**Title:** SpectroDMF: An Open Source Portable Visible Spectrophotometer for Microdroplet Measurements in Digital Microfluidics

**Authors:** Akhmadi Surawijaya[1], Muhammad Ogin Hasanuddin[2], Alzana Armaniar Farhani, Balkan Khilmi Assakandari, and Anindhita Nayazirly

**Affiliations:**
School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Bandung, Indonesia;

**Contact email:** [1]moginh@staff.stei.itb.ac.id, [2]moginh@itb.ac.id

**Abstract:** Hippotherapy is one of the highly effective treatment methods for Cerebral Palsy (CP) rehabilitation by using horse riding activity, which is beneficial to the patient because the stimuli: horse gait which is very similar to mechanical gait in humans and also visual input from the environment. However, the need of large area, quiet environment, and high maintenance costs of the facilities lead to expensive treatment. To solve this problem, we use a store-bought horse riding simulator device, and also give visual input through a simple game and an immersive virtual environment. The device then can be put in a room in a hospital for the patient's therapy. A therapy in hospital is covered by the Indonesian healthcare, thus affordable an beneficial, especially for children with CP families with low-income socioeconomic condition. This article provides the design of the system, block diagrams, game design, build instructions, and software codes needed for building the device.

**Keywords:** UV-VIS Spectrophotometry

**Specifications table:**

| | |
|---|---|
| **Hardware Name** | SpectroDMF |
| **Subject Area** | • Biomedical Engineering<br>• Electrical Engineering and Computer Science<br>• Physical Rehabilitation |
| **Hardware Type** | • Hippotherapy Platform for CP Rehabilitation |
| **Closest Commercial Analog** | No commercial analog is available |
| **Open Source License** | CC-BY 4.0 |
| **Cost of Hardware** | IDR 100,000,000 |
| **Source File Repository** | *DOI URL to an approved source file repository: Mendeley Data, the OSF, or Zenodo (instructions).*<br>*For example: "https://doi.org/10.5281/zenodo.3346799"*<br>*If there is no external repository write "Available in the article"* |

## 1. Hardware in context

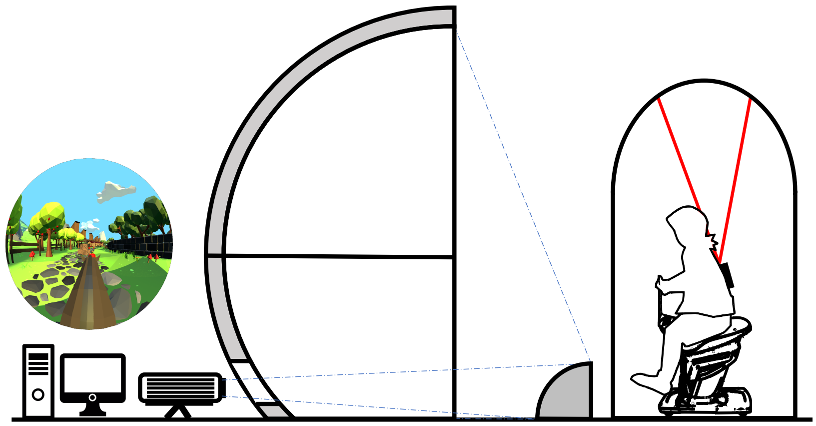
Hippotherapy is one of the Cerebral Palsy (CP) rehabilitation methods using a horse's movements characteristics to provide motor and sensory input to the patients [?]. A number researchers report positive results on randomized controlled trials and a studies of hippotherapy to support the method's effectiveness. Improving motor function, symmetry of muscle contraction, spasticity, posture, and walking is the benefit gained from hippotherapy [?].

However, hippotherapy activities are costly and challenging to conduct due to several factors. The therapy instructor has to have a horse riding instructor license and therapist qualification. They also must be able to prepare the horse and guide the patients in a session. Finding a therapist with the skill mentioned earlier is challenging in a developing country like Indonesia. Aside from human resource costs, horse-keeping requires massive land use for a ranch or farm, which is expensive and impossible to do in urban environments [?]. Currently, no place offers a hippotherapy session with real horses in Indonesia. The last activity reported about hippotherapy sessions in Indonesia was in 2009 [?], making access to real-horse hippotherapy unavailable for children with CP in Indonesia.

