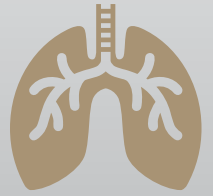
DeepBreath

Chest movement analysis

Nili Furman

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 volume change** and chest movement **phasing** in humans, using a depth 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 2019
- C++
- **RealtimeBreathing ☺**
- ~~Dear Imgui~~
- OpenCV
- plog

- Qt Creator
- Qt5
- C++
- Qt tool for VS

Methods

Data Collection

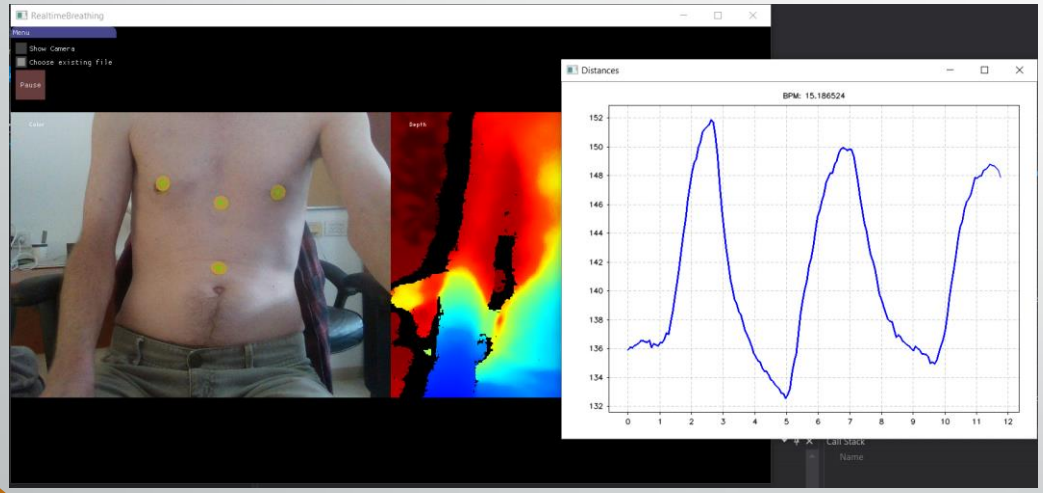
Image Processing

Math

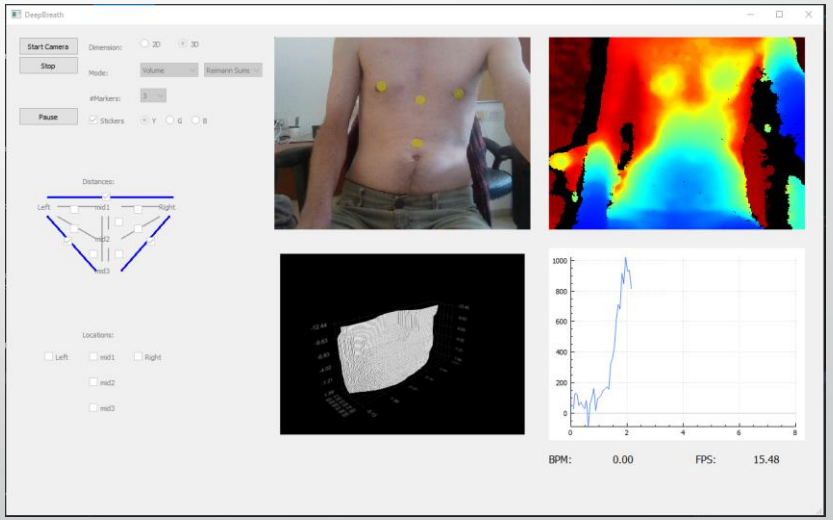
Before All...

