on an object is known, but the reaction of the object to that force is not. Although there are some attempts at modeling object reactions, e.g., deformations, for virtual objects, these are done at a large scale, e.g., for the entire object, making such modeling unrealistic.

Tactile sensing is key to autonomous robotic interaction with the outside world. Building a tactile sensor as accurate and capable as a human's prehensile grip is an ongoing challenge. In one approach, a compliant medium and a camera observe suspended or imprinted dots and their displacements to infer the tactile force due to the interaction of the robotic arm with the outside world. The use of suspended dots is challenging both in terms of manufacturing and accuracy: too high a density of the dots minimizes sensing range, and too low a density reduces spatial sensitivity.

DESCRIPTION

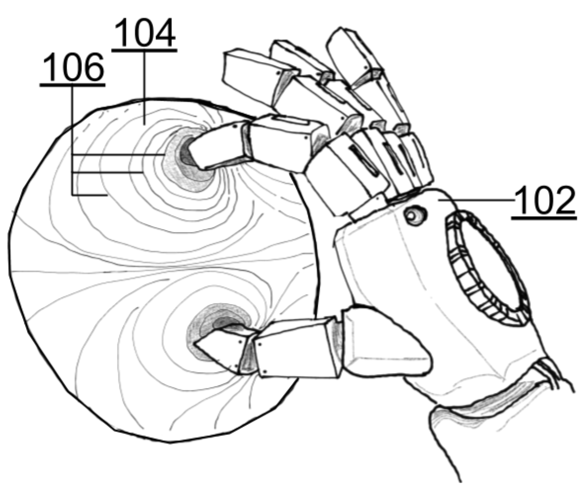

Fig. 1: Strain contour pattern on an object being picked up

As illustrated in Fig. 1, this disclosure describes techniques to determine a contour map (106) of the strain on an object (104) being picked up, e.g., by a robotic arm (102) or other prehensile device.

The techniques leverage the observation that the polarization of light incident on a surface changes, upon reflection, to be parallel to the surface (this is true for most non-metallic surfaces like plastic, glass, etc.). The polarization angle of light reflecting off a given point on the surface can thus be an indicator of the deformation of the surface at that point.

Per the techniques, cameras sensitive to light polarization are used to detect the polarization angle of the light being reflected off objects. Such cameras can be built by configuring pixels to detect light coming in from specific polarization angles. The polarization angle of light reflecting off a given point on the surface is used to infer various object reactions to the gripping pressure, e.g., the pressure map on the object, the contour map of the deformation of the object, the flex points or lines on the object, etc. A fine-grained map of object reaction to applied pressure is obtained. The techniques can be combined with other techniques for object-surface deformation mapping, e.g., slip detection, the use of traditional cameras insensitive to polarization angle, etc.

The obtained map of object reaction to applied pressure is fed to a machine learning model along with known object parameters to train the machine learning model. Upon training, the machine learning model can map light polarization (object reaction) to object parameters, and vice-versa. The machine learning model can be used to automatically generate object characteristics for virtual objects. For example, a real-world object, e.g., a plastic mold, can be scanned to obtain parameters that can be applied to a virtual version of that object. In this manner, tactile feedback in virtual reality is made fine-grained, realistic, and efficient, without extensive manual programming.

CONCLUSION

This disclosure describes techniques to determine a contour map of the strain on an object being picked up by a robotic arm or other prehensile device. Per the techniques, cameras sensitive to light polarization are used to detect the polarization angle of the light being reflected off the picked-up object. The polarization angle of light reflecting off a given point on the surface is used to infer various object reactions to the gripping pressure, e.g., the contour map of the deformation of the object, etc.