1. Introduction

Do we need Indoor Positioning?

Source: Image by StartupStocks from Pixabay

GPS positoning systems work well outdoors, but ...

Source: Image by CIker-Free-Vector-Images from Pixabay

Humans spend majority of their time in indoor spaces ...

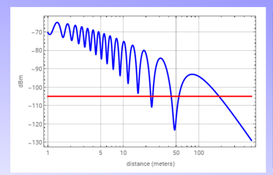
Be it offices or supermarkets ...

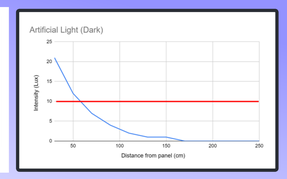
Source: Image by THAM YUAN YUAN from Pixabay

Why not make life easier with an indoor positioning system?

2. Motivation

Why choose Visible Light Communication?





Radiowaves*: Multipath propagation

- Multipath propagation - cannot pinpoint origin based on received intensity
- Overcrowded (Cellular, Bluetooth, Wi-fi, GPS)

Visible Light: Line-of-sight propagation

- Line-of-sight propagation - can find one origin/source based on intensity
- Largely untouched spectrum

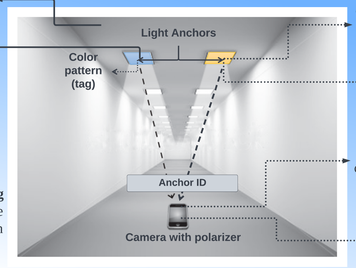
**Source: https://demonstrations.wolfram.com/RadioPropagationAndMultipathWithDiversityAntennas/*

3. System

How does Visible Light Indoor Positioning Work?

Use of existing lighting infrastructure

A grid-pattern** **tag** made from adhesive tape placed between two polarizers - communicates *Anchor ID*



A VLP system* for an indoor space

Components:

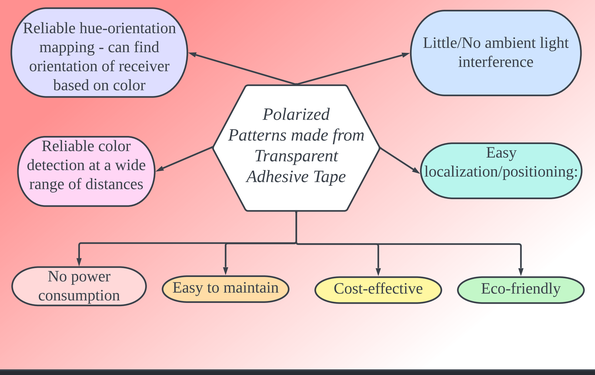
- Transmitter (light source)
- Modulation Scheme (tag made from tape and polarizer)
- Receiver (smartphone camera with a polarizer)
- Localization (i.e. *Positioning*) scheme/algorithm

**Source: T.-H. Do and M. Yoo, "An in-Depth Survey of Visible Light Communication Based Positioning Systems," Sensors, vol. 16, no. 5, p. 678, May 2016, doi: 10.3390/s16050678.*

***Source: Z. Tianet al., "Augmenting Indoor Inertial Tracking with Polarized Light," Proceedings of the 16th Annual International Conference on Mobile Systems, Applications, and Services, Jun. 2018, doi: 10.1145/3210240.3210340.*

8. Conclusion

Why choose these color patterns for VLP?



Analysis of Birefringent Materials To Create Static Polarized Patterns For Visible Light (Indoor) Positioning

Author: Naval Tapan Bhagat
n.t.bhagat-1@student.tudelft.nl

Supervisor: Miguel Chavez Tapia
Professor: Marco Zuniga Zamalloa

TU Delft Delft University of Technology

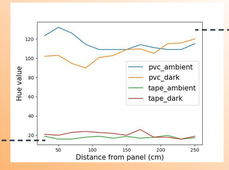
7. Results

Results are in :)

Visibility Range

- **Visibility range: 18-21** ***(hue values)***
- **No interference from ambient light**

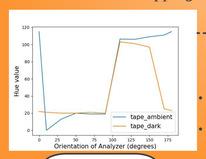
Transparent Adhesive Tape



Plastic/Cling wrap

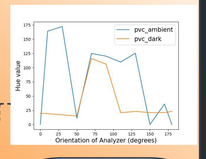
- Visibility range: 90-130 *(hue values)*
- High interference from ambient light

Hue-Orientation Mapping



Transparent Adhesive Tape

- **Step-pattern mapping - can find orientation from color**
- **Small interference from ambient light**
- Bell-curve - two orientations for same color
- High interference from ambient light

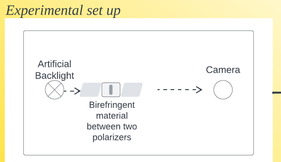


Plastic/Cling wrap

6. Methodology

Let's do some experiments!

Experimental set up



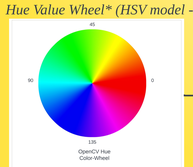
Visibility Range

Move camera backwards at set intervals and record hue (color) in both dark and ambient environments.

Hue-Orientation Mapping

Rotate second polarizer at set intervals and record hue (color) in both dark and ambient environments.

Hue Value Wheel (HSV model - OpenCV)*

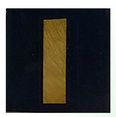


Hue values can range from 0 to 180

**Source: Image by Pete Linforth from Pixabay*

5. Research Question

Tape or Plastic?



Transparent Adhesive Tape

Plastic/PVC (cling-wrap)

Both are:

- Cheap
- Light-weight
- Birefringent

But, which one is suitable for a Visibile Light Indoor Positioning (VLP) system?

Research Question

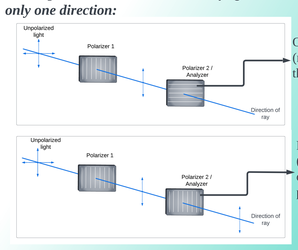
For each material:
Can a smartphone camera capture the color (hue-value) correctly in the following three conditions?

- Varying distances (**visibility range**)
- Varying orientations of second polarizer (**hue-orientation mapping**)
- Dark and Ambient light enviornments (**invariance to ambient light interference**)

4. Background

Polarization and Birefringence

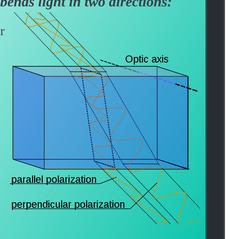
Linear polarizers allow oscillation of light in only one direction:



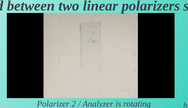
Orthogonal polarizer (no light passes through)

Parallel polarizer (only **one** direction of light passes through)

Birefringence* (bi-refraction) bends light in two directions:



A birefringent material placed between two linear polarizers shows birefringence effects



Polarizer 2 / Analyzer is rotating

**Source: By Mikael Häggström - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=10953566*