Acquiring material properties of objects for tactile simulation through point cloud scans

Haocheng Yang H.Yang@student.tudelft.nl
Supervisor: Kees Kroep h.j.c.kroep@tudelft.nl

1. Research Background

Tactile internet enables communication in a new layer of immersion, touch. It has the potential to transform the landscape of digital communication. Shown in **Figure 1.** Applications: immersive conferencing, remote surgery.

Latency bottleneck: However, the achievable scale of tactile internet is severely limited by its 1ms round-trip network latency [2].

Physics simulation as workaround: fake the "touch" interaction with virtual environment simulation, bypassing latency requirements. Shown in **Figure 2.**

Virtual environment from point cloud scans: quick acquisition of environmental data in real-time.

Material estimation for simulation: to acquire physical properties such as friction and tactile texture.
- Machine learning
- Visual combined with haptic information
- Using LiDAR point intensity [3]

2. Research Questions

How to acquire material properties of objects for tactile simulation through point cloud scans?
- How to correctly estimate and recognize **the material properties** of objects represented by segmented point clouds?
- How to identify **compound materials**? i.e. a glass jar with a plastic lid.
- How to acquire **physical properties** from the object material to be used for physics simulation, e.g. friction?
- How to acquire **tactile texture** from the object material so the user can experience the object with suitable tactile sensation?

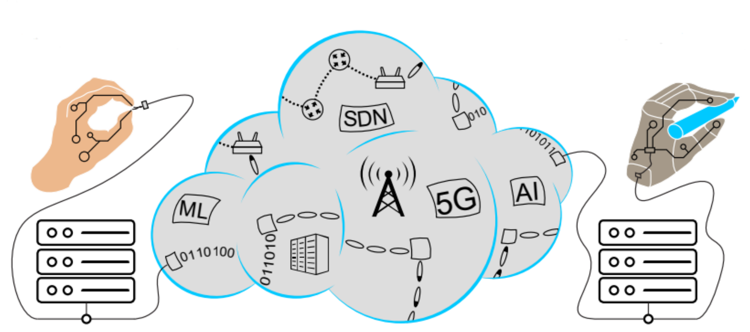

Figure 1. Operating in tactile internet, Remotely holding a pen [1].

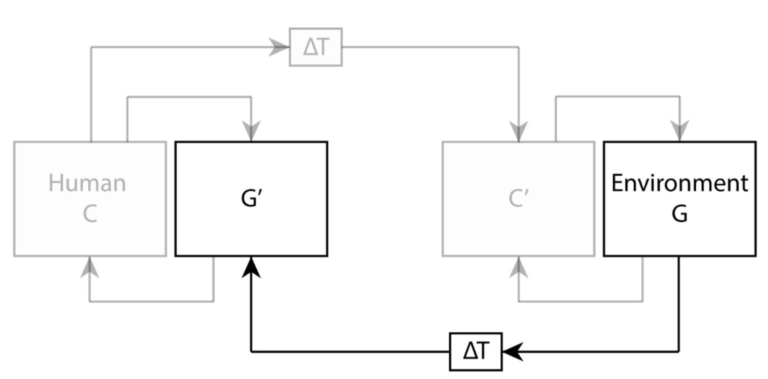

Figure 2. Using virtual simulation to achieve tactile internet.

3. Methodology

Material recognition from mesh texture
- Idea: match material features with **scale-invariant feature transform**
- Generate mesh from point cloud
- Texture the mesh by assigning point color to mesh vertex
- Due to **UV distortion**, recognition is impossible. Shown in **Figure 4.**

Material estimation with intensity [3]
- Point normal and **intensity correction**
- **Emissivity:** heat radiated by material surface
- **Albedo:** fraction of sunlight a surface reflects
- **Reflectance:** ratio of reflected light energy relative to the amount of incident light

Material estimation without intensity
- Unavailability of clouds with intensity data
- Mock intensity with **grayscale**

Friction estimation from material
- Friction is **empirical measurement** [4]
- Requires matching pre-prepared library

Tactile texture from material
- Depends solely on the **visual expectation**
- Hypothesis: users will be satisfied as long as it correlates with visual information

4. Results

With mocked intensity, the method cannot discern objects of the same color but different material. See **Table 1.**
- (b) is different from (a) and (c)
- (e) differs greatly from (d) and (f), but of the same material
- (g) and (i) have identical material properties, however (g) is metal and (i) is cloth.

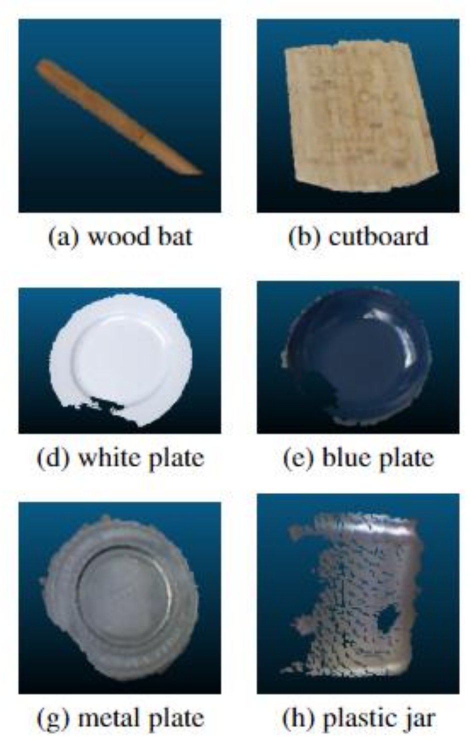

Figure 3. input point clouds.

