Hacking my brain:
Free virtual reality implementations and their potential for therapeutic use

Ruben Rodriguez <ruben@gnu.org>
**LibrePlanet 2022**

I'm not a doctor, this talk is not medical advice!

- Not a lawyer either
- My financial advice also sucks

Premise: I have *lazy eye*. What is that?

- The proper name is ***Strabismus***; misalignment of the eyes
- Often caused by problems in the muscles of the eyes
- Sometimes caused by farsightedness, trauma, or infections
- In my case, I was born with muscle problems in the eyes
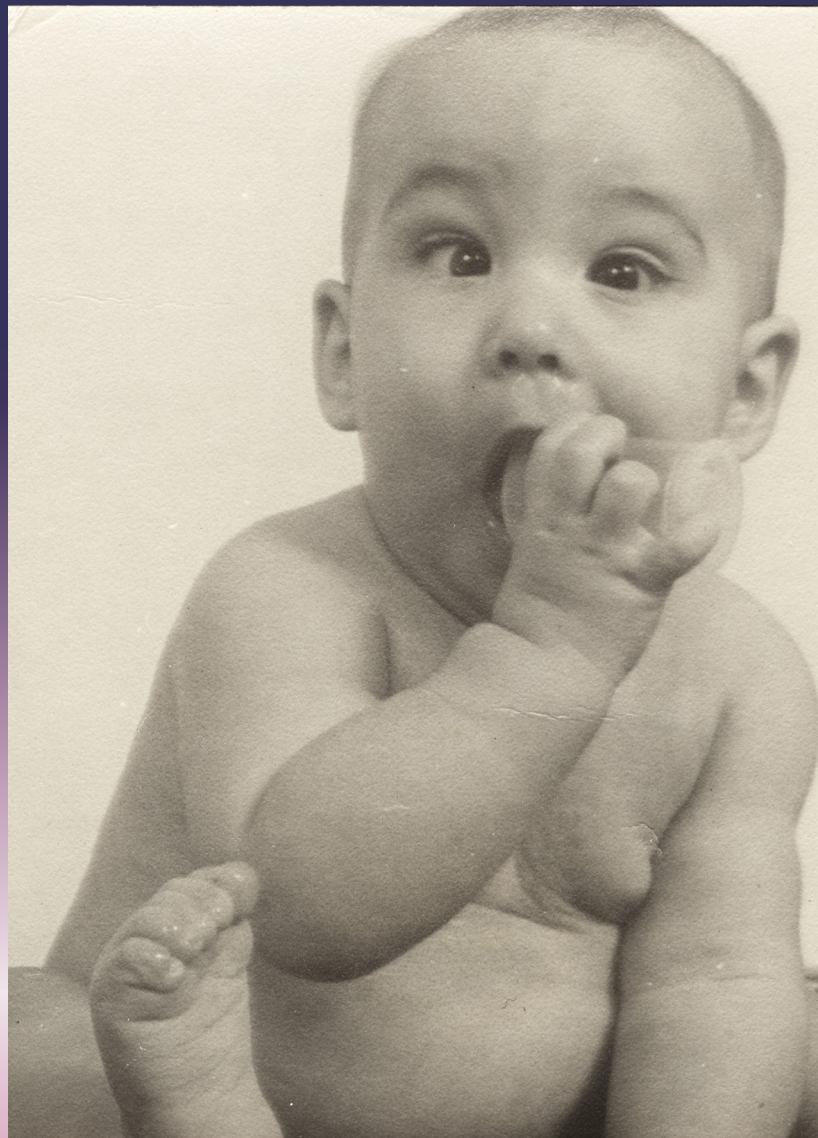
From physical to neurological

