Realtime Breathing

Respiratory rate and chest movement analysis

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Goals And Motivation

- Investigate how artificial intelligence can be applied to visual information in order to detect abnormalities in chest motion.
- Introduce a simple and non-invasive procedure to measure respiratory rate of human patients, using a video camera.
- Contribute to Intel Realsense documentation and collection of examples.

Tools And Environments

Intel Realsense
Depth Camera D435

- Intel Realsense Github source code & examples
- SDK 2.0

- Visual Studio 2017
- C++
- CMake
- Dear Imgui
- OpenCV
- cv-plot

Methods

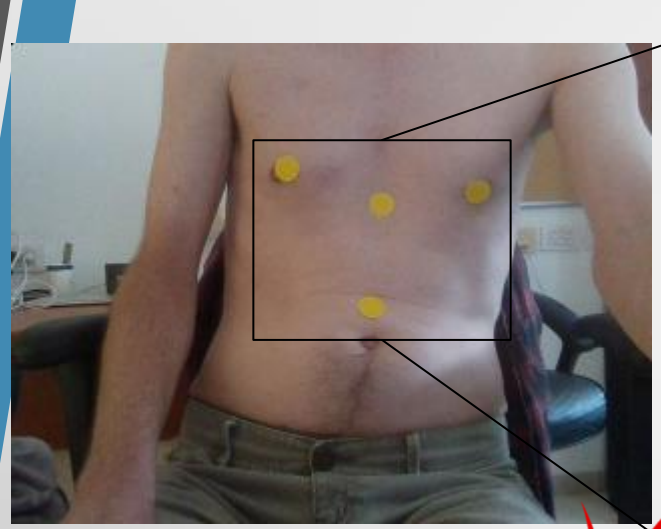
- Data Collection
- Image Processing
- Math

