

The Environmental Impact of Computer Graphics

Birds of a Feather
SIGGRAPH '24

Monday, 29 July 2024
11am - 12pm MDT
Room 702

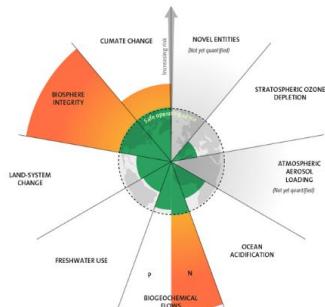
Speaker: Axel

Hello everyone, and thank you for attending our session in this packed program. Today we're going to talk about the environmental impact of Computer Graphics. The first question you might ask is: why is that important?

The Environmental Impact of Computer Graphics

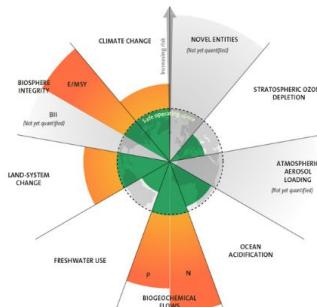
We're reaching our planet boundaries

2009



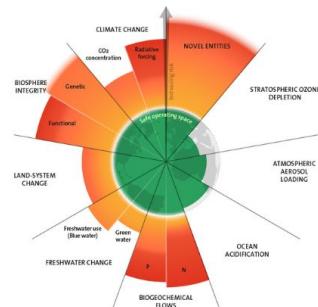
7 boundaries assessed,
3 crossed

2015



7 boundaries assessed,
4 crossed

2023



9 boundaries assessed,
6 crossed

[source] Richardson et al 2023

Speaker: Axel

Well, the issue, which has been identified multiple times in the past few years, is that we're reaching or even are already past some of our planet boundaries. This will most likely affect both personal and professional lives, so it seemed relevant to us to discuss that at SIGGRAPH.

The Environmental Impact of Computer Graphics

Goals

This is an **open discussion**.

Feel free to give your opinion at any point!

Speaker: Axel

Let's go on to probably the most important thing of this session: This is not going to be a formal, top-down presentation. The goal is to have an open discussion between members of the Computer Graphics community, whatever their background. To be more precise, we'll interleave some small quiz on various things such as orders of magnitude, and open discussion moments where we'll ask you questions directly to start the discussion.

So, the bottom line is: we want to hear your thoughts and opinion on these complicated subjects, so don't hesitate to take the mic, or ask questions that we will try to answer altogether.

The Environmental Impact of Computer Graphics

Disclaimer

We are **not professionals of environmental impact**, we do research in **Computer Graphics**.



Research Scientist
Adobe



Research Engineer
*University Grenoble Alpes Inria,
CNRS, Grenoble INP, LJK*



Research Scientist
Adobe

Speaker: Axel

Before diving in, a small disclaimer: we're not professionals of environmental impact. We did do research to prepare this session, and learnt a lot in the process, but keep in mind that we may have overlooked or simplified some things, or that numbers might sometimes not be exact, as we focused on more on the order of magnitude for instance.

Let's start with the first quiz!

Quiz #1

Orders of magnitude

Speaker: Elie

One thing that it always helpful for this kind of discussion is to remind ourselves of some **orders of magnitude**.

Quiz #1

Orders of magnitude

How many long to render an animated feature film?
(if rendered on a single device)



**EVERYBODY RAISE
YOUR HAND !**

Speaker: Elie

So here are the rules of this little quiz: **Everybody raise their hand**, then as long as you agree with my statements, you keep your hand up.

Quiz #1

Orders of magnitude

How many long to render an animated feature film?
(if rendered on a single device)

- a. More than 1 month

Speaker: Elie

Keep your hand up if you think that it would take **more than a month** to render an animated feature film on a **single device**.

Quiz #1

Orders of magnitude

How many long to render an animated feature film?
(if rendered on a single device)

- a. More than 1 month
- b. More than 1 year

Speaker: Elie

Keep it up if you think it would be **more than 1 year**.

Quiz #1

Orders of magnitude

How many long to render an animated feature film?
(if rendered on a single device)

- a. More than 1 month
- b. More than 1 year
- c. More than 100 years

Speaker: Elie

Keep it up if you think it would be **more than 100 year!**

Quiz #1

Orders of magnitude

How many long to render an animated feature film?
(if rendered on a single device)

- a. More than 1 month
- b. More than 1 year
- c. More than 100 years
- d. More than 10 000 years

Speaker: Elie

Keep it up if you think it would be more than... **10 000 year?**

Quiz #1

Orders of magnitude

How many hours are required to render an animated feature film?
(if rendered on a single device)

Some examples:

- **Toy Story 3** (2010): 7h/frame, 100 min -> 1M hours = **115 years**
- **Cars 2** (2011): 11.5h/frame, 106 min -> 1.8M hours = **200 years**
- **Luca** (2021): ~24h/frame, 96 min -> 3.3M hours = **380 years**

Sources: [\[Toy Story 3\]](#) [\[Cars 2\]](#) [\[Luca\]](#) [\[How to train your Dragon 2\]](#)

Speaker: Elie

Here are some example, around several hundreds of years.

Blinn's law: As technology advances, rendering time remains constant (attributed to Jim Blinn)

Quiz #1

Orders of magnitude

How many hours are required to render an animated feature film?
(if rendered on a single device)

Some examples:

- **Toy Story 3** (2010): 7h/frame, 100 min -> 1M hours = **115 years**
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- **Luca** (2021): ~24h/frame, 96 min -> 3.3M hours = **380 years**

What about **non-final frames**?