Some researchers suggest using a Horse Riding Simulator (HRS) instead of using actual horses because it can significantly reducing the cost of hippotherapy. An HRS device is commonly available in the market as an exercise or fitness machine. Many recent researches [?, ?, ?, ?] reported that HRS usage also shows positive results for CP treatments similar to hippotherapy with a real horse. Using a simulator, we only need a room with all the required equipment, eliminating the need for large horse farms in rural areas. However, this setup also has several drawbacks. Children are quickly bored doing monotonous and repetitive actions in a room without fun stimuli. The room setup also loses visual stimulation from the outside environment, which usually helps motivate the children to finish the therapy session and return to the next session.

Providing fun content to the children is essential to prevent the lack of enthusiasm of the children. One of the fun activities is *exergaming* or active video gaming that requires bodily movements to play [?]. Exergaming also benefits children with CP by improving muscle strength [?], balance [?], range of motion [?], and physical fitness [?] depending on the type of body movements required to control the game. In this report, we design an exergaming video game to solve the problem mentioned earlier in the form of a horse racing-like game with tasks to pick apples and avoiding obstacles. We name the game *Sirkus Apel*, which means "apple circus" in Indonesian. We also develop a controller that requires the user to move their back to control the in-game horse. A case report shows that back exercises also benefit children with CP, with the subject showing excellent motor progression [?].

A room setup also removes the refreshing view of a horse ranch which provides visual stimulation to the children. This problem motivates us to design the game in an immersive virtual reality (VR) environment to enhance the exergaming experience. However, considering the safety of the children with CP, we decide not to use the usual head-mounted display (HMD) for this purpose. The use of HMD can be hazardous for children because it obstructs their view of the environment, especially when riding an HRS device. Numerous researchers [?, ?, ?, ?, ?] also report another problem of HMD usage: *motion sickness* caused by the inconsistency between the visual input of the eyes and the user movements. This condition can cause nausea, headache, disorientation, and



(a)

(b)

Figure 1: (a) System design diagram. (b) Design implementation in use.

vomiting, which is very dangerous and uncomfortable, especially for children with CP.

Considering the problems mentioned before, we built a dome-based VR. By creating a dome-like structure, we can project the VR content to a specialized dome instead of to the HMD. Taking the VR content outside of HMD also eliminates the view obstruction problem and minimizes the risk of motion sickness [**?**]. We built our dome-based VR using the design of iDome by Paul Bourke [**?**]. The design of iDome is inspired by a planetarium semi-sphere shape. The semi-sphere is cut in half to place the users in front of the dome, not under it. This setup provides a broad immersive view without any obstruction of projection hardware but keeps the user aware of the surroundings.

## 2. Hardware description

Describe the hardware, highlighting the customization rather than the steps of the procedure. Highlight how it differs/which advantage it offers over pre-existing methods. For example, how could this hardware: be compared to other hardware in terms of cost or ease of use, be used in the development of further designs in a particular area, and so on.

Add 3-5 bulleted points to broadly explain to other researchers how the hardware could be potentially useful to them, for either standard or novel laboratory tasks, inside or outside of the original user community.

- Use of the hardware 1
- Use of the hardware 2
- Use of the hardware 3

### 2.1 Dome Design

As an Immersive Virtual Environment infrastructure, we build DOME, for several reasons
$D_g$ = eye height in sitting position (cm) for 7-17 years old

$$F - measure = 2 * \frac{precision * recall}{precision + recall} \tag{1}$$

with:

$TP$ = True Positive

## 3. Design files

for dome design we use, design from paul bourke http://paulbourke.net/dome/iDome/ *The complete design files must be either uploaded to an approved online repository, uploaded at the time of submission on the online Editorial Manager submission interface as supplementary materials [CAD files, videos,. . . ], or included in the body of the manuscript [e.g. figures]. The three approved online repositories are Mendeley Data, the Open Science Framework, and Zenodo. See repository instructions here. Design files should be in preferred format for making modifications. See OSHWA's open-source definition for details.*

