ThermalArt

Making art tangible with temperature

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Temperature is something that is always present, you can constantly feel it. However, in most cases, it is rarely used as a way to convey information. The addition of temperature as a way of displaying or conveying something is a relatively unexplored area. We took the opportunity to work on this new interaction, and we have shown that images can be expressed through the sensation of temperature and can be used as an additional way to experience art. A creative approach using the so-called Peltier elements helped us realise this work.

1 Introduction

General Introduction

The feeling of temperature is omnipresent, yet in forms of art, it is rarely used at all. ThermalArt is a project whereby using temperature to display images, a new dimension can be added to expressing one's creativity. Using temperature in this unconventional way requires some new innovation. By using software to convert images into readable data, and then using temperature-controlled hardware to display that, we can now portray visuals with heat.

The problem approach

The way images are going to be displayed via temperature is done via Peltier elements. Peltier elements are small square plates that use thermoelectric cooling to change the temperature of their surface. Peltier elements can be used for both heating or cooling [1]. Not only that, but Peltier elements are also readily available to consumers for non-industrial purposes, making them excellent for this project.

By arranging the Peltier elements adjacent to each other into a grid, we can replicate a screen that can display images, but instead of light, it shows visual elements with heat. This is the core idea of our approach to tackling the problem of displaying imagery via temperature. (Fig 1, Appx 1A) Unity is then used to convert digital images into a virtual grid that displays different colors are different temperatures [2][3]. We can then use image processing or make our own custom images to display on our new screen. To communicate with Unity, Arduino PCBs are used to transfer information to the elements themselves. Unity calculates what Peltier element at what coordinate should have what temperature, and then relays this information to the PCBs. The PCBs, in turn, are connected to each individual element, which they deliver the signals to. (Fig 2, Appx 1A)

This way, we can physically represent patterns or artworks with heat.

Paper outline

This paper will go over the general course of this project. The general background, approach to problems, along with the results, conclusions and any implications for the future it may have.

The research question of this project is: *"How can an image be expressed through sensation of temperature and can it be used as an additional way to experience art?"*

2 Short Subject Background and problem definition

Background

The usage of temperature to display images is a relatively unexplored area. The execution of a concept like this could lead to interesting innovations or consequent concepts as the idea itself is rather unconventional. A project like this can have a lot of applications. It could have its applications in museums, for example, where artists could use it as an exhibit, and as a new way to express oneself. A project like this could also lead to potential innovations in other fields, such as being a potential alternative for blind people to be able to experience art in a new way [4].

We wanted to invest time into this project as it was a fun and interesting idea that was rather unique. The main goal is making an exciting product that could catch the attention of the users, and hopefully teach them something or otherwise entertain them in some way.

Our approach

As for our approach to the problem, there isn't much to say. Other types of PCBs such as Raspberry Pis, or other software implementations in another programming language would have been possible. Still, they would have made little impact on the final product, as the backend has little effect on the user experience as long as it is functional and works without issues.

User Analysis

The user group we should aim at is people who maybe do not feel something special with conventional paintings and art. Our user group could therefore be defined as "The general public", it is vital for us to take all kinds of users into account as our user group does not necessarily have to fill a certain niche. The user group we aim for isn't necessarily people who often go to museums; it can be any person interested at that moment in time.

3 Making art tangible with temperature

Practical problems and their solutions

Because of the nature of Peltier elements, some unforeseen design choices had to be made. This, combined with the relatively small scale of the project, meant some compromises had to be done as well. Because Peltier elements are square, they are easily arranged as pixels into a screen-like grid. A wooden frame, along with zip ties is used to keep the elements in place. Acrylic tubing is used to cool the elements, and some plastic trays are used to organise the PCBs. An example of the hardware setup can be seen in figure 3A & 3B, Appendix 1A.

The grid in our prototype is 6x6, making for a total of 36 individual Peltier elements. This grid, while functional, is not very big. This is because of a combination of many reasons.

Peltier elements are not very power efficient [5], and require a relatively large amount of electricity to function. Because of this, and given the scale of our project, it was not feasible to make the grid much larger than it is. Currently, two 1000W power supplies are in use to power all of the individual elements. Using more elements than this, while possible in our case, would still not be very practical as many hardware implications and problems could arise from having a more complicated setup.