- **How to train your dragon 2** (2014): 90Mh = **10 000+ years!**

Sources: [\[Toy Story 3\]](#) [\[Cars 2\]](#) [\[Luca\]](#) [\[How to train your Dragon 2\]](#)

Speaker: Elie

And what about not just the final frame but **all the trial and error render jobs**? Now it reaches a huge amount of time!

Quiz #1

Orders of magnitude

What about the **impact** of these years of compute on the **physical world**?



Various types of environmental impact

Speaker: Elie

So we've been talking about render time, but how does this **translate into environmental impact**? There are **multiple types** of impact that we should keep in mind.

Quiz #1

Orders of magnitude



How much energy to render an animated feature film?

(compared to one's *monthly electricity consumption*)



Speaker: Elie

Let's translate these render times into **energy**. Raw Watt-hour values are **hard to interpret alone**, so we will compare them to a **simple reference**, namely the monthly energy consumption of an average person.

Quiz #1

Orders of magnitude



How much energy to render an animated feature film?

(compared to one's *monthly electricity consumption*)

- a. More than 10 people



Speaker: Elie

Everybody raise their hand, and keep it up if they think rendering an animated feature film requires **an amount of energy equivalent to 10 people over a month**.

Quiz #1

Orders of magnitude



How much energy to render an animated feature film?

(compared to one's monthly electricity consumption)

- a. More than 10 people
- b. More than 100 people



Speaker: Elie

Keep your hand up if you think it corresponds to more than 100 people.

Quiz #1

Orders of magnitude



How much energy to render an animated feature film?

(compared to one's *monthly electricity consumption*)

- a. More than 10 people
- b. More than 100 people
- c. More than 1 000 people



Speaker: Elie

Keep your hand up if you think it corresponds to more than 1 000 people.

Quiz #1

Orders of magnitude



How much energy to render an animated feature film?

(compared to one's *monthly electricity consumption*)

- a. More than 10 people
- b. More than 100 people
- c. More than 1 000 people
- d. More than 10 000 people



Speaker: Elie

Keep your hand up if you think it corresponds to more than 10 000 people.

Quiz #1

Orders of magnitude

How much energy to render an
animated feature film?

(Assuming 500W per render node, 6 MWh/person/year)

- **Toy Story 3** (2010): 115 years -> **500 MWh** -> **1 000 people** over a month
- **Cars 2** (2011): 200 years -> **900 MWh** -> **1 800 people** over a month
- **Luca** (2021): 380 years -> **1 650 MWh** -> **3 300 people** over a month

What about **non-final frames**?

- **How to train your dragon 2** (2014): 10 000+ years -> **45 000 MWh** -> **90 000 people**

Speaker: Elie

We are around a couple of thousands of people for the final frames of a movie, and a **whole town** if we count all intermediary frames!

Quiz #1

Orders of magnitude



How much raw mineral is extracted to manufacture computing devices for a typical data-center?

(in metric tons, knowing the Eiffel tower is 10,000 tons)

- a. $\leq 10,000$ tons (1 Eiffel tower)
- b. $\leq 100,000$ tons (10 Eiffel towers)
- c. $\leq 1,000,000$ tons (100 Eiffel towers)
- d. $\geq 1,000,000$ tons



Speaker: Octave

Thank you Élie! Moving on. Energy use may be hard to grasp, but there are very concrete impacts of the digital world as well. Let's look at metal use.

If you had to guess,

Quiz #1

Orders of magnitude

200,000 tons of rocks

-> Weight of 20 Eiffel towers

-> Volume of 26 olympic swimming pools



Copper, gold, silver, palladium,
dysprosium, neodymium, yttrium, ...

How much raw mineral is extracted to manufacture computing devices for a typical data-center?

(in metric tons, knowing the Eiffel tower is 10,100 tons)



Artist: Dillon Marsh

Speaker: Octave

The answer is 200,000 tons of rocks, or about the weight of 20 Eiffel towers, and the volume of 26 olympic swimming pools.

Excavating all that rock has very real impacts on Earth's landscapes, as illustrated on this artwork by Dillon Marsh. The density of minerals is so low that digging this large hole only yields enough copper to create a sphere this size.

Besides, crafting GPUs requires a varied range of sometimes rare metals like copper, gold, silver,

This yields complex supply chains and pressures communities worldwide, because some of these rare earths are only found in very specific places.

Quiz #1



Orders of magnitude

How much water does a typical data center consume per year?

(reference: 400,000 litres of water per household)

- a. $\leq 10M$ litres (25 households)
- b. $\leq 100M$ litres (250 households)
- c. $\leq 1B$ litres (2,500 households)
- d. $\geq 1B$ litres (2,500 households)

Speaker: Octave

Moving on to water!

Quiz #1

Orders of magnitude

How much water does a medium size data centre consume per year?
(in litres)

Depends on location, size, type of cooling system...

Small-scale data centre	Large-scale data centre
24.9 millions liters (60 households)	760 million liters (1900 households)

Large AI models are typically trained there

A **medium-sized data centre** (15 megawatts (MW)) uses as much water as **three average-sized hospitals**.

Recommended read: *The Cloud is a Factory*, Nathan Ensmenger.

Source: <https://dgtlinfra.com/data-center-water-usage/>

Speaker: Octave

Obviously and somewhat unfortunately, the answer is “it depends”.