UI

Realtime Breathing



Deep Breath



Responsive UI

EVENT – BASED

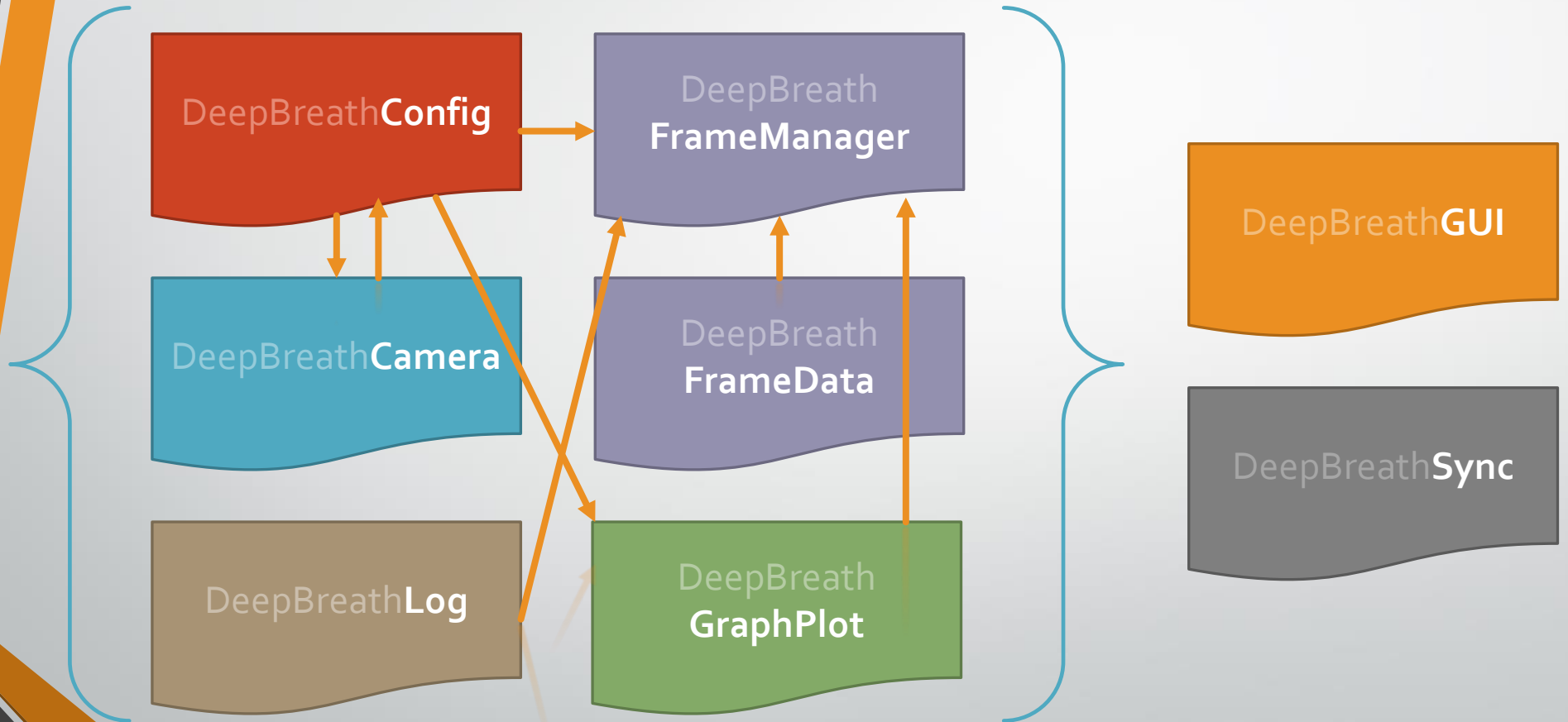
USER FRIENDLY

READABLE & EASY TO MAINTAIN

Refactoring

- All-in-one → Object Oriented
- Singletons
- Logger
- Synchronization objects
- Config file used only for default selections on app start

Refactoring



Data Collection - Currently

Assumptions:

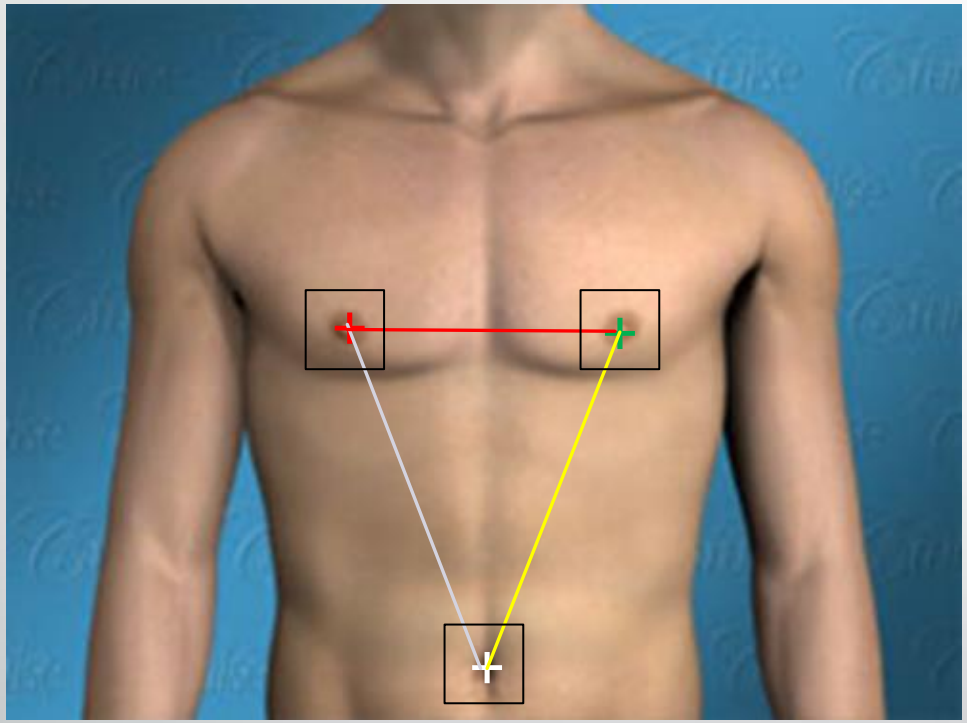
- 3-5 yellow stickers of ~2cm diameter
- Positioned accordingly
- Good visibility on chest