Because Peltier elements draw a lot of power, they also generate a lot of heat. This means they need to be cooled in some way to perform optimally. In our case, each element is liquid-cooled via passive diffusion. Each element is connected via tubes filled with water, which lead to a small reservoir (Fig 4, Appx 1A). Over time, this reservoir could in theory heat up sufficiently that the elements can no longer be properly cooled. In practice, this doesn't happen as the reservoir is sufficiently large and the general use of the grid usually isn't long enough to change the temperature of the liquid noticeably. Should the project be scaled up, liquid cooling similar to computer processors with radiators featuring fans would also be possible, but in our case, this is not necessary.

Because the current elements in use are relatively large, this means it limits the maximum size of the screen as a few elements already cover a large amount of surface area. Should a concept like this get adopted in the future, it would be possible to use smaller Peltier elements, opening up the possibility of a higher resolution Peltier element screen without taking up as much space, as the total surface area is smaller than when using more compact elements. Smaller elements would also use less power, meaning the inefficient power draw from Peltier elements wouldn't be as big of an issue. However, this would of course also require completely different practical solutions in terms of cooling for example.

The Peltier elements in question can actually not display multiple temperatures. They only have three settings:

- Off
- Cold
- Warm

This means that technically only three colours would be possible. In our case, we wrote code that would make it possible to display five different colours, by making the elements "flicker".
A lukewarm colour would for example flicker evenly between "Off" and "Warm" at a given frequency, which would in practice result in a surface temperature that is in between "Off" and "Warm" (Fig 6, Appx 1B).

Technically with this approach, it is possible to display an infinite range of temperature-colours, by having the Peltier elements flicker with different ratios for each color. In practice, however, this would result in colours that wouldn't be very distinguishable from each other, unless the temperature range of the elements is sufficiently large or the frequency at which elements can flicker is fast enough to support it. In our case, we opted to go for five colours so that they are more easily differentiated from each other [6] (Fig 7, Appx 1B).

The code in Unity is written in C#. It is also fairly modular; the design should be scalable to larger resolutions without much hassle in the software. In other words, the main restrictions of the size of the current Peltier grid are the hardware limitations of the current setup, as well as the physical limitations of consumer-grade Peltier elements.

User evaluation

For our user evaluation, we conducted two surveys, testing for the intuitiveness of the system and the general content of the users. The user group tested is relatively small (n=6) because of the current conditions, but do give a pretty good picture of the results nonetheless.

4 Results and Evaluation

User evaluation

The results of the user evaluations can be seen in Appendix 2A and B.

For a good portion of the results from the user evaluation testing the results usually show a trend, with many answers from users evaluated being very similar. Some results, however, are pretty mixed. In some cases of user testing, some elements did not work. Some users in turn noticed this, and this had an impact on their judgement of the system. This too, has impacted the results to a certain degree.

Most users tested found the system easy to use and not unnecessarily complex. However, when asked if they could imagine that most people would learn to use this system very quickly, the results skew towards both sides and are fairly inconclusive. This is likely because of the current lack of a good, intuitive user interface that would be easy to learn for most people (Fig 5, Appx 1A). Most importantly, most users could clearly tell the difference in temperature between the elements, and the patterns tested were clearly recognisable.

For the second user evaluation a new user interface was created, see figure 8, Appendix 2b. This was important to show the user more around our product. The feedback gotten from the second user test resulted in the final user interface (Fig 9, Appx 1B). This interface has a lot more information (Fig 10, Appx 1B).

Feedback received

We have received feedback from a handful of users, spread over 2 user tests, with some features being implemented.

One example of feedback we received early on was the boosting of the contrast of certain images. While code for this actually exists in the current codebase, it isn't in use right now as there are only five colours, and most test patterns feature designs that intentionally make use of these five. One feature that we have been willing to implement is image processing, meaning actual paintings are able to be imported and then converted to a temperature image accordingly. This does not currently exist, but for this, a contrast boosting function would be useful.

Changes to our approach

As mentioned in chapter **3**, some compromises had to be made because of the nature of Peltier elements. We ended up going with a grid with a relatively smaller resolution with fewer colours. This is slightly underwhelming, but since this is mostly just a proof-of-concept prototype, it is not a big deal. Most other parts of our initial approach ended up working out, however. In newer versions, the UI is now more informative and clearer of what the user can do. The transformation progress is a big part of this information.