[RESULTS]

All of this to say that computing in “The Cloud” has more real impacts than this metaphor would imply.

If this is of interest to you, I warmly recommend reading “The Cloud is a Factory” by Nathan Ensmenger.

But we’re getting a bit far from computer graphics now. Axel, why don’t you tell everyone about how our role in this ?

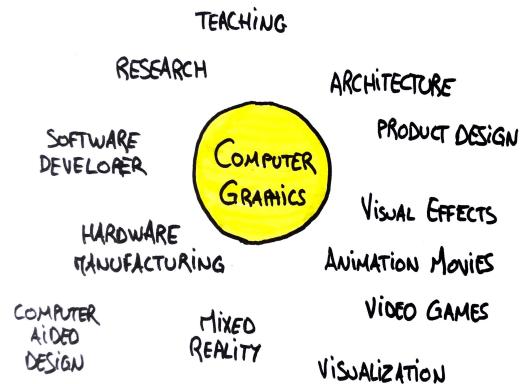
ELAPSED TIME: 10min

The Environmental Impact of Computer Graphics Outline

Two sides

Impact of Computer Graphics
(Research, Tech, Art, etc.)

Mitigate Environmental Issues
Using Computer Graphics



Recall this is an **open discussion**

Speaker: Axel

Thank you Octave. Hope you enjoyed this first quiz! Let's continue with the more interactive that I talk to you about. To give you an idea of the outline, we identified two sides for the discussion: first, the impact of Computer Graphics (let it about research, art, software, hardware, etc...), and second, how Computer Graphics can help regarding environmental issues.

Open discussion #1

Direct and Indirect Impact of Computer Graphics

Speaker: Axel

Let's start with the first part about the impact of Computer Graphics. The first question that we may ask ourselves is: what is actually the impact of our field?

Open discussion #1

Direct and Indirect Impact of Computer Graphics

Measuring

Research practice:

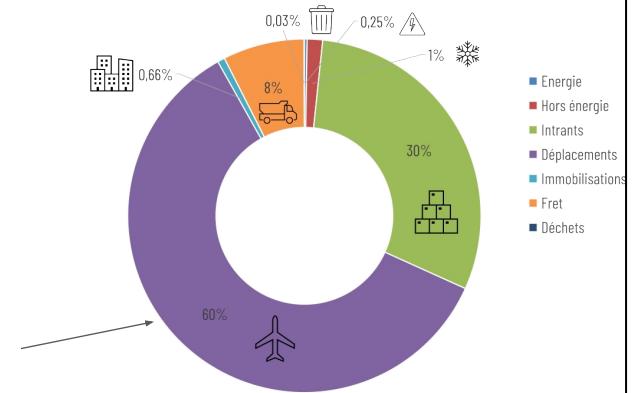
Impact reports in Computer Vision papers

Studio practice:

<https://garnot.com/en/carbon-simulator>

Event practice:

Annecy Film Festival reports its [carbon impact](#)



Speaker: Axel

We should start by measuring the impact. This is not an easy task, and it's also easy to overlook some of the impact. Here we list some initiatives that we're aware of in various fields of CG: for instance, reporting the impact of the method in Computer Vision papers, using existing carbon footprint calculators in Studios directly, or, at a bigger scale, report the impact of large events such as the Annecy Film Festival which gathers around 17,000 people each year. So, measurement is one side, but then the second part is about reducing the impact of what we do.

Open discussion #1

Direct and Indirect Impact of Computer Graphics

Reducing

Avoid waste: What are the key bottleneck to address?

Sobriety: What are we ready to change? Which values drive our work, what kind of world do we want to go towards?

Speaker: Axel

So in this, there are more questions than answers, because it depends on your actual activities and what are the bottlenecks that you identified.

Then there is the more personal question of Sobriety that you may ask yourself: what are we ready to change? What future world do we want to go towards?

Open discussion #1

Direct and Indirect Impact of Computer Graphics



Measuring

What does your institution and your peers in other institutions do?

What impact are we overlooking?



The mic is yours!

Reducing

Avoid waste: What are the key bottleneck to address?

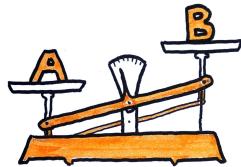
Sobriety: What are we ready to change?
Which values drive our work, what kind of world do we want to go towards?

Speaker: Axel

I'm done talking, here is a recap of the last two slides to help start the discussion; and now the mic is yours, so please share your thoughts!

Quiz #2

Equivalent impacts



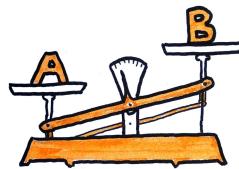
Would you rather...

Speaker: Elie

We're done with the first open discussion, time for second quiz! We are going to highlight pairs of items that have an equivalent **impact**.

Quiz #2

Equivalent impacts



Would you rather...



Generate 2 images with AI

OR

Entirely recharge your smartphone

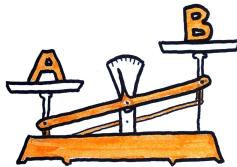


Speaker: Elie

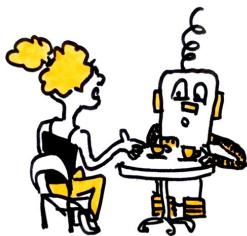
Would you rather... generate 2 images using AI, or entirely recharge your phone?
That's the same amount of energy.

Quiz #2

Equivalent impacts



Would you rather...