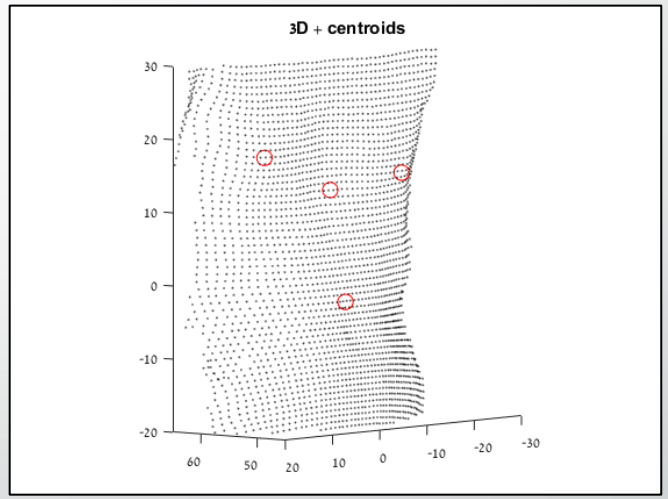
Data Collection – Future Work

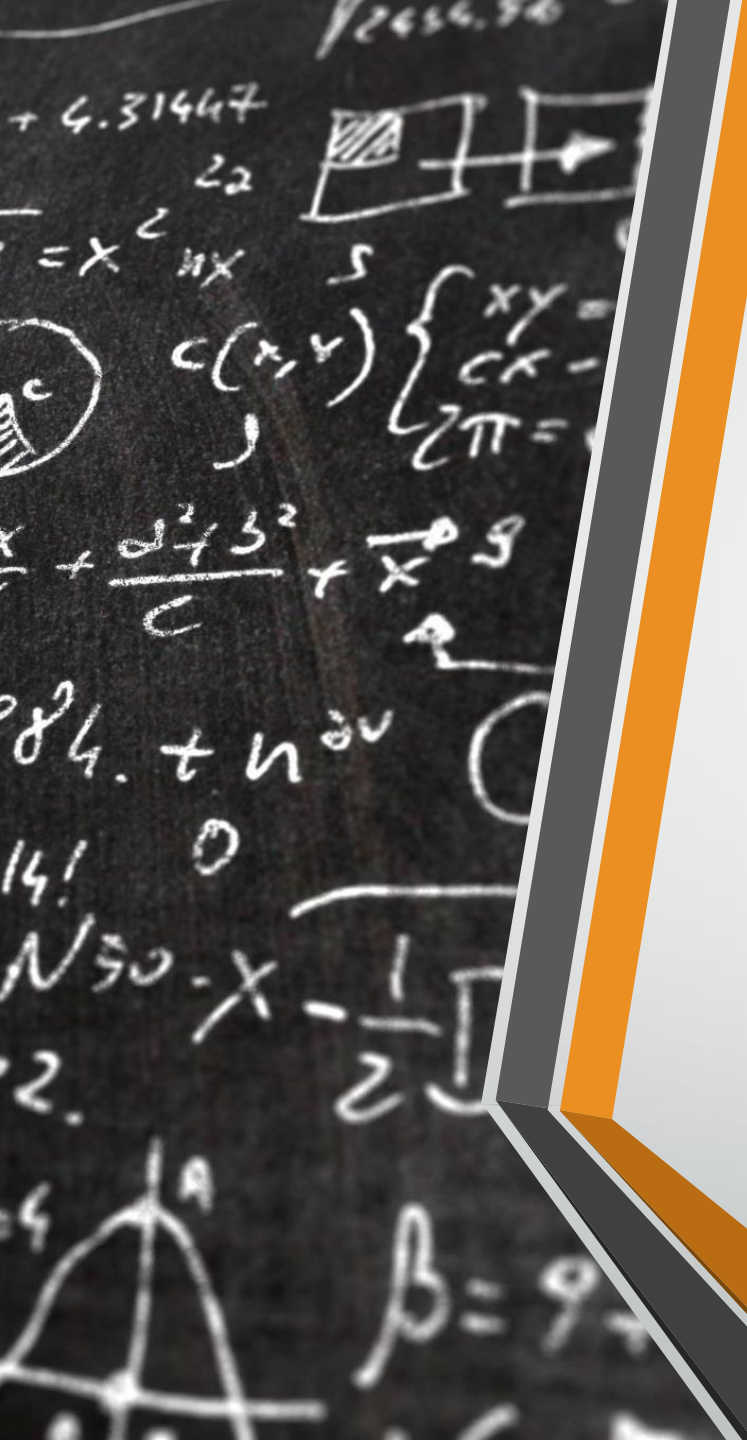
Assumptions:

- Reasonable distance from the camera
- Minimal background movements
- For 2D only: Nipples and bellybutton ☺
- Edge detection?