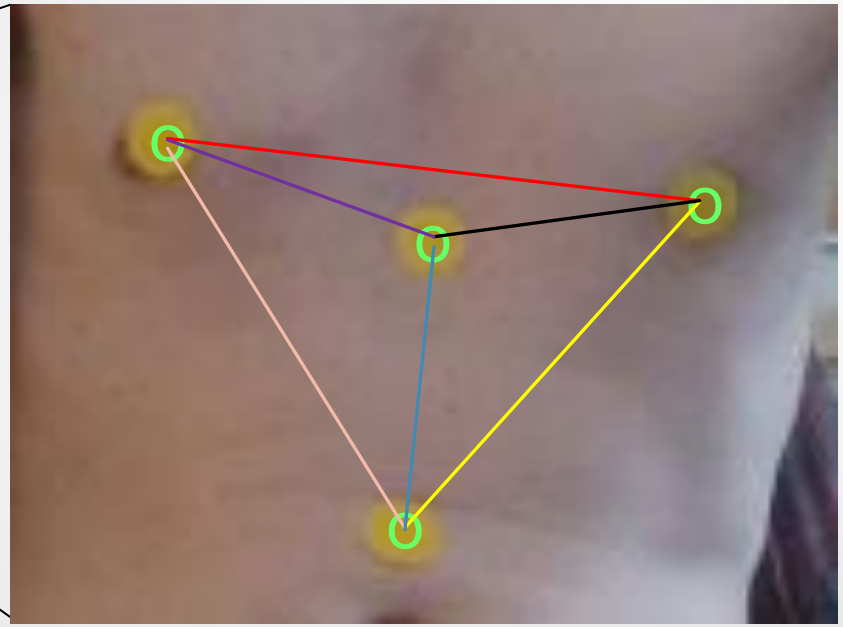
Data Collection

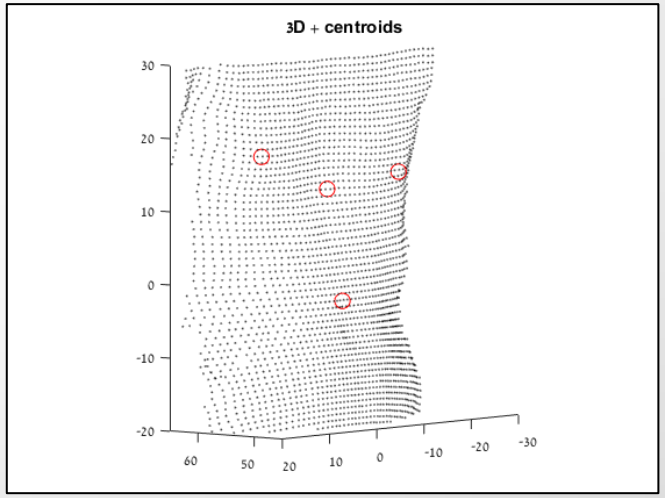
Assumptions:

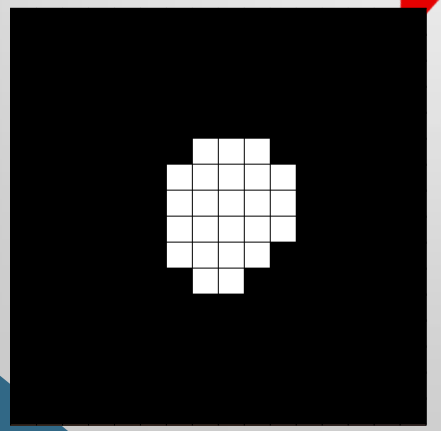
- 4 or 5 stickers of ~2cm diameter
  - Supported colors: yellow, blue and green
  - Diameter may vary but must be consistent for all stickers
- Positioned accordingly
- Good visibility on chest
  - Required for color distinction

Image Processing









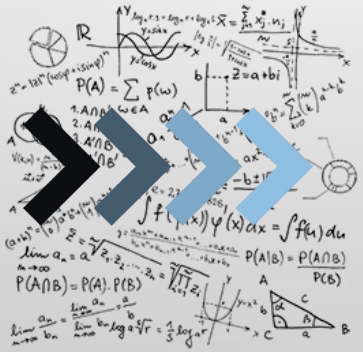


Image Processing (Detail)

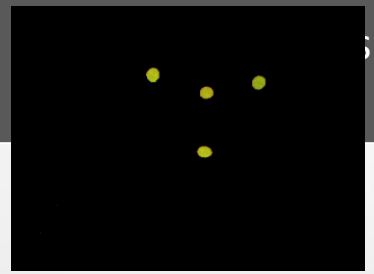
Frame Polling

- **Frameset** ~25 fps
  - Depth
  - Color
- **Wait** mechanism

Image Processing (Detail)

Frame Polling → Alignment

- **Align depth to color**
  - Sizes difference
  - Allow uniform pixel coordinates



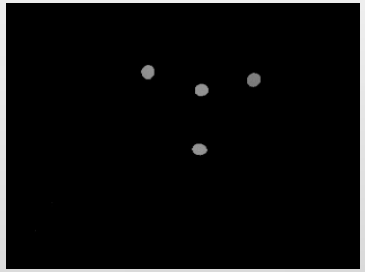
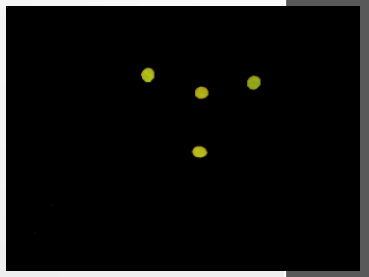
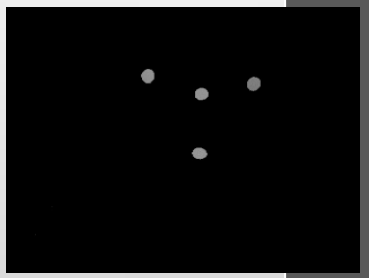


Image Processing (Detail)