Ask GPT-3 for 20 answers

OR

Save a bottle of water

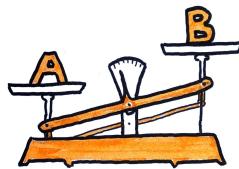


Speaker: Elie

Would you rather... ask 20 question to ChatGPT or save a bottle of water? That's the same amount of water.

Quiz #2

Equivalent impacts

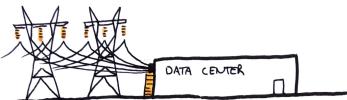


Would you rather...

Power AI data centers for a year (2027
projection)

OR

Supply the Netherlands
in electricity for a year



Speaker: Elie

Would you rather... power AI data centers or supply the entire Netherlands in electricity?

By the way, datacenters in Ireland now consume more than its inhabitants.

Open discussion #2

Computer Graphics to mitigate Environmental Issues

Speaker: Octave

Alright ! Hope you'll have new fun facts to tell your friends with all that.

Before our next open discussion, I'd like to briefly talk about the positive impact that computer graphics can have on the environment.

I truly believe that we, as computer graphics practitioners, have a humble but exciting part to play there.

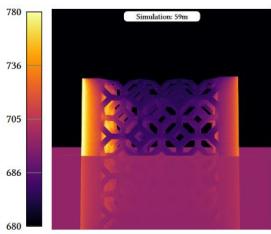
Let's look at a couple examples!

Open discussion #2

Computer Graphics to mitigate Environmental Issues

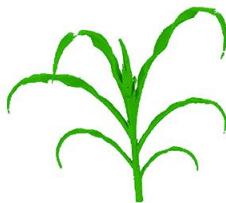
Examples of Research topics

Rendering for radiative transfer



Coupling Conduction, Convection and Radiative Transfer in a Single Path-Space: Application to Infrared Rendering
SIGGRAPH 2021

Development of drought-resistant plants

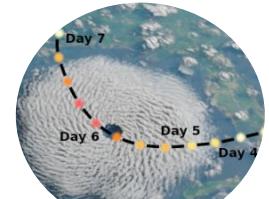


Voxel Carving Based 3D Reconstruction of Sorghum Identifies Genetic Determinants of Radiation Interception Efficiency
Plant Direct 2020

Ecosystem & Climate simulation



Scintilla: Simulating Combustible Vegetation for Wildfires
SIGGRAPH 2024



Cyclogenesis: Simulating Hurricanes and Tornadoes
SIGGRAPH 2024

Speaker: Octave

Perhaps the most obvious leverage point is scientific research on environmental issues.

In recent history, a few CG technical papers have looked at issues such as ...

[Voxel carving, algorithm for ...]

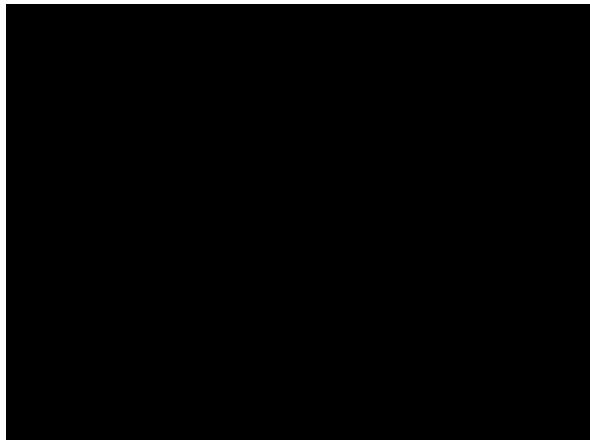
Just yesterday at the papers FF, we saw...

We are not going to replace scientists in environmental science, but we can bring a fresh take on these topics, and build intuitive visualizations and novel algorithms to these fields.

Open discussion #2

Computer Graphics to mitigate Environmental Issues

Examples of projects



Speaker: Octave

But it doesn't stop at research !

At its heart, Computer Graphics is about enhancing communication.
Sharing one's values effectively can be done in a number of ways.

Take fiction. With Wall-E, Pixar leveraged the best available animation tools and artists to tell a story that is certainly cute on a surface level, but also deeply rooted in the harm that humans are doing to the planet. There are many such stories waiting to be told!

Perhaps less poetic but very effective nonetheless is data visualization.
For instance, this animated map by NASA makes the effects of climate change on temperature much easier to understand than raw numbers would, but a lot more could be done.

How about making it interactive, allowing people to zoom in on their particular location ?

Adding simulation elements to show what the future would be like ?

Maybe showing what the landscape would look like in a specific region, street-view style ?

Letting users play with parameters to see what happens ? Or even further, turning it into a game by letting them make policy decisions to save their little planet ?

This would make for exciting challenges in rendering, real time simulation, high performance data analysis, human-computer interfaces...

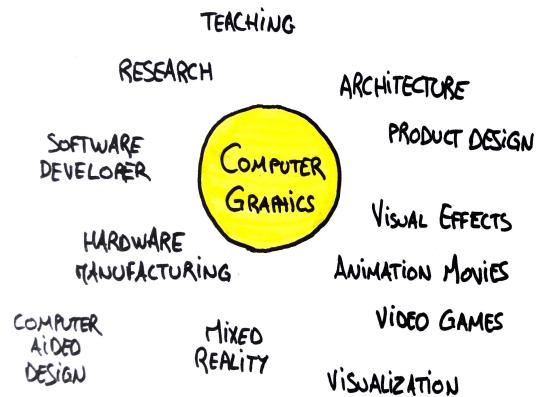
The technical papers, user studies, demos, and art installations are just waiting to happen!