Image Processing







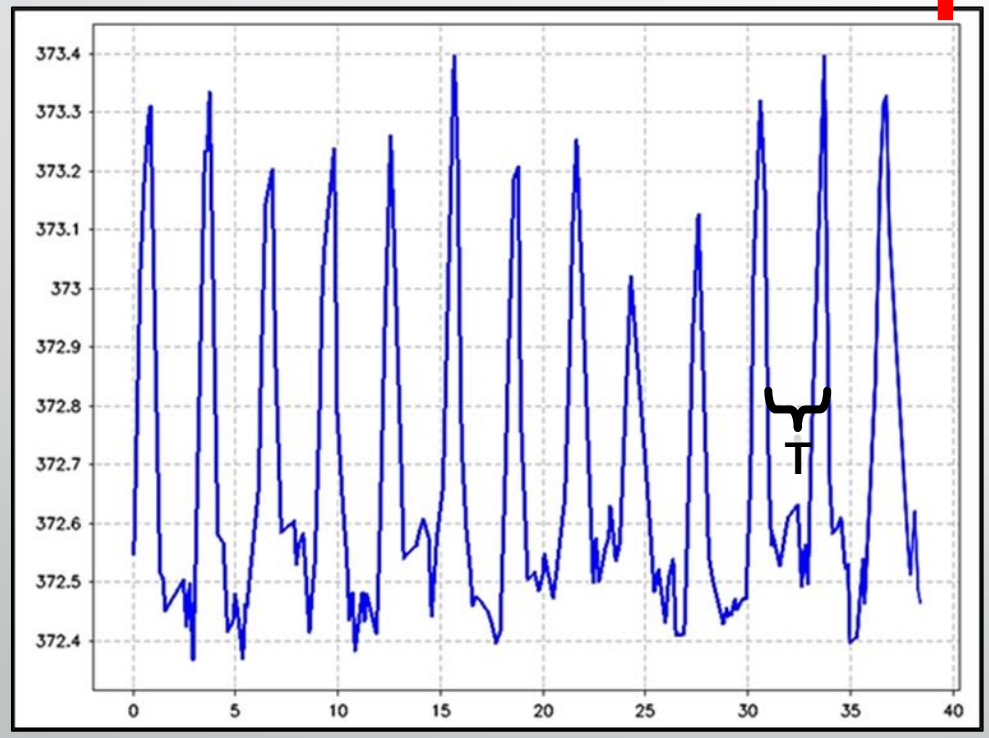
Math

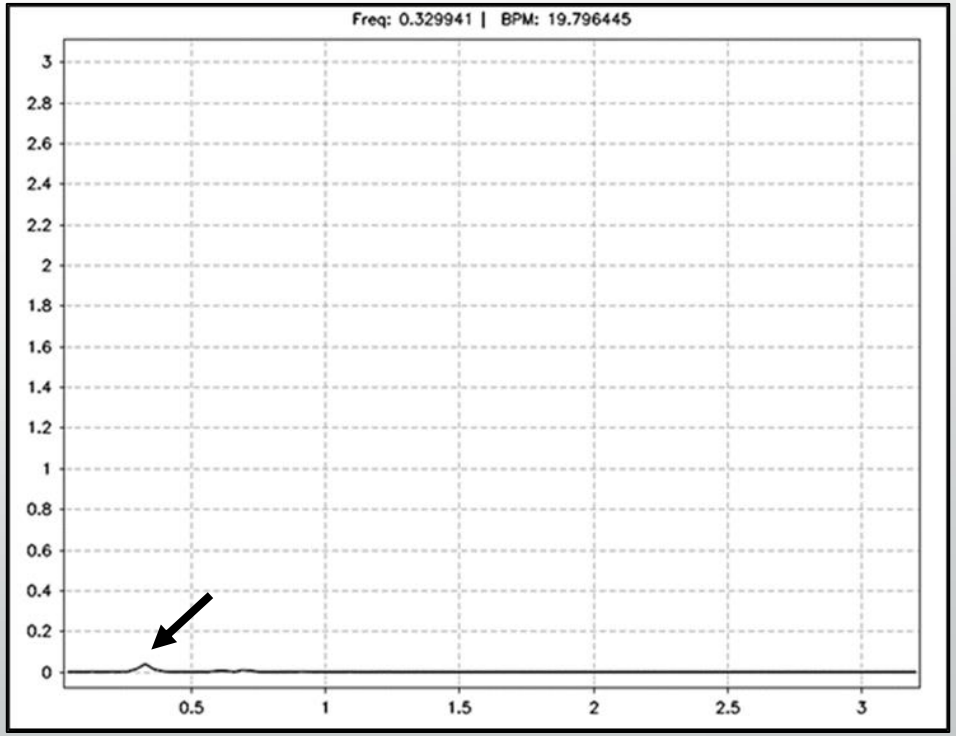
- **Riemann Sums & Tetrahedron Volume**
- Fourier Transform
- ~15 sec intervals overlapping
- Values of peaks