Frame Polling → Alignment → Color Detection



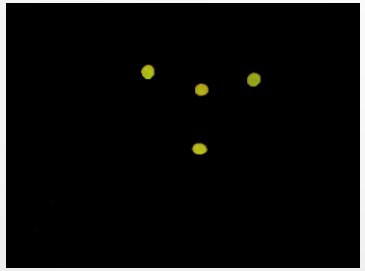


- **RGB to BGR**
  - OpenCV format
- **BGR to HSV**
  - Wider and more accurate selected color range
- **Binary mask**
- **BGR to GRAY**
- **Image threshold**
  - Binary B&W
  - Input for CC

Image Processing (Detail)

Frame Polling → Alignment → Color Detection → Connected Components

- **connectedComponentsWithStats()**
  - Returns centroids
  - Saved in FrameData
- Noise…



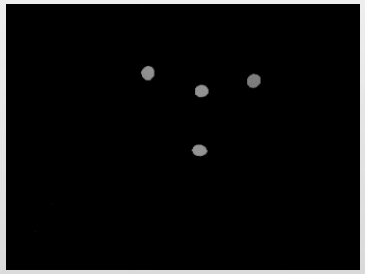
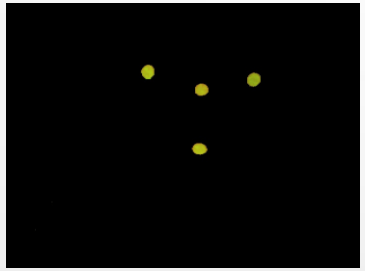


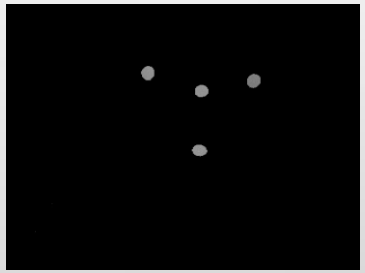
Image Processing (Detail)

Frame Polling → Alignment → Color Detection → Connected Components → Frame Manager

Set of last frames processed

- **Cleanup**
  - Missing frames
  - Poor detection
- **Distances** calculation





Intel SDK – Frame Polling & Alignment

- rs2::**pipeline**
  - **start**()
  - **stop**()
  - **wait_for_frames**()
- rs2::**config**
  - **enable_stream**()
  - **disable_stream**()
  - **RS2_STREAM_DEPTH** or **RS2_STREAM_COLOR**

- rs2::**align**
  - **align_to_depth(RS2_STREAM_DEPTH)**
  - **align_to_color(RS2_STREAM_COLOR)**
- rs2::**frameset**
  - **get_depth_frame** ⇢ rs2::depth_frame
  - **get_color_frame** ⇢ rs2::video_frame
  - **colorizer**
  - Each frame has profile & ID

Intel SDK – Frame Manager

- depth_frame.**get_distance**(x, y)
- 3D distances calculation
  - **rs2_deproject_pixel_to_point**(…)
    (rs-measure example)
- **get_timestamp**()