Index	Object	Estimated Material properties		
		Emissivity	Albedo	Reflectance
(a)	Wood Bat	0.62	0.15	0.38
(b)	Cutboard	0.39	0.36	0.60
(c)	Salt shaker	0.56	0.19	0.43
(d)	White plate	0.11	0.80	0.89
(e)	Blue plate	0.81	0.04	0.19
(f)	Beige plate	0.06	0.97	0.94
(g)	Metal plate	0.55	0.21	0.45
(h)	Plastic jar	0.58	0.19	0.42
(i)	Cushion	0.55	0.21	0.45

Table 1. Material properties of segmented point clouds using mock intensity.

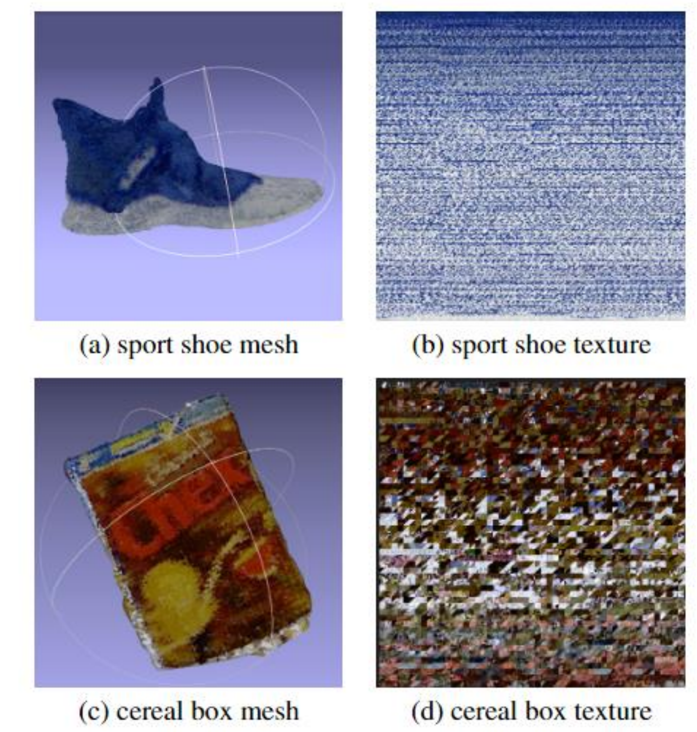

Figure 4. Constructed meshes from segmented point cloud (left) and their colored texture (right).

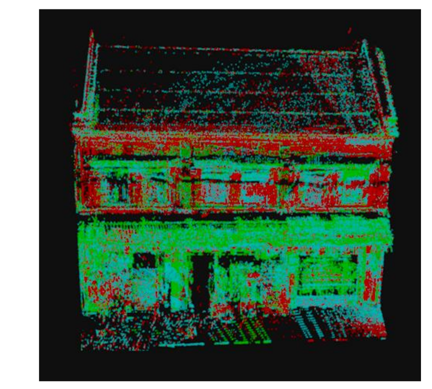

Figure 5. Recognized compound material from point cloud.

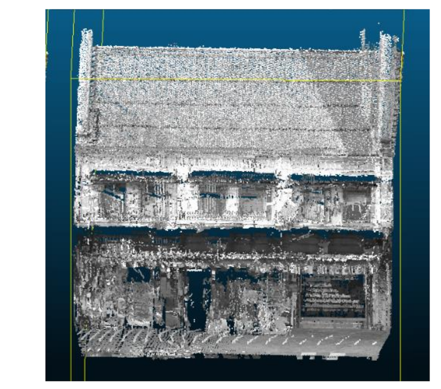

Figure 6. Intensity of point cloud visualized as grayscale.

5. Conclusions

Method to estimate material properties from segmented point cloud so it can be simulated in a physics simulation.

It is not viable to estimate point cloud material from mesh texture
- UV distortion, as shown in **Figure 4**.

Architectural method of using cloud intensity and RGB information to estimate material properties can be viable.
- Requires extension to indoor objects

Intensity plays an integral role in material estimation; therefore, it cannot be omitted.
- Unable to account for material differences, can only account for color differences

6. Future Work

Kinect V2 for low-cost, sufficient quality infrared intensity images. Alternative to high-cost LiDAR scanner.
- Create point clouds with intensity
- Further validation of material estimation method with intensity

A Controlled experiment on user's expectant quality of tactile texture when presented with visual footage.
- Wizard of oz
- Does not require full system implementation
- Let users rate the quality of experience with varying tactile texture simulation quality, given different texture images

References

[1] J. C. Kroep, V. Gokhale, J. Verburg, and R. Venkatesha Prasad. Etvo: Effectively measuring tactile internet with experimental validation. 7 2021.

[2] Gerhard P. Fettweis. The tactile internet: Applications and challenges. IEEE Vehicular Technology Magazine, 9(1):64–70, 2014.

[3] Miktha Farid Alkadri, Michela Turrin, and Sevil Sariyildiz. A computational workflow to analyse material properties and solar radiation of existing contexts from attribute information of point cloud data. Building and Environment, 155:268–282, 5 2019.

[4] Vladimir Malyshev. Tribological aspects in friction stir welding and processing, pages 329–386. 12 2014.