Math - Previously

- 2D samples

FT

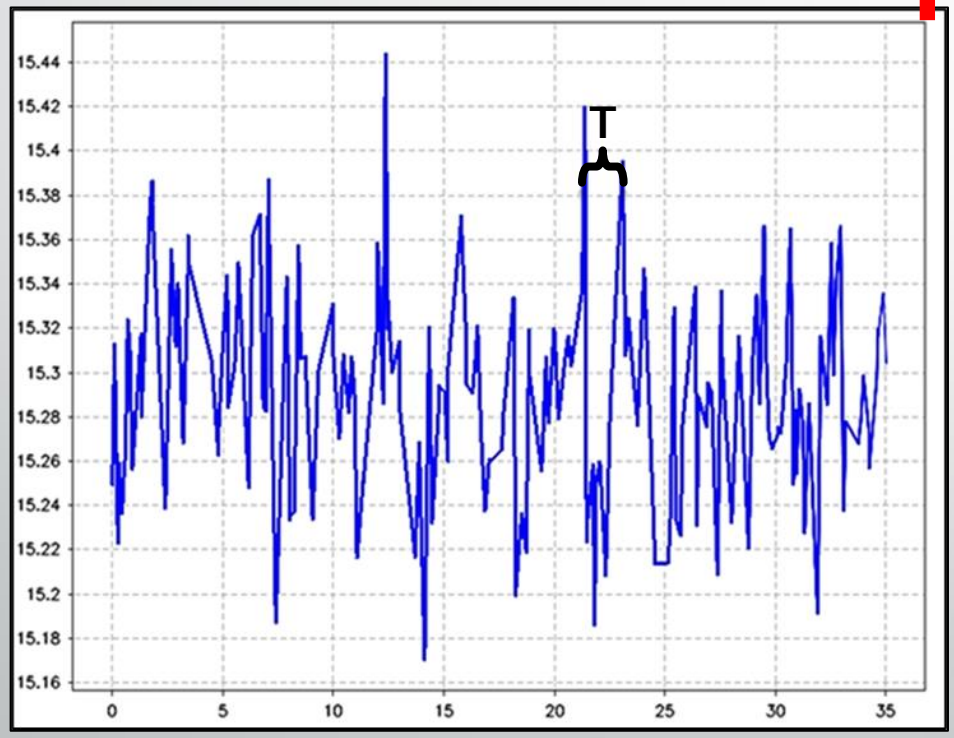


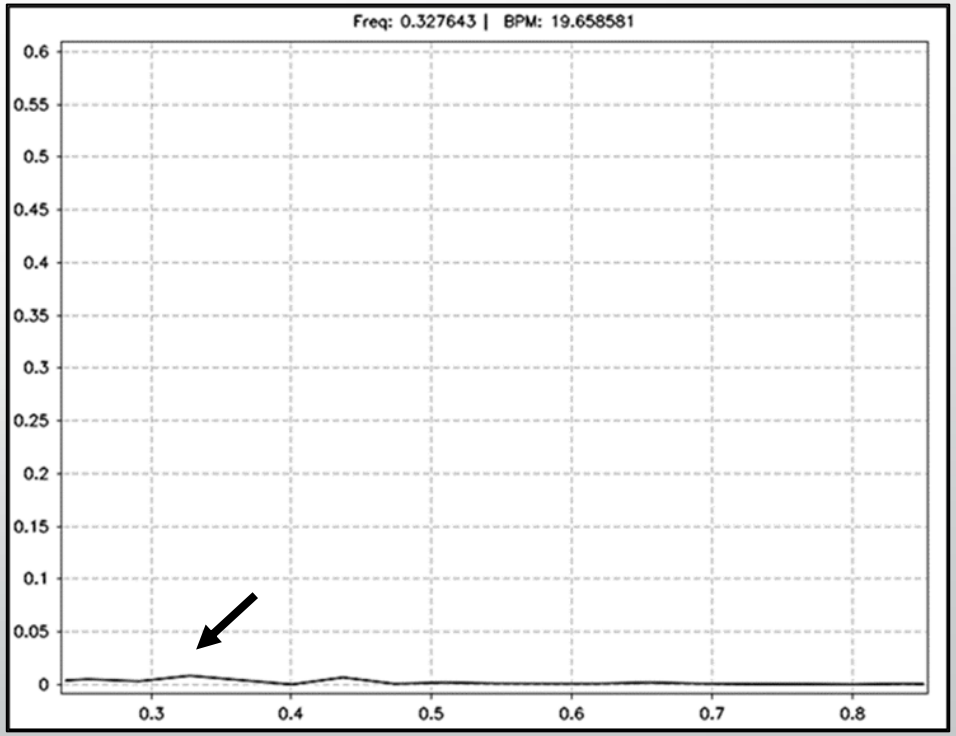


Math - Previously

- 3D samples

FT





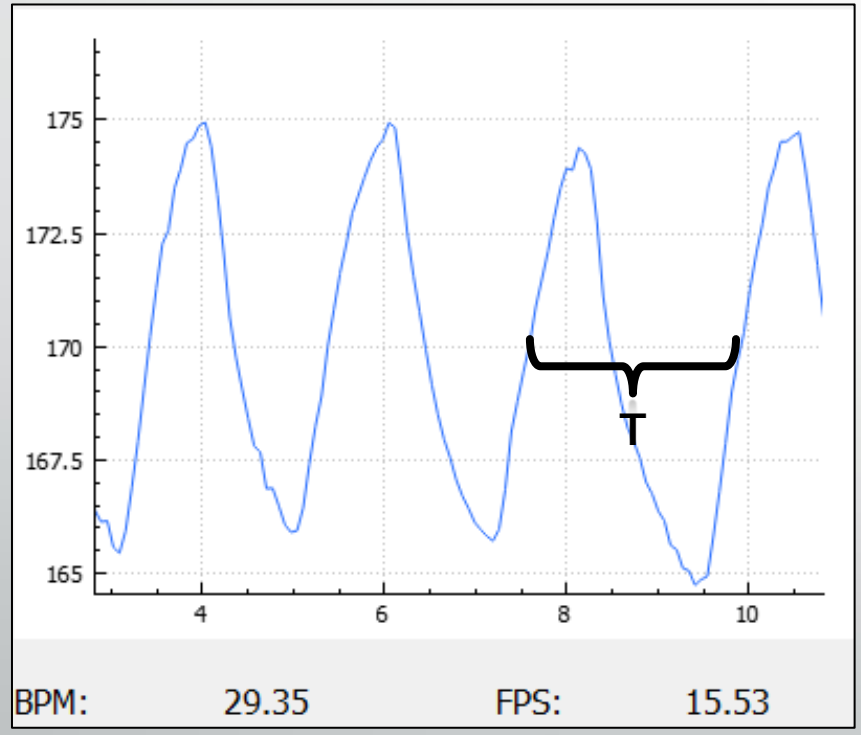
Math – Now

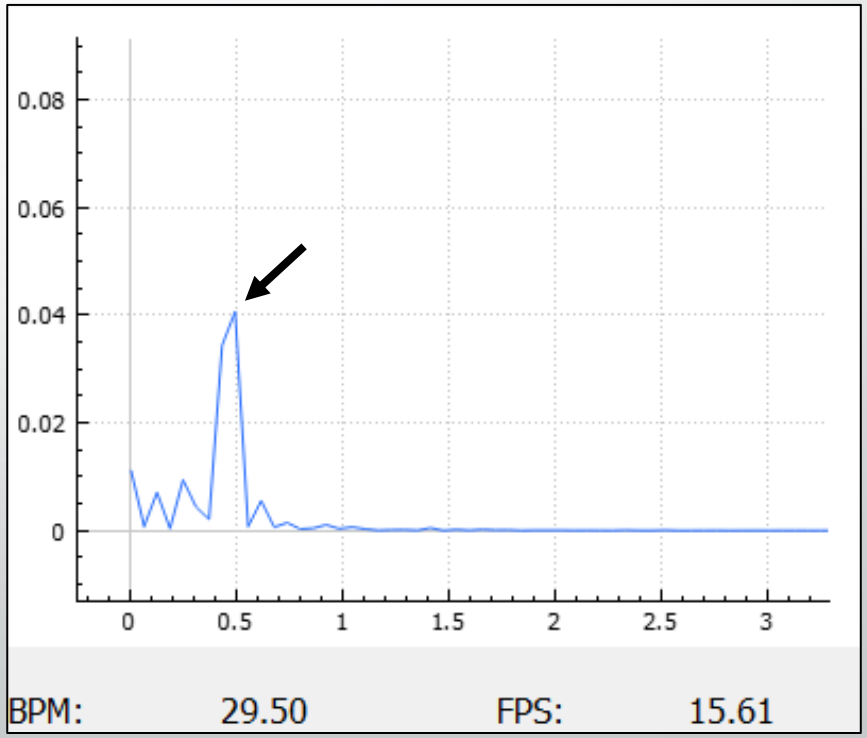
- 2D samples
  - No change
- 3D samples
  - Based either on distances or **breath volume change**
  - Volume-based BPM measurements are almost identical to previous
  - Riemann Sums volume is more accurate