- *CAD files. Authors are encouraged to use free and open source software packages for creating the files. For CAD files, OpenSCAD, FreeCAD, or Blender are encouraged, but if not available source files from proprietary CAD packages such as Autocad or Solidworks and other drawing packages are acceptable.*
- *3D printing. Supplementary files that facilitate the digital replication of the devices are encouraged. For example, STL files for 3-D printing components. We recommend uploading CAD files to the NIH 3D Print Exchange as Custom Labware and providing a link to the location.*
- *Electronics. PCB layouts and other electronics design files can be uploaded to the Open Hardware Repository or other repositories.*
- *Software and firmware. All software files used in the design and operation of the hardware should be included in the repository. Provide a description of software and firmware and use extensive comments in the code.*

### 3.1 Design Files Summary

| **Design file name** | **File type** | **Open source license** | **Location of the file** |
|---|---|---|---|
| *Design file 1* | *e.g. CAD file, figures, videos* | *All designs must be submitted under an open hardware license. Enter the corresponding open source license for the file.* | *Enter a link to the online location or the sentence: "available with the article", as appropriate* |
| *Design file 2* | . . . | . . . | . . . |

*For each design file listed above, include a short description of the file here (one or two sentences)*

## 4. Bill of materials

*For a complex Bill of Materials, the complete Bill of Materials (editable spreadsheet file e.g., ODS file type or PDF file) can be uploaded in an open access online location such as the Open Science Framework repository. Include the link here. Alternatively, the Bill of Materials can be uploaded at the time of submission on the online Elsevier submission interface as supplementary material.*

- *To make it easy to tell which item in the Bill of Materials corresponds to which component in your design file(s), use matching designators in both places, or otherwise explain the correspondence.*
- *For material type, select from: Metal, semi-conductor, ceramic, polymer, biomaterial, organic, inorganic, composite, nanomaterial, semiconductor, non-specific, or other*

| **Designator** | **Component** | **Number** | **Cost per unit - USD** | **Total cost - USD** | **Sou** |
|---|---|---|---|---|---|
| *Designator 1* | *Name of Component 1* | *Number of units* | *Cost per unit* | *Total cost* | *Sou* |
| *Designator 2* | ... | ... | ... | ... | ... |

## 5. Build instructions

*Provide detailed, step by step instructions for the construction of the reported hardware include all necessary information for reproducing the submitted hardware.*

- *Explain and, when possible, characterize design decisions. Including design alternatives if they exist.*
- *Use visual instructions such as schematics, images, and videos.*
- *Clearly reference design files and component parts described in the Design File Summary and Bill of Materials.*
- *Highlight potential safety concerns that may arise*

## 6. Operation instructions

*Provide detailed instructions for the safe and proper operation of the hardware.*

- *Step-by-step operational instructions for operating the hardware.*
- *Use visual instructions as necessary.*
- *Highlight potential safety hazards.*

## 7. Validation and characterization

*Demonstrate the operation of the hardware and characterize its performance over relevant critical metrics*

- *Demonstrate the use of the hardware for a relevant use case.*
- *If possible, characterize performance of the hardware over operational parameters.*
- *Create a bulleted list that describes the capabilities (and limitations) of the hardware. For example consider descriptions of load, operation time, spin speed, coefficient of variation, accuracy, precision and etc.*

## 8. Declaration of interest

The authors declare that no known personal relationships and/or financial interests that could have influenced the work reported in this paper.

## 9. Human and animal rights

The author declare that the work reported has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). Informed consent was obtained from all subjects involved in the study and their privacy rights is preserved.

## References

- *Include at least one reference, to the original publication of the hardware you customized.*
- *Include other references as required. Include references to put your device in context in the literature. For more information on the reference format in HardwareX please see the Guide for Authors at: https://www.elsevier.com/journals/hardwarex/2468-0672/guide-for-authors*