Open discussion #2

Computer Graphics to mitigate Environmental Issues

Any ideas how to apply our skills to mitigate environmental issues?

The mic is yours!



Speaker: Octave

Alright, let's start another open discussion. With these examples in mind, do you have ideas on what each of us can do in our specific subfields ?

[What's Next?](#)

Leverage points



Discuss in papers
and reviews



Make it *cool*



Talk to your peers

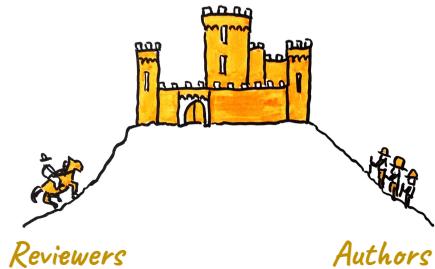
Speaker: Axel

Thank you for participating to the discussion, I think there were some great thoughts that were shared on the matter.

Now in order to conclude, we wanted to share with you a non exhaustive list of leverage points that we identified and that can help this initiative move forward.

What's Next?

Discuss in papers and reviews



Energy consumption

(rendering, simulation, training, ...)

Risk of obsolescence

(hardware-specific techniques, ...)

Use the “Limitations” sections of your papers
“Ethics and diversity” field of your reviews.

Speaker: Axel

The first one is oriented more towards researchers. The idea is to discuss the impact of what we do in a very concrete manner, such as rendering or simulation energy consumption, training carbon footprint, etc.. in both papers and reviews. We could use the limitation sections, and the Ethics and diversity field of reviews to encourage and discuss that more.

We mentioned a few times during this session the impact of hardware, so another thing that we wanted to mention is the risk of obsolescence and the issue of developing hardware specific techniques. While it is true that using the latest hardware is exciting, by doing so we also encourage other researchers to do the same, which may lead to a problematic hardware race.

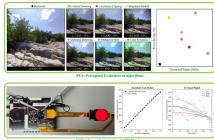
[What's Next?](#)

Make it cool



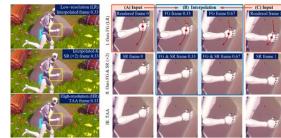
New constraints make nice research problems!

Doing **more** with **existing hardware** rather than running after new devices.



PEA-PODs

Monday, 11:25am



Mob-FGSR

Wednesday, 9:40am

Retro gaming & computing, demo scene, battery-free computing, low-power consumption devices, ...

Speaker: Elie

We should see environmental constraints as interesting research problems rather than something limiting our work. I'd like to mention 2 papers presented this year in other SIGGRAPH sessions and that in their way contribute to doing more using existing hardware rather than focusing on new hardware features.

The Environmental Impact of Computer Graphics Conclusion

And talk to your peers!



One final thing: let's stay in touch!



t.ly/Y44dh

Speaker: Octave

Bonus slides

Audience's reaction and feedback

We consolidated the audience's feedback in this separate slide deck:

Audience reacts to

The Environmental Impact of
Computer Graphics

Birds of a Feather

SIGGRAPH '24

Birds of a Feather
SIGGRAPH '24

https://docs.google.com/presentation/d/1cF4niAnTQUtNm e49YolcFxwbB4rNZ9K19WFH1lr66_Y/edit?usp=sharing

End of slideshow

Audience reacts to

The Environmental Impact of
Computer Graphics

Birds of a Feather
SIGGRAPH '24

Monday, 29 July 2024
11am - 12pm MDT
Room 702

Birds of a Feather
SIGGRAPH '24

Foreword

Context

This is a report of people's reaction and suggestions during our session at SIGGRAPH 24.
The reader may or may not agree with everything.

The Environmental Impact of Computer Graphics

Birds of a Feather
SIGGRAPH '24

Monday, 29 July 2024
11am - 12pm MDT
Room 702

Original slides presented during the session

https://docs.google.com/presentation/d/1f7vwCSpXdWbhOtKyVFZVbgwy9WGavzQ_GB48OALEJss/edit?usp=sharing

Foreword

Audience and setup

There were about **60 attendants** during the session.

We communicated a bit ahead of the event through social media, academic mailing lists and a few personal invites, and it was listed in the SIGGRAPH event program.

The audience was in general very **eager to react** and come to the open mic.

Despite this requiring to come up to the stage in front of the whole room because we only had one mic.



(This is not what the stage looked like)

Foreword

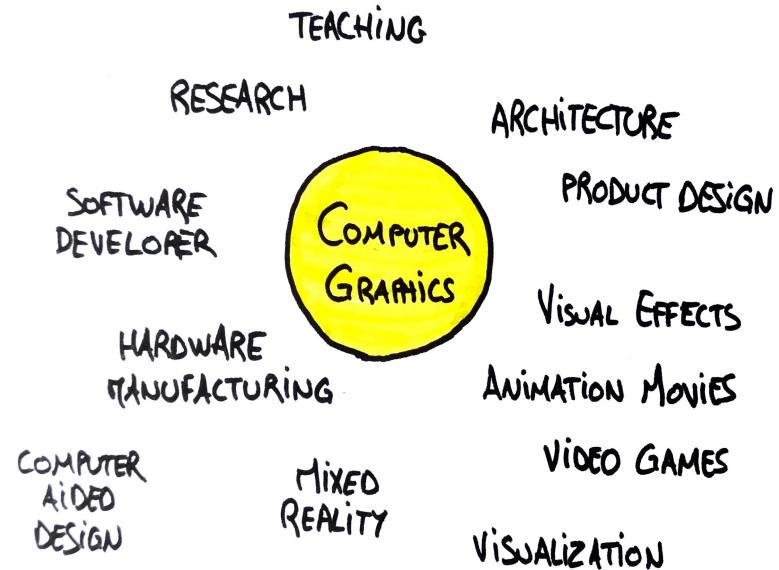
Outline

Two open discussions

#1 Impact of Computer Graphics

(Research, Tech, Art, etc.)