5 Conclusion and Discussion

Overall, despite some minor issues, the prototype has been a success. The grid itself is functional and delivers the promise of being able to display images in the form of heat. As shown by our user testing, most users had positive experiences with the current prototype and thought it was useful as well. But due to the current lack of an exemplary user interface and other minor issues, some results ended up being mixed. However in the second user test a improved UI was implemented. With the feedback from this test a final UI was made.

This final prototype should be a cool new interaction, that shows that images can be expressed through the sensation of temperature and can be used as an additional way to experience art.

6 Future Work

This project has shown that displaying images in temperature is not only possible. In our testing users have shown that they were interested, meaning this could have the potential to be of use for the more general public. Its hardware limits the current prototype that has been developed, but the concept itself is relatively scalable for the use of higher resolutions or a higher color density. A project like this could also lead to potential innovations in other fields, such as being a potential alternative for blind people to be able to experience art in a new way.

References

1. R. A. Taylor and G. L. Solbrekken, "Comprehensive system-level optimization of thermoelectric devices for electronic cooling applications," in *IEEE Transactions on Components and Packaging Technologies*, vol. 31, no. 1, pp. 23-31, March 2008.
2. GSP 16. "Thermal Images." *Interpreting Thermal Images*, Humbolt State University, 2019.
3. Sébire, Adam. "Thermographic Thermal Imaging Art." *Adam Sébire*, Adam Sébire, June 2015,
4. Pivac, Dunja "The art experience of blind people" in *Hrvatska revija za rehabilitacijska istraživanja 2017,* Vol 53, Supplement, str. 127-140, May 2017.
5. Zhao, Dongliang "A review of thermoelectric cooling: Materials, modeling and applications, " in *Applied Thermal Engineering*. 66 (1–2): 15–24, May 2014.
6. "Heatmaps and Color Gradients." *Wikipedia Heatmap*, 16 Oct. 2020,