Math – Now (Distances)

- 2D samples

FT

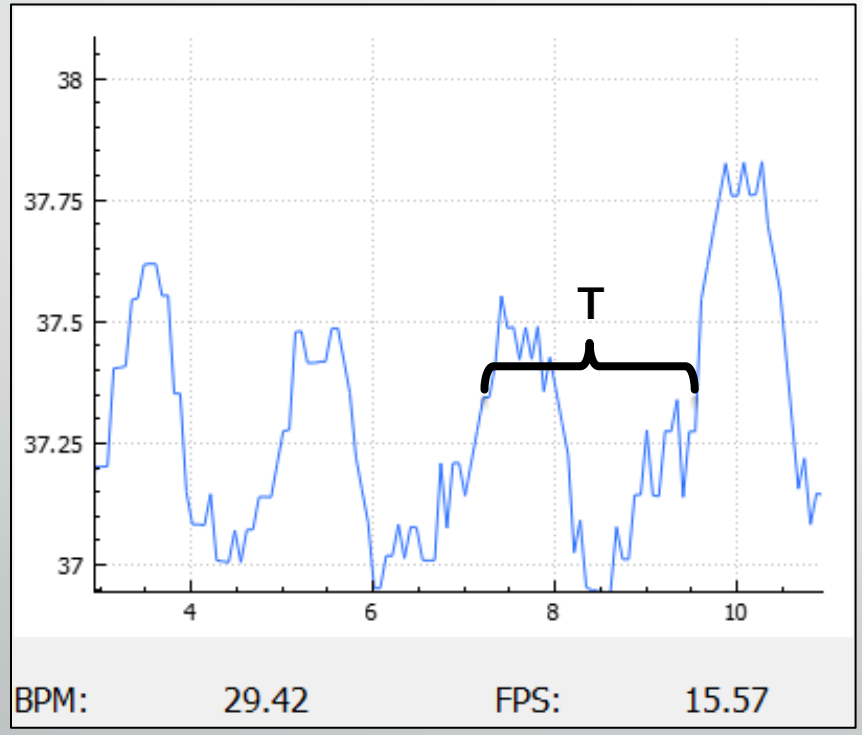


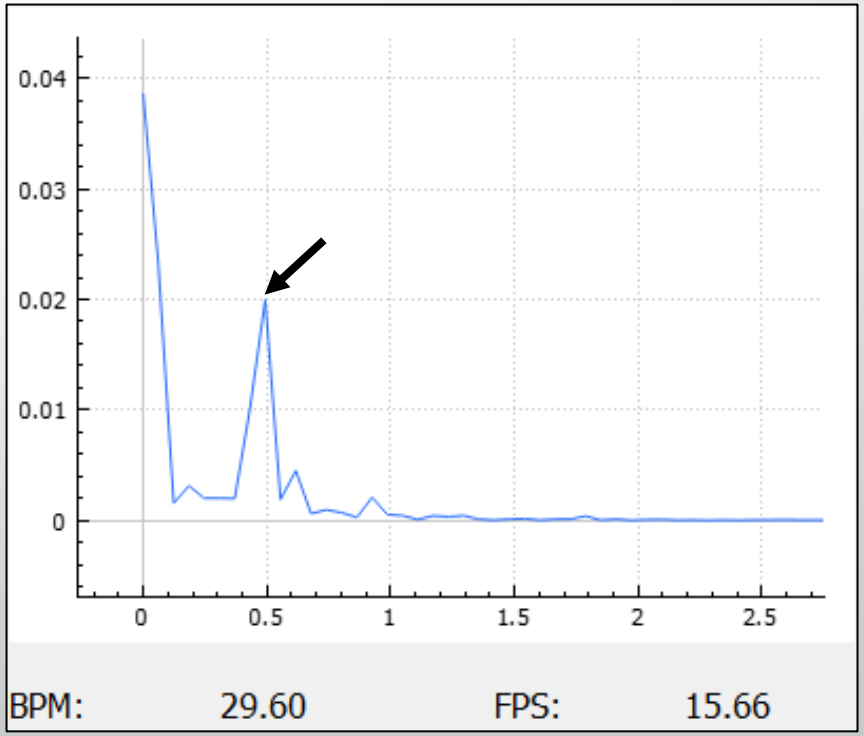


Math – Now (Distances)