#2 Mitigate Environmental Issues Using Computer Graphics



Open discussion #1

Direct and Indirect Impact of Computer Graphics

#1.1 Measuring

#1.2 Reducing

Open discussion #1.1

Measuring the Impact of Computer Graphics

What are **key bottlenecks**?

Impact of telecommuting

*What is the environmental impact of a **full remote** studio vs **on-site** studio?*

Impact of on-site conferences

*How could we **reorganise research** so that it does not require so many people to travel overseas?*

*What is the **cost/benefit balance** of being on-site vs remove? We should assess it more carefully.*

Cost of opportunity

*What are we **not** investing time in that could lead to less impactful graphics?*

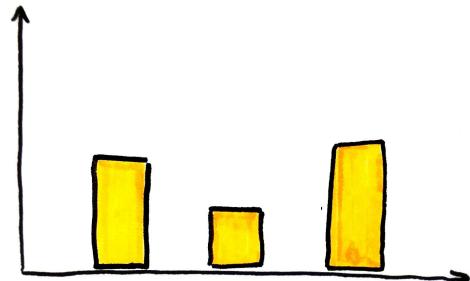
Should we spend more time getting the most out of old devices rather than running for new ones?

Open discussion #1.1

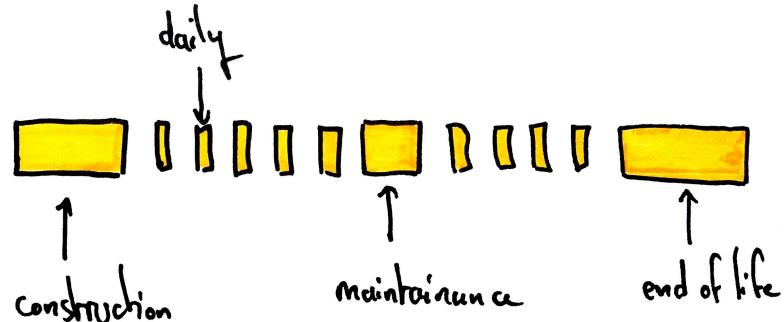
Measuring the Impact of Computer Graphics

We need detailed **impact breakdowns**.

We're usually good at measuring things like compute time, memory etc. Let's apply similar methodology to environmental impact.



Relative impact of different operations
Breakdown over tasks



Impact journey for a piece of hardware (and software?)
Breakdown over time

Open discussion #1.1

Measuring the Impact of Computer Graphics

How to **incentivize communication and transparency** about environmental impact?

- It is hard for studios to deliver figures about **movie productions**.
 - Nobody wants to be the first to publish figures.
- How to have **research papers** disclose their environmental impact?
 - Other fields like Computer Vision sometimes impose it.
 - Could be through the review process (stronger), or through a post-publication “stamp” program.
- Should we set up **hard constraints**, e.g. per individual or per project **rate limits**?

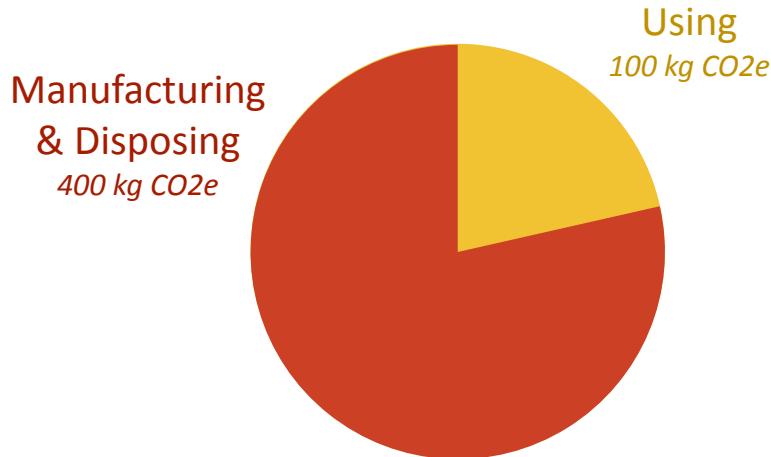


**Discuss in papers
and reviews**

Open discussion #1.1

Measuring the Impact of Computer Graphics

Impact of hardware manufacturing is huge.



*Environmental impact of a laptop
(rough estimation [\[source\]](#))*

How to address it at our level?

Studios

Don't renew render farms too often.

Research

*Don't **incentivize** end applications to force hardware upgrade by writing algorithms portable to older devices, or at least provide a **fallback solution**.*

Open discussion #1.1

Measuring the Impact of Computer Graphics

Some initiatives and tools to help measuring environmental impact:

These initiatives need help and adoption!