- The brain adapts to the condition:
    - To prevent double vision (*diplopia*) and headaches, the brain learns to ignore the input from one eye
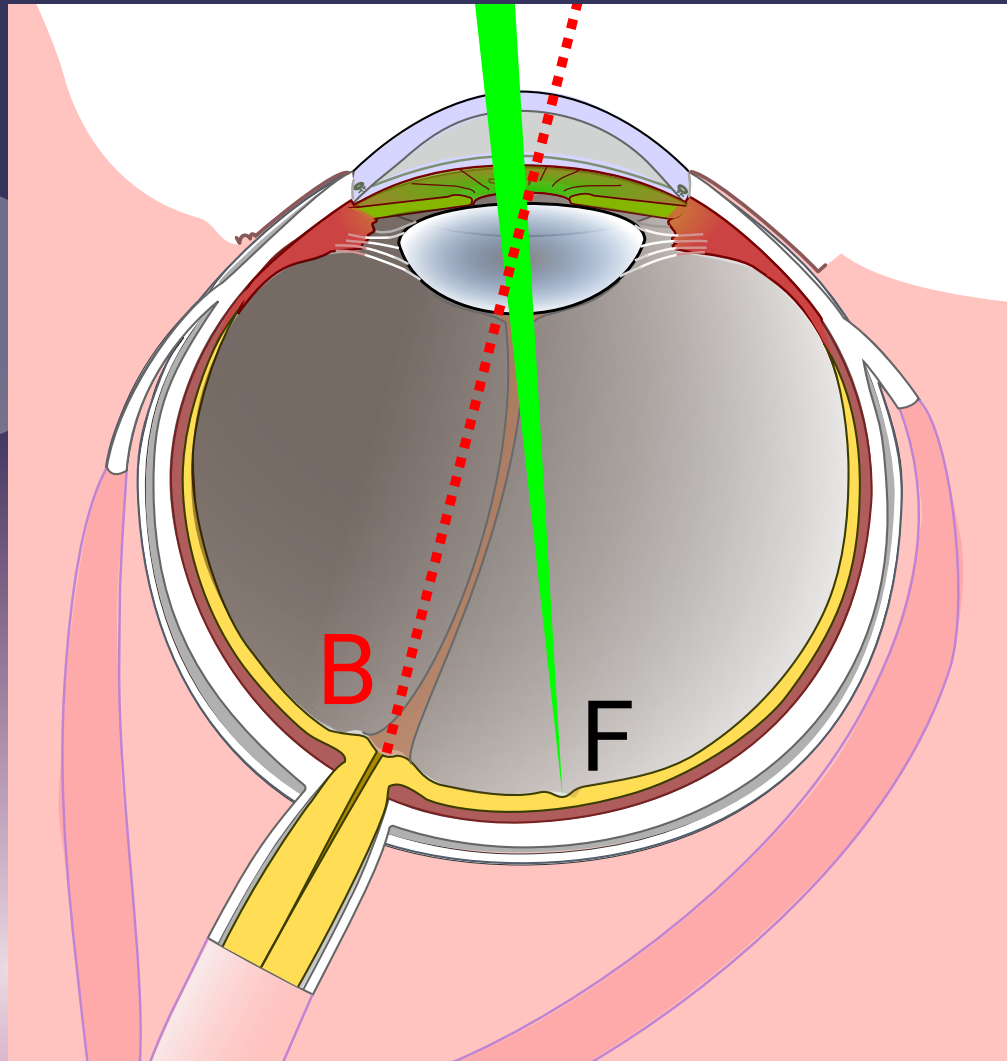
From physical to neurological

- The brain adapts to the condition:
  - To prevent double vision (*diplopia*) and headaches, the brain learns to ignore the input from one eye
- That is called ***Amblyopia***
  - Bad pattern recognition, face recognition, and reading skills; learning disabilities, increased prevalence of mental health issues and emotional disorders
  - Stereo-blindness: Depth perception limited to visual cues like perspective and motion parallax

Treating the body

- First, the physical condition (*strabismus*) is treated
  - Surgery
  - Glasses (fresnel prism lenses)
  - Medication (botox, stimulants)
- I got an operation at 2yo, and my eyes became aligned