Intel SDK – Rendering

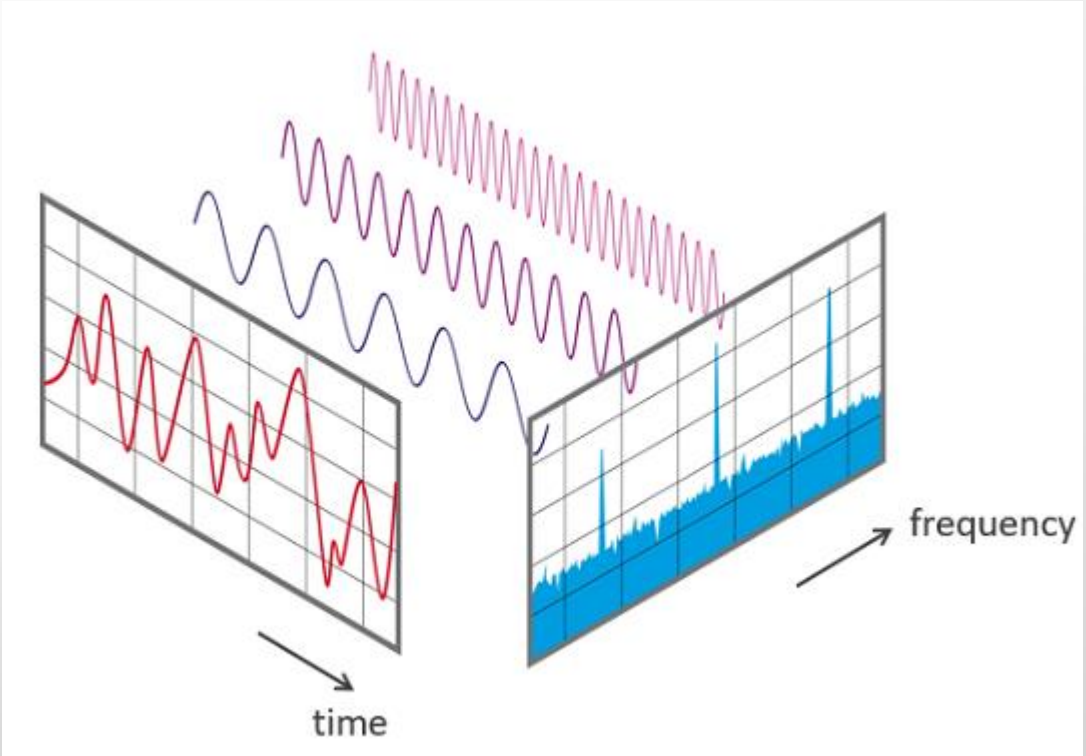
- map<int, rs2::frame> render_frames
  - Stores frames to be rendered
  - render_frames[frame_id] = **colorizer.process**(frame)
- Class **window** (from **example.hpp**)
  - **show**(rs2::frame)

Data Extraction

- Frames IDs
- Frames timestamps (Color & depth)
- Stickers coordinates in pixels (2D & 3D) and cm (3D only)
- 2D & 3D Distances ⇒ 2D & 3D means