Animation Studios



Carbulator

<https://carbulator.fr/>

Video Game Studios



<https://jyros-jeuvideo.com/en/home-english/>

French Special

See the “*Ecoresponsabilité & Animation*” session from latest *Rencontres de l’Animation* (yearly meeting of the animation industry):

<https://www.youtube.com/watch?v=bQWv9PxTVZE&list=PLAyuZalnjRlgfZ6Osi6AcoRIJi4P9GoeD&index=15>

The **600M€** of annual public funds distributed by the French CNC to **audiovisual creation** will require recipients to assess the **environmental impact** of their production, from **March 2025** on.

https://www.cnc.fr/professionnels/actualites/transition-ecologique-et-energetique--le-cnc-met-en-place-une--ecoconditionnalite--de-ses-aides_1805866

Open discussion #1

Direct and Indirect Impact of Computer Graphics

#1.1 Measuring

#1.2 Reducing

Open discussion #1.2

Reducing the Impact of Computer Graphics

Do less.

Less operations for the same result.

Do better.

So that a given operation has less impact.

Change expectations.

Find new storytelling about what is to be considered a better result.

Examples

Prevent digital waste, reuse results, optimize processes

When and Where to run commute jobs?

Sometimes a nice expressive rendering is better than a heavy realistic one.

Open discussion #1.2

Reducing the Impact of Computer Graphics

We need both:



**Guidelines
Good Practices**

Inform & Empower



**Standards
Certifications**

Unlock prisoner's dilemma

About software development, about the good allocation of compute power, etc.

Example



**Green
Software
Foundation**

<https://greensoftware.foundation/>

Open discussion #1.2

Reducing the Impact of Computer Graphics



Another example: <https://www.net-zero-initiative.com/en>

Three proposed pillars, in this **order of priority**:

- **Reduce**
Start with measuring. Beware of rebound effect!

- **Help others reducing**
Offer new solutions to customers/users, address new usages

- **Capture (develop carbon sinks)**
Can Computer Graphics really do something here?

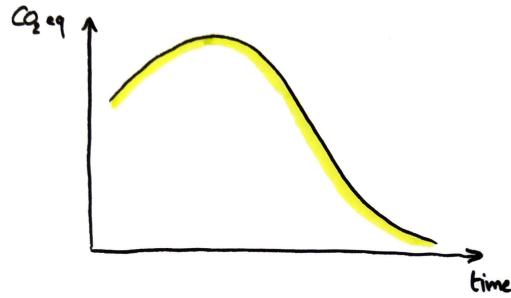


Open discussion #1.2

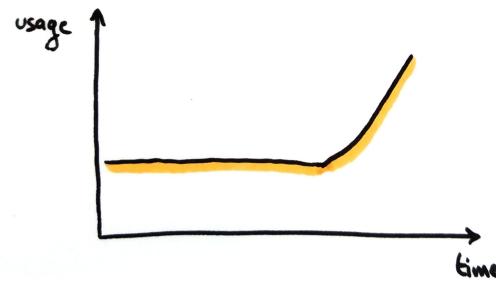
Reducing the Impact of Computer Graphics

Keep in mind the *rebound effect* (a.k.a. Jevon's paradox).

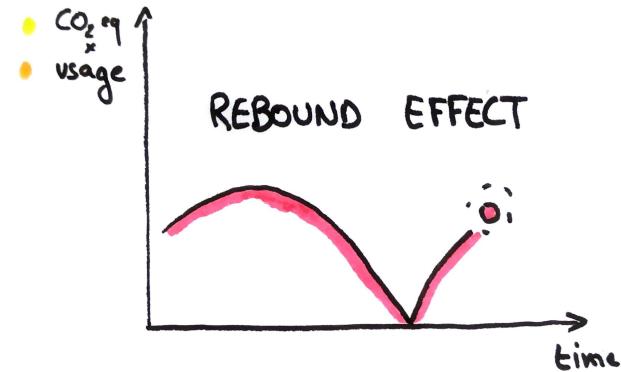
It may take many forms in practice!



1. Technology gets
more efficient



2. Usage increases



3. Global impact
gets worst

Open discussion #1.2

Reducing the Impact of Computer Graphics

Does **real-time rendering** reduce environmental impact of movie productions?

- Less need for heavy render farms
- Cheaper retakes
- But are there *rebound effects* to account for?

Open discussion #1.2

Reducing the Impact of Computer Graphics

Carbon offset? Let's be careful with that.

Risks of:

- **Impact shifting**

See next slide

- **Double accounting**

- **Desynchronized offsets**

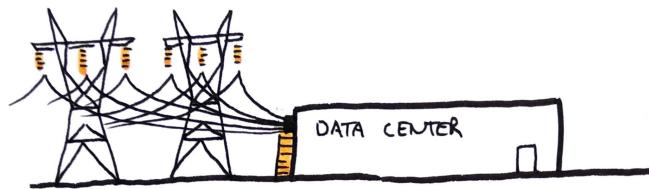
*Producing green energy at a point in time **does not balance** consumption of energy at a different moment.*

Open discussion #1.2

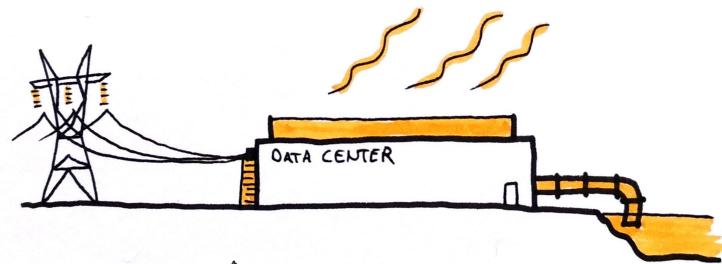
Reducing the Impact of Computer Graphics

An example of **Impact Shifting**:

Data-centers try to reduce their **Power Usage Effectiveness (PUE)** through **water cooling**.



