DeepBreath

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 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 Github source code & examples
- SDK 2.0
- Visual Studio 2019
- C++
- RealtimeBreathing 😊
- DearImGui
- OpenCV
- plog
- Qt Creator
- Qt5
- C++
- Qt tool for VS
Methods

Data Collection  Image Processing  Math
Before All...
Responsive UI

- Responsive UI
- Event-based
- User friendly
- Readable & easy to maintain

+ Thread
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
Math - Previously

- 3D samples
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

![Graphs showing 2D samples with BPM and FPS values](image_url)
Math – Now (Distances)

- 3D samples
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)

$$\frac{S_{Base} \times h}{3}$$
Math – Riemann Sums

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

\[
\sum_{i=0}^{\max x} \sum_{j=0}^{\max y} |\text{depth}(d_{i,j}) - \text{fixedDepth}| \cdot \Delta A_{i,j}
\]
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
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?