- 3D samples

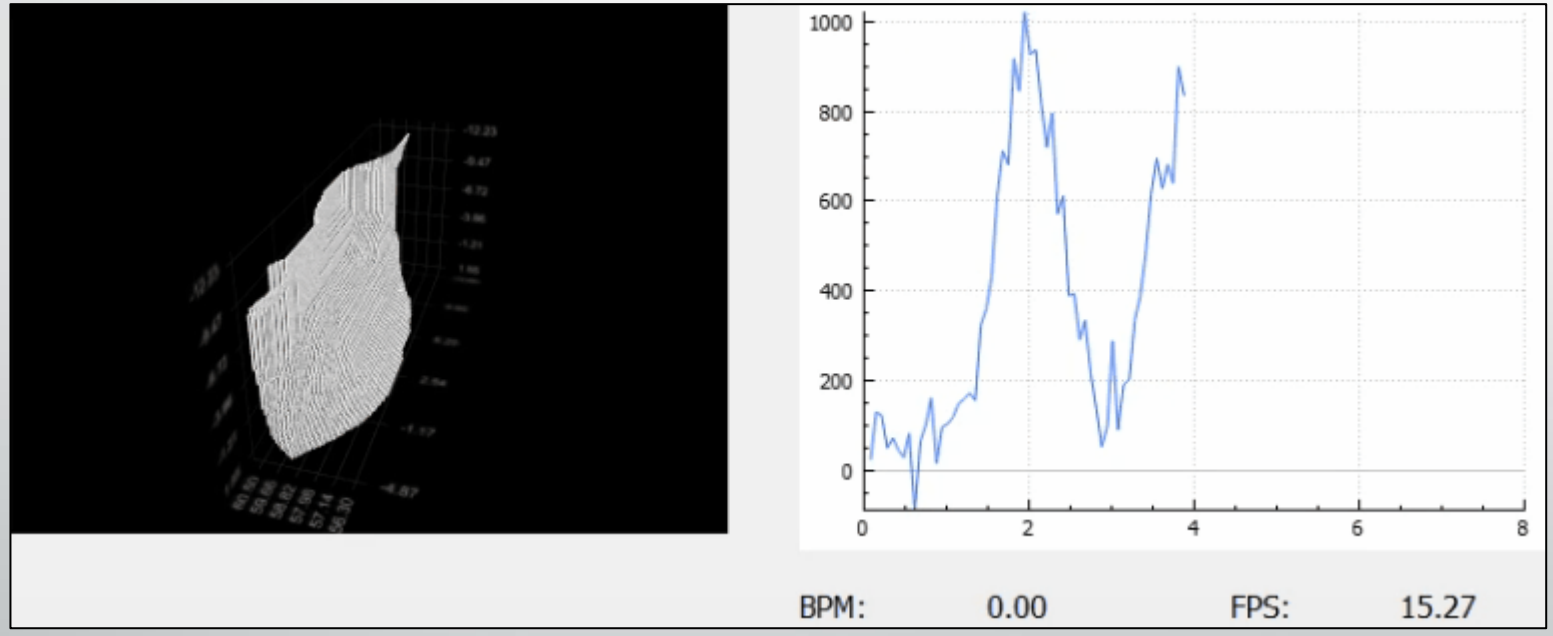
FT



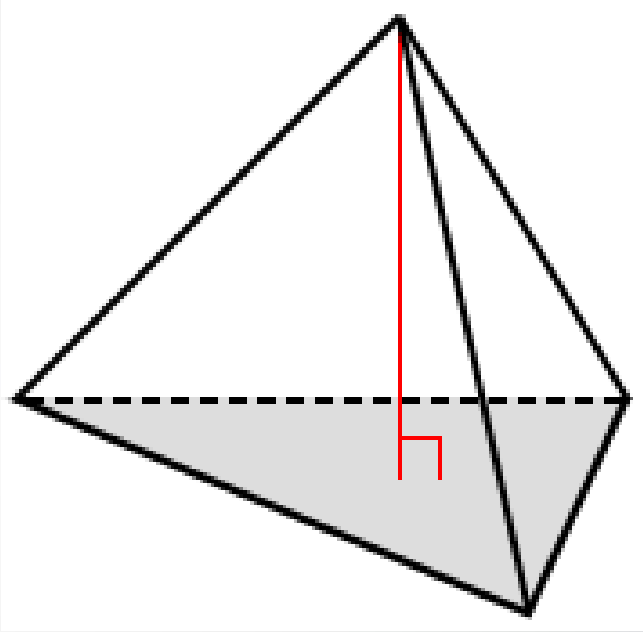


Math – Now (**Volumes**)

- Volume based

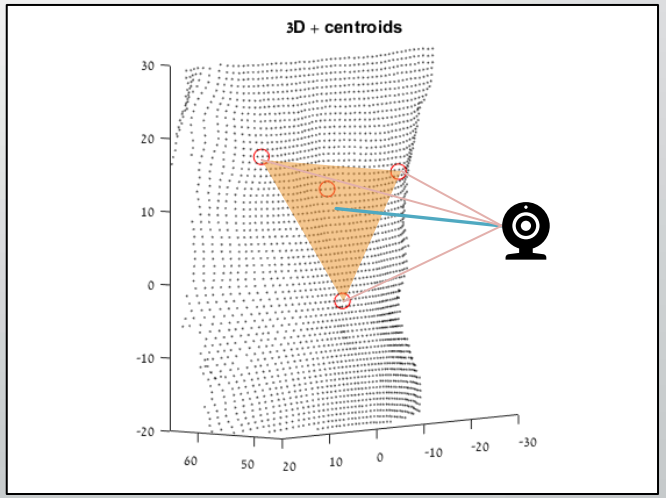


Math – Tetrahedron Volume



- Base – 3 markers: $left, right, mid3$
- h – depth of a fixed point in bounding box (on $z = 0$ plane of the camera)