Poor PUE*
 No water consumption



Better PUE*
 Important water consumption

Which one is better?

*PUE: Power Usage Effectiveness

Open discussion #1.2

Reducing the Impact of Computer Graphics

Where to run render/training jobs?

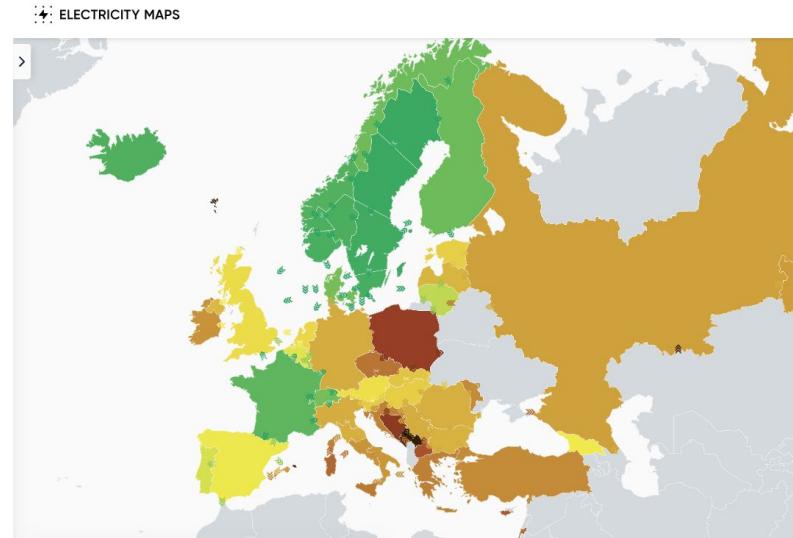
The **energy mix** matters!



Try reusing energy lost by the computation,
e.g., with Quarnot



<https://qarnot.com/>



*Electricity Maps provide live information about
the energy mix of electric grid*
<https://app.electricitymaps.com/map>

Open discussion #1.2

Grid-aware scheduling

When to run render/training jobs?

Grid-aware = Carbon-aware + Availability-aware

Risk of black-out due to data-centers
(e.g., in Ireland, or PJM warnings in Virginia)

Renewable energies have a scheduling issue
-> could grid-aware computation balance it?

24/7 Carbon-Free Energy Compact
Instead of carbon offsets at unneeded time of day

I WANT MY RESULT RIGHT NOW



A lot of compute jobs could afford to automatically wait for a greener energy mix rather than running right away.

Open discussion #2

Computer Graphics to mitigate Environmental Issues

Open discussion #2

Computer Graphics to mitigate Environmental Issues

Foreword

We should be careful with *techno-solutionism*:

- We're a bit in a **hurry**, there is no time to wait for a new magical technology.
- Heavy deployment of technological solutions often have **hidden downsides**.

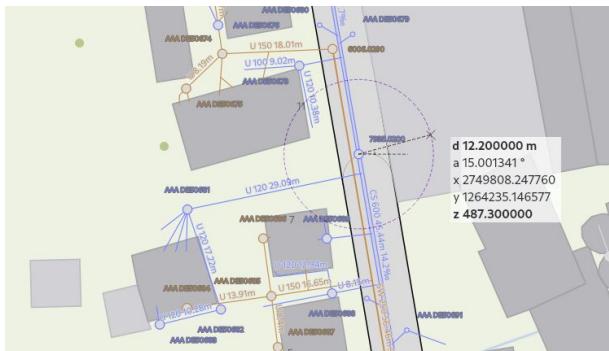
Open discussion #2

Computer Graphics to mitigate Environmental Issues

Making the invisible visible

Using environmental data viz

Recalling orders of magnitude



*Geographic Information Systems,
e.g., QGIS (open source) or ArcGIS*



An open-source library for interactive maps

<https://leafletjs.com>



The Ocean Cleanup uses MapBox
<https://theoceancleanup.com/sources/>
<https://www.mapbox.com/showcase/the-ocean-clean-up/>

Open discussion #2

Computer Graphics to mitigate Environmental Issues

Storytelling

Our environmental impact also comes from the messages we convey!

Our **movie/game productions** can propose alternative and positive visions of our society and how it could work in a more responsible and sustainable way.

Talking **outside of our community** can help stepping back and better understand what's **good and bad** in what we do and/or the way we do it.

Open discussion #2

Computer Graphics to mitigate Environmental Issues

Fabrication papers

Many SIGGRAPH papers present innovative manufacturing techniques.

The **evaluation metric** for these should include (or even focus on) a study of the environmental consequences:

- Choices of material used
- Amount of material needed
- etc.

Open discussion #2

Computer Graphics to mitigate Environmental Issues

Interdisciplinarity

With what other fields should we collaborate more?

What **skills** do we **collectively miss** to make our research/creation more **positively impactful**?

- Policy making
- Education
- Health
- etc.?

Conclusion

Leverage points

Dare talking about “politics”

In research labs, in conferences, in production studios, in the industry, ...



Make it count in review processes and peer recognition

This is how our community moves forward.

Don't ignore this issue

When writing annual or multi-year plans, when writing PhD/internship topics, when picking your next project, ...