Appendix 1A: Figures

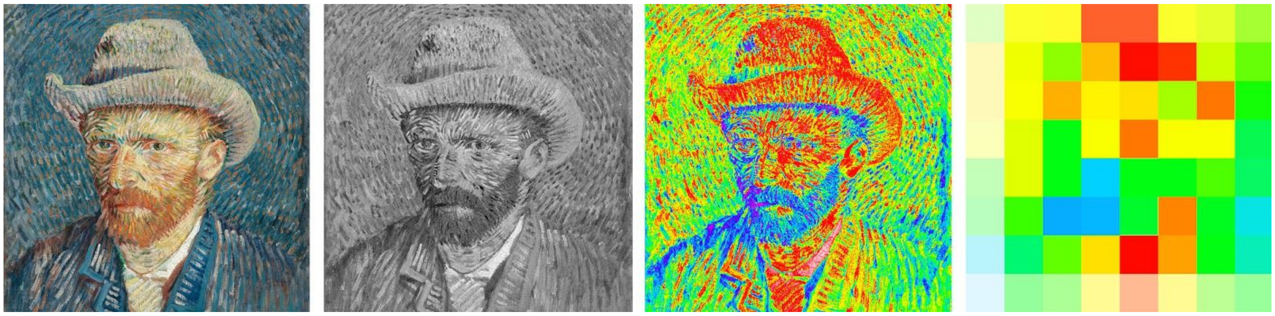


Figure 1: transformation visualisation

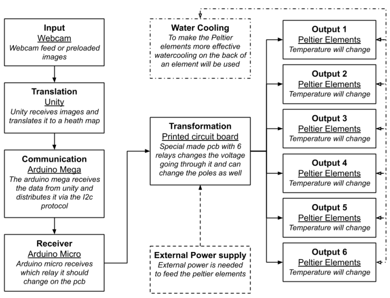


Figure 2: Pcb communication setup

Figure 3A & 3B: Hardware setup showing the grid of Peltier elements

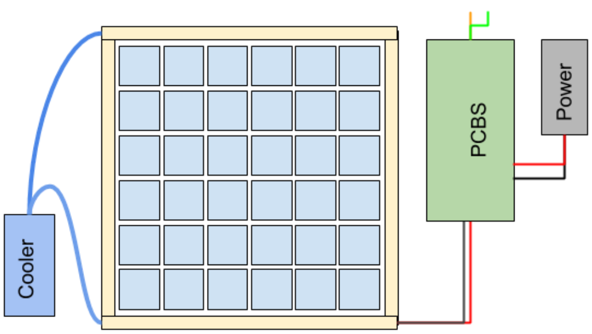


Figure 4: board setup top-down overview

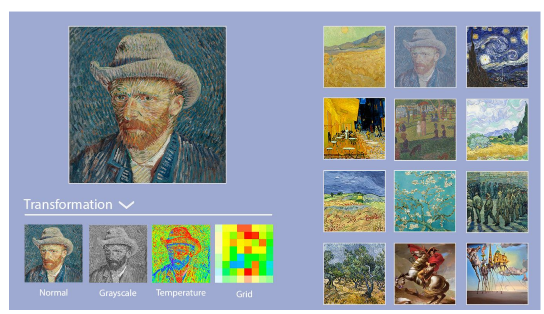


Figure 5: current interface overview

Appendix 1B: Figures

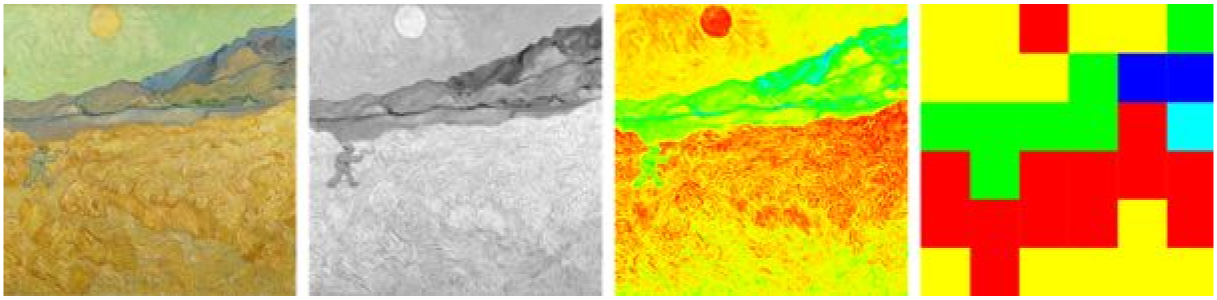


Figure 6. New transformation progress

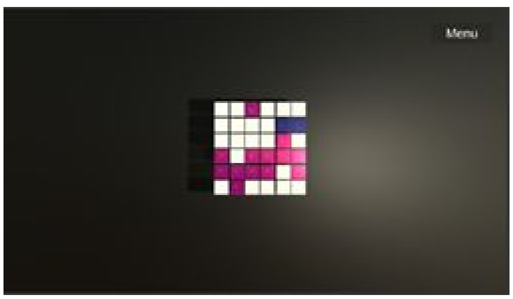


Figure 7. Unity form 1 first state

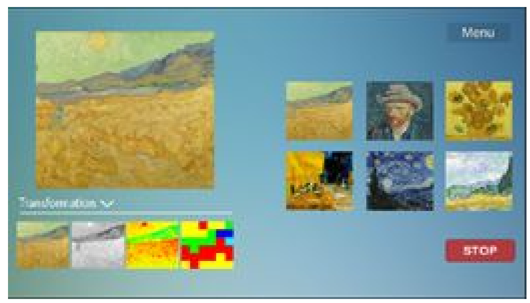


Figure 8. User interface for second test

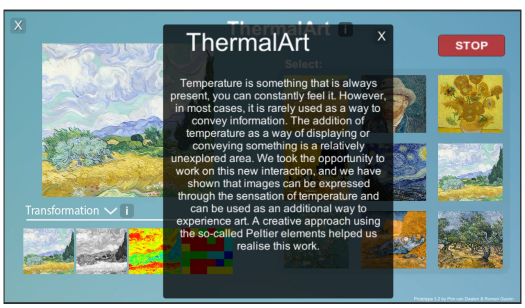


Figure 9. User interface with info

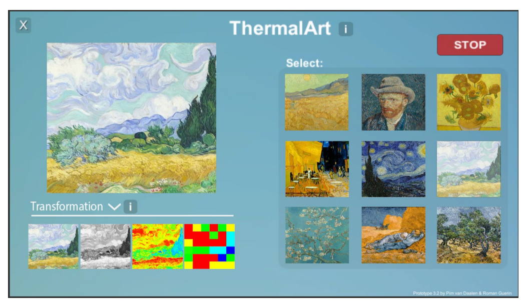
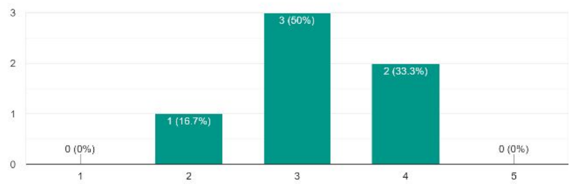