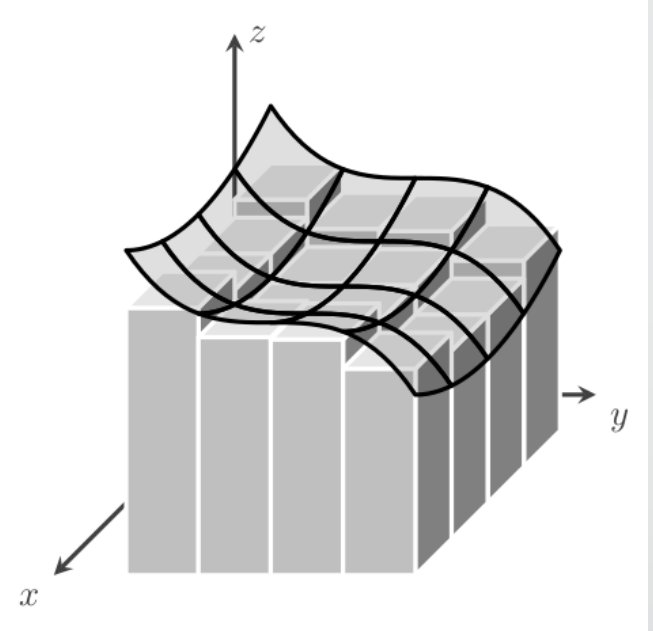
$$\frac{S_{Base} * h}{3}$$

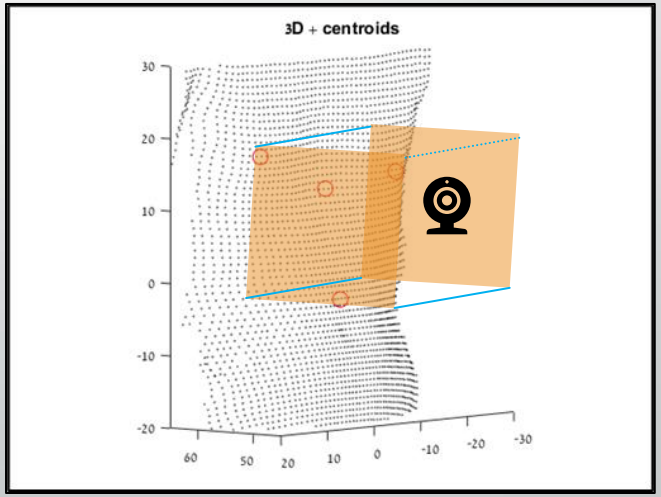


Math – Riemann Sums

- Surface – chest
- $c_{i,j}$ – IR emitter projection (depth frame)
- $d_{i,j}$ – centroid of the quadrilateral formed from adjacent $c_i's$.

$$\sum_{i=0}^{\max x \ (depth)} \sum_{j=0}^{\max y \ (depth)} \left| depth(d_{i,j}) - fixedDepth \right| \cdot \Delta A_{i,j}$$





Resolutions

Additional Methods and Items, Problems & Solving

Realtime Breathing – preserved

- **Basic algorithms used in Realtime Breathing remained**
  - Color detection
  - Connected components
  - Samples normalization (for volumes as well)
- Camera streaming operations
  - General logic preserved, modified to work with threads (under a dedicated object and synchronization object)

Additional Methods

- **Hole filling filter**
  - Solution by interpolation to the missing depths
  - ```
    rs2::spatial_filter spat;
    spat.set_option(RS2_OPTION_HOLES_FILL, 5);
    …
    spat.process(depth)
    ```
    ```

Under The Perfect Environment…

- Tetrahedron Volume
  - Fast and indicative
  - More prone to errors – requires more noise cancellation (not entirely reliable)
- Riemann Sums
  - Slower but extremely accurate
  - Reduction of the calculated surface to the bounding box only significantly reduces latency and provides satisfying results in sufficient speed

Real Samples (Ichilov)

- Results depend on the videos and patients' chest motion patterns?
- Most videos showed better results with **Tetrahedron volumes**
  - In some videos volumetric data wasn't indicative at all (volume changes were seen out of the scope of the stickers, frame rate was too low, abnormal phasing of the chest?)
- Most of the BPM values calculated by volumes were not accurate

Scatter Widget

- Read Access Violation on a frequent large amount of samples
  - Widget doesn't provide a lock mechanism while rendering
  - Reimplemented with heritage based on the open-source
  - Reduced rendering rate by 2 (in addition to dumping invalid frames)
- Still not bullet proof

Logging

- Logs only relevant headers and their values
- Global object

GL Widgets (Camera Streams Rendering)

- New bug
  - Appeared of a sudden in the last month
  - Might be related to support issues of the drivers and Realsense SDK in Windows (More in the documentation)
- Always affects the rendering of the frames that arrive later (Not the first frame in the frameset)
- **Doesn’t affect actual frames**
  - Frames arrive safely for measurements
  - Measurements are not affected

Pointcloud

- get_vertices()
  - Not sorted
  - Can’t be easily converted to a matrix
  - Expensive for the whole frame (can’t be reduced)
- **Therefore: sticking to the old** `rs2_deproject_pixel_to_point`
  - Heavy for each pixel as well, but…
  - Delimiting the deprojection area to the bounding box of the markers is fast enough

Results

- Camera measurements of **respiratory volume change** supply information about actual respiratory volumes (but the connection is unclear)
- Current BPM measurements results resemble previous results
- 3D measurements supply additional and improved information of chest movement, such as phase changes. (Location mode)
- Open source! ☺

Future Work

- Phasing information visualization
  - Processing of the locations data to the relevant information
- Remove stickers dependency
  - Preparation exists under `DeepBreathFrameManager::identify_markers`

Questions?