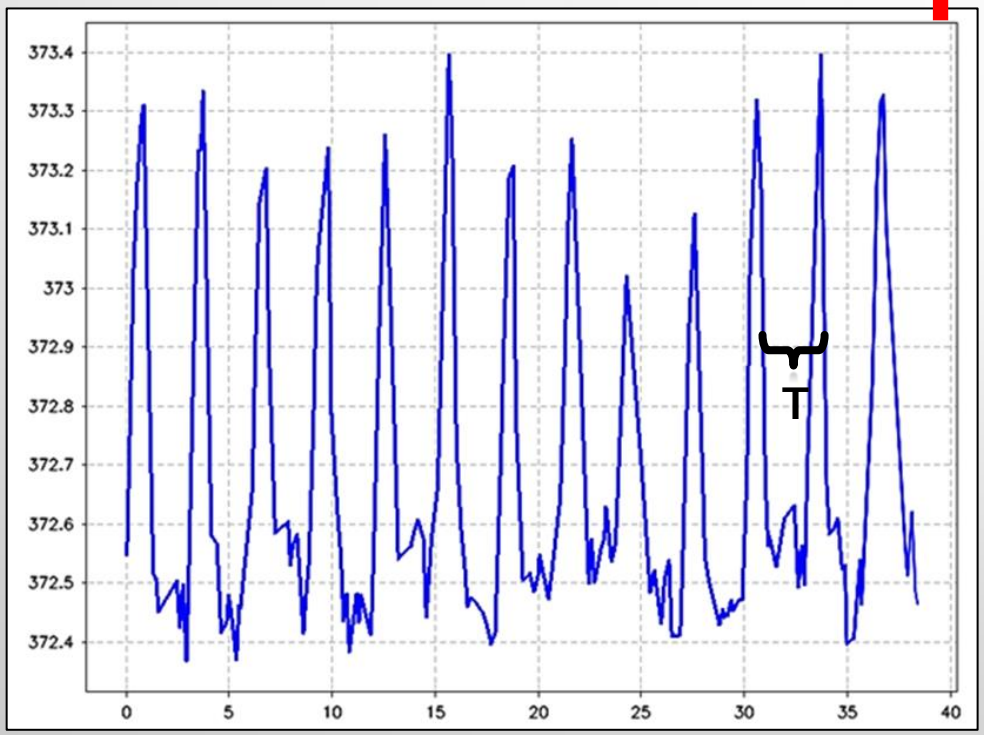
Math

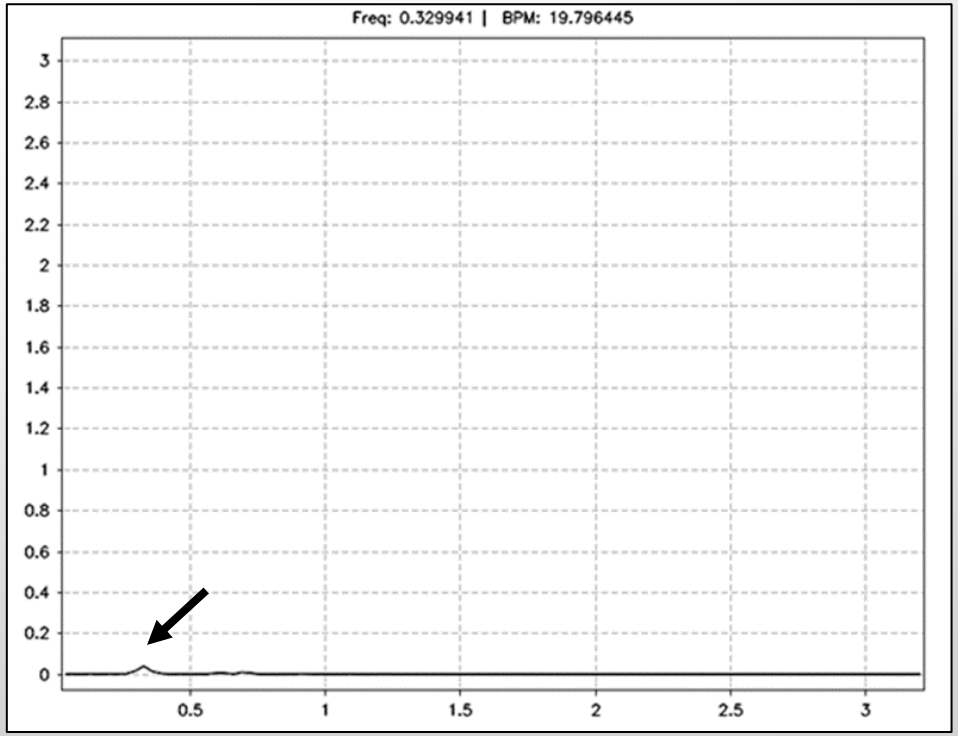
- Fourier Transform
- Data from 256 frames "intervals" **overlapping**
- Frequency of highest peak (after noise reduction)