Figure 10. User interface plain

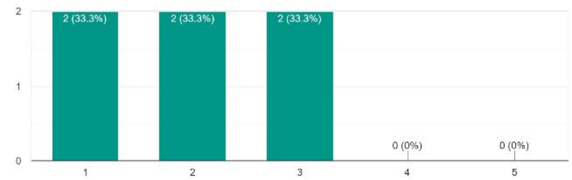
Appendix 2A: User evaluation responses

Evaluation 1 SuS:

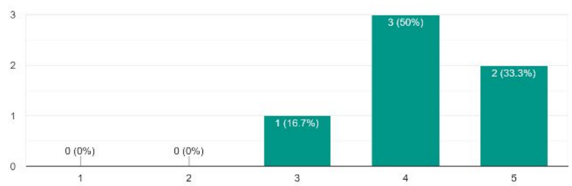
1. I think that I would like to use this system frequently
6 responses



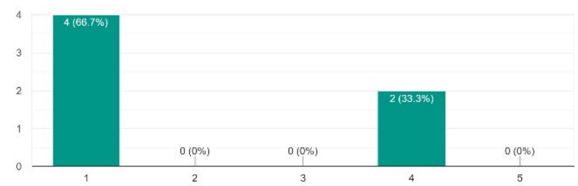
2. I found the system unnecessarily complex
6 responses



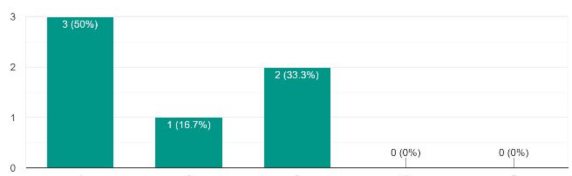
3. I thought the system was easy to use
6 responses



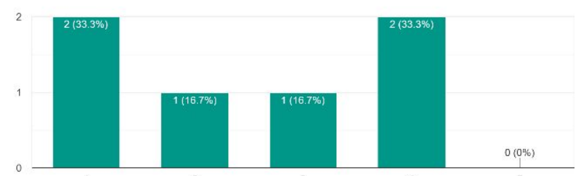
4. I think that I would need the support of a technical person to be able to use this system
6 responses



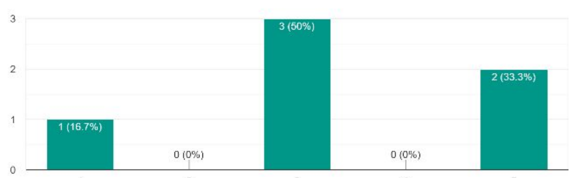
5. I found the various functions in this system were well integrated
6 responses



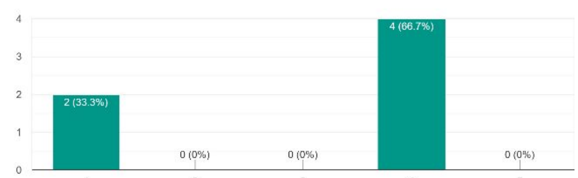
6. I thought there was too much inconsistency in this system
6 responses



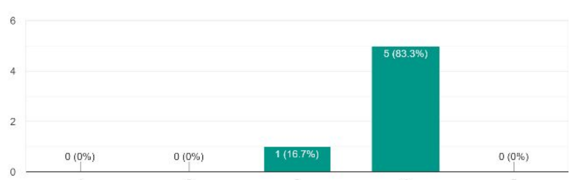
7. I would imagine that most people would learn to use this system very quickly
6 responses



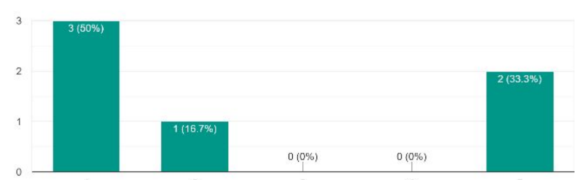
8. I found the system very cumbersome to use
6 responses



9. I felt very confident using the system
6 responses



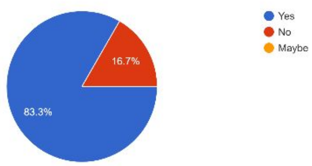
10. I needed to learn a lot of things before I could get going with this system
6 responses