Treating the mind

- Strabismus **leads** to amblyopia
- Correcting the strabismus often doesn't fix the amblyopia
- The brain has *set* on an non-optimal solution to the problem
- The brain needs to be taught to use both eyes again
  - Patches
  - Glasses
  - Vision Therapy

Old style treatment

- I wore a patch on my "good" eye from 4 to 8
- Reading was very hard
- It did not work, my brain refused to use my left eye
- After 8, doctors said there was no way to fix the condition
- No further therapy was prescribed
- I still have amblyopia

A new view

- It was long established as *fact* that amblyopia had no cure
- Despite this, in the 1950s to 70s, Frederick Brock, William Ludlam and others successfully treated amblyopia
- This was not well known until the 2000s, when treatments started to be devised again
- New treatments often included computer games
- They now are usually done with VR headsets

Proprietary treatments

- The first examples of treatment with videogames were just academic and research driven, not distributed to the public

- The most popular vision therapy VR programs are
  - Vivid vision, formerly "Diplopia", crowdsourced project in 2014
    - Price varies by clinic: $700-$1200 for 3 months
    - You need nonfree software plus a prescription
  - Optics Trainer
    - "Unlimited license": $4999 (freedom not included)

Making a replacement

- I first attempted this in 2013-2014 with the Oculus Dev kit 1
- Modified 3D video player Bino to correct my eye parallax
- Got epic headaches and double vision
- Gave up

First attempt, failure causes

2014

- Oculus DK1 specs:
  - 640 × 800 pixels per eye
  - 60fps
- No free software VR stack
- No free 3D game engines (Godot was just published)
- No time

Second attempt

2021-2022

- HP Reverb G1 specs
  - 2160 x 2160 pixels per eye
  - 90fps
- Free software OpenXR stack: Monado
- Free software 3D game engine: Godot + Godot OpenXR
- Time!

Hacking Godot

- I'm not a game developer, or an OpenGL programmer
- Godot is an amazing game engine that takes care of all the low level components so no OpenGL knowledge is needed
- Provides a physics engine, shape primitives and much more
- Godot OpenXR is a plugin to implement integration with VR
- Programmed in GDScript, which looks just like Python
- Lots of free assets, examples and tutorials

Application {
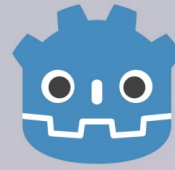
GODOT
Game engine

GODOT OpenXR

OpenXR runtime

Monado

3D drivers

Mesa
OpenGL Vulkan

Limitations of Godot OpenXR

- The goal is to tweak each eye's:
    - Parallax
    - Inter-pupilar distance
    - Culling mask (what objects are shown to each eye)
    - Image correction (brightness, contrast, blur)
- Godot represents the VR headset as a single camera
- No access to each eye's projection camera

I built a *virtual* VR headset...

- Two virtual screens placed in front of the in-game cameras
  - Can correct parallax
  - Custom culling masks
  - Custom brightness, contrast and blur, per eye
- Computationally very inefficient
  - Sufficient for the simple games needed for visual therapy
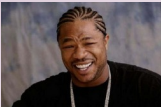
Made two applications so far

- 3D movie player
  - Plays conventional Side-By-Side stereoscopic videos
  - FFmpeg backend, plays almost anything
  - Projects into a virtual cinema screen
- Breakout-style game
  - Move the paddle using the HMD tracking
  - Dichoptic Training and Dichoptic Contrast Enhancement (DiCE)

Demo time!

What's next?

- Collaborate with behavioral optometrists
    - Validate the methodology
- More games
    - Depth detection game
    - Depth navigation game
- Improve interface
    - Provide calibration, and progress tracking

Question time

- Thanks!

- You can contact me at ruben@gnu.org or ruben@trisquel.org

- Both demoed programs available at:
    - https://gitlab.trisquel.org/vr