Math – 2D Sample

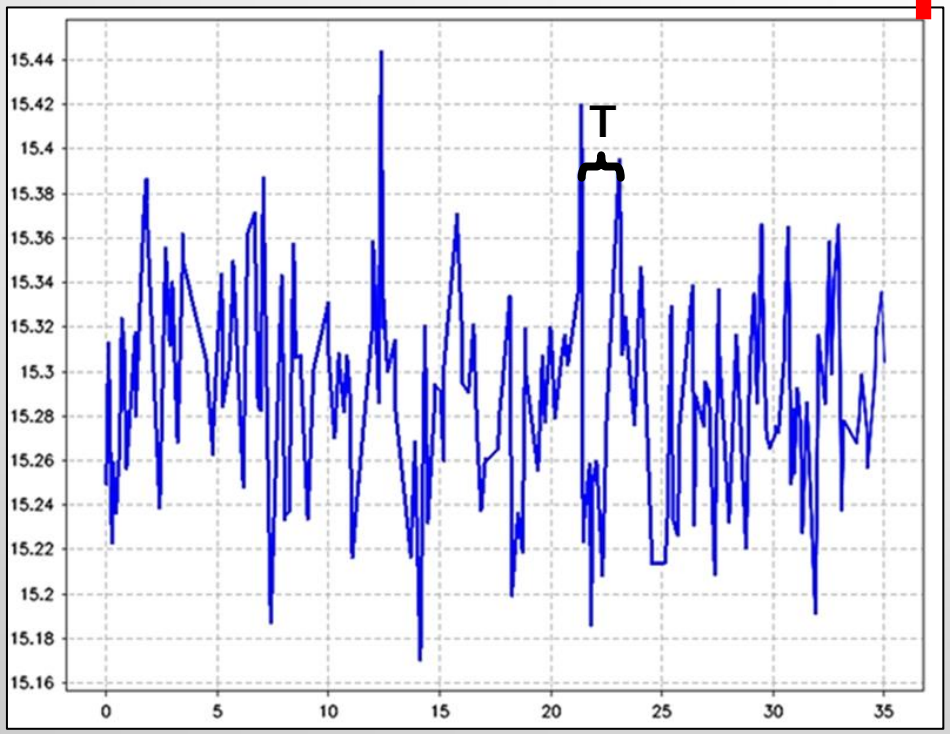
FT

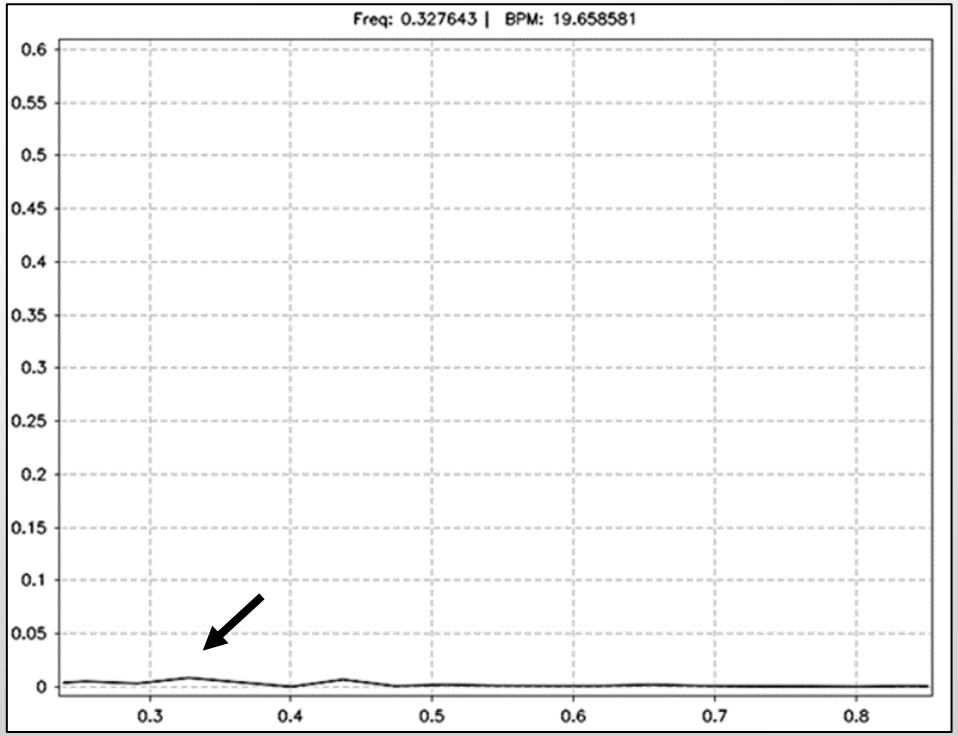




Math – 3D Sample

FT





Our Resolutions

Intel SDK, Viewe mples

- Intel Realse
  - p and properties
  - So emetation
  - **NO D MENTATION**

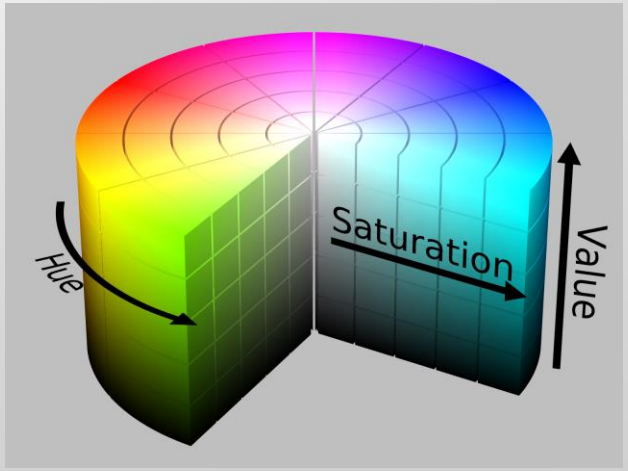
CREATING BASIC GUI BY OURSELVES

Hough vs. Connected Components

- Hough Algorithm to find circles
  - Not robust enough
  - Requires multiple (expensive) iterations to work correctly
- Solution: Connected Components Algorithm (with stats)
  - Robust and efficient
  - Finds centroids
  - But…
    - Noise sensitive
    - Relies on fine color detection

Color Detection – HSV

- RGB color ranges are too strict
  - No feasible ranges for a color considering its shades and highlights
- Hue, Saturation, Value
  - Allows wide selection of yellows (and blues, greens…)
  - Wide shades and saturation range
  - Pretty precise

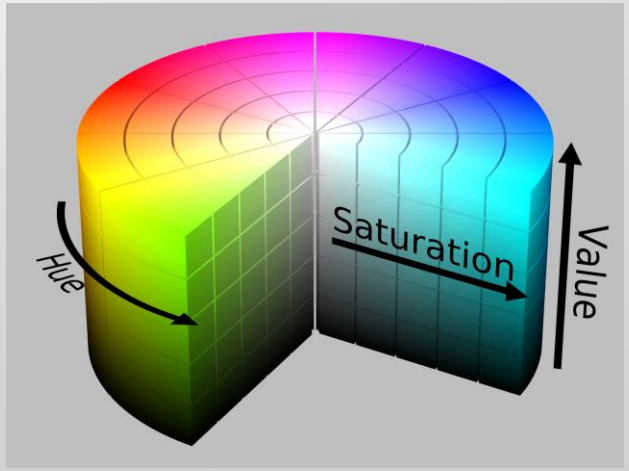


Color Detection – HSV

- For yellows: (20,50,50) → (40,255,255) (OpenCV)

- Blues: (90,20,10) -> (135,255,255)

- Greens: (35,30,30) -> (85,255,255)



Fourier Transform – Noises

- Filters (hpf, lpf…)
  - Avoid aliasing
  - Results remained unaffected – aliasing was not the cause
- Alternative frequency determination method: average time elapsed between peaks
  - Works well in 2D
  - Extensively affected by parameters fine tuning
    - More data is needed to validate current tuning
- **Samples normalization**
  - Each iteration, according to current max and min values
  - Normalized and shifted to [-1, 1]
  - Results improved significantly

Results

- 2D measurements are quite precise, but prone to small error.
- 2D implementation is based on color detection and can be altered to be used in other platforms.
- 3D measurements are noisier and thus less reliable. Depth is not always achieved via the 3D camera (might be improved by usage of a wider depth range and more precise depth camera).
- 3D measurements supply subtle enough depth information for abnormal chest movement, and further processing can be done to detect abnormal motion. (anti-phase breathing, breath volume, etc.)
- Fourier transform might be insufficient for BPM calculation in 3D due to non-negligible noises.

Expected vs Results

- Camera and manual measurements will be identical (up to a small error extent) Although camera measurements are valid only under certain conditions
- RGB measurements will be sufficient at certain circumstances; Implementation can be relevant for other platforms.
- 3D measurements might supply additional information ~~and assist in case of non favorable conditions (frame disturbances).~~
  3D measurements are more prone to noises and disrupts and supply less legible information
- ~~Lay a footprint on Realsense Github!~~ ☺ ☹

Future Work

- Breath Volume
- Phase Shift
- Remove stickers dependency

Questions?