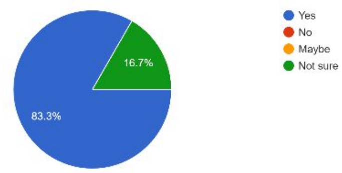
Appendix 2B: User evaluation responses

Evaluation 1 questionnaire

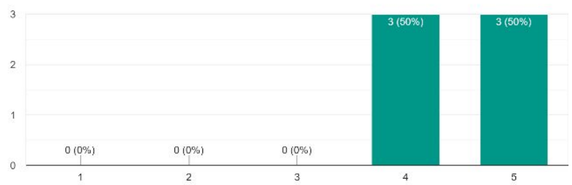
11. Did you understand the goal of the project?
6 responses



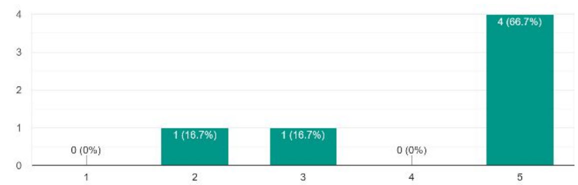
12. Do you think this could be useful?
6 responses



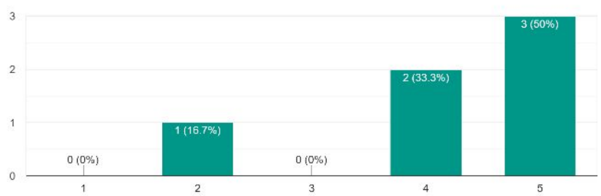
13. Could you feel the difference in temperature?
6 responses



14. Could you feel the difference in temperature per element?
6 responses



15. Did you understand the interface
6 responses



16. Is there something you liked in particular?
6 responses

difference in temp

Binnen een paar tellen werd een deel van de elementen heel heet, dus het werkt snel

I liked the art

Het is mooi gemaakt en makkelijk te gebruiken

The interface for selecting the paintings

17. Is there something you disliked in particular?
6 responses

interface to empty

Nee

The elements weren't working as well

Not really

No real tutorial that showed me what was going on

18. What would you recommend us to change?
6 responses

make the transform for each picture

Het product af te maken

More clear transformation pictures

Er zou meer variatie kunnen komen in de patronen van de warmte elementen. Vaak voelde ik niet een groot verschil tussen verschillende schilderijen

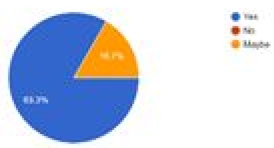
Making every heating element react to the painting on its own according to the placement in the painting

Appendix 2C: User evaluation responses

Evaluation 2 questionnaire

11. Did you understand the goal of the project?

6 responses

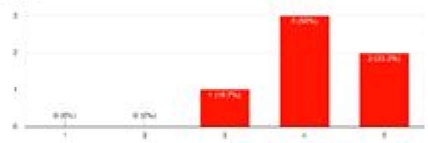


12. Do you think this could be useful?

6 responses

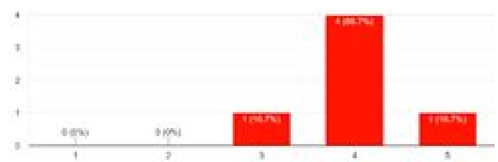
13. Did you understand the transformation?

6 responses



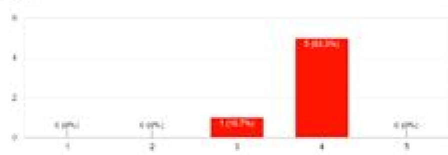
14. Did what you feel resembled that of what you felt?

6 responses



15. Did you understand the interface?

6 responses



16. Is there something you liked in particular?

6 responses

- The tranformation
- Difference in temperaure of what you feel at the moment
- Werkt al beter dan de vorige keer
- Cool technique but still not sure of what it does
- Looks good
- Ziet er strak ui

17. Is there something you disliked in particular?

6 responses

- Missing info
- Transformation is very small
- Lijkt me leuk als je het beeld kan uitvergroten ofzo
- -
- way better already
- mis nog wat informatie

18. What would you recommend us to change?

6 responses

- Create a info Button
- Maybe the transformation could be bigger and have more info
- zie vraag 17
- what you could do is to show more what you select or something
- Add a titel!!
- laat informatie zien waarom mensen dit zouden gebruiken. het menu spreekt voor de rest wel voor zichzelf