Planetary Limits, Anti-Limits in Computer Systems And The Missing Scenarios

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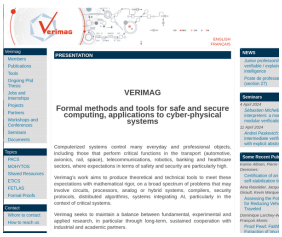
Campus d'Après Grenoble

June 4th, 2024 — GDR GPL, Strasbourg

Who Am I?

- Research at **Verimag**, background in critical embedded systems and high-level models for systems-on-a-chip, now working on the impacts of digital technologies
- Teaching at **Ensimag** (OSes, HW architecture, real-time systems, formal validation...), vice-director for Social and Environmental Responsibilities (RSE)
- In charge of the **VerIT project** (new curricula for future jobs in green ICT)



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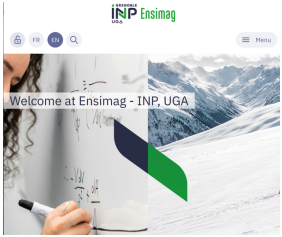

ensimag.grenoble-inp.fr

ensimag.grenoble-inp.fr/fr/l-ecole/projet-verit

Social and Environmental Responsibilities of the Digital World

Many concerns:

- Generalized surveillance, privacy matters
  Les mesures de vidéosurveillance algorithmique introduites par la loi JO 2024 sont contraires au droit international [1]
- Fragility of the infrastructures, cybersecurity, failures
- Illectronism, digital divide
- Algorithmic governmentality, inequalities, biases
  Notation des allocataires : l'indécence des pratiques de la CAF désormais indéniable[2]
- This talk: **Planetary limits and the impacts on the environment**

[1] https://www.lemonde.fr/idees/article/2023/03/06/les-mesures-de-videosurveillance-algorithmique-introduites-par-la-loi-jo-2024-sont-cor

[2] https://www.laquadrature.net/2023/11/27/notation-des-allocataires-lindecence-des-pratiques-de-la-caf-desormais-indeniable/

Impacts On The Environment

GHG only:

- Between 1.8 and 3.9% of total GHG emissions according to [1]
- Growth rate estimates: 6% per year according to the Shift Project

+ Other impacts...

[1] Charlotte Freitag, Mike Berners-Lee, Kelly Widdicks, Bran Knowles, Gordon S Blair, and Adrian Friday. The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations. Patterns, 2(9):100340, 2021. https://www.sciencedirect.com/science/article/pii/S2666389921001884.

Impacts On The Environment: When and How Will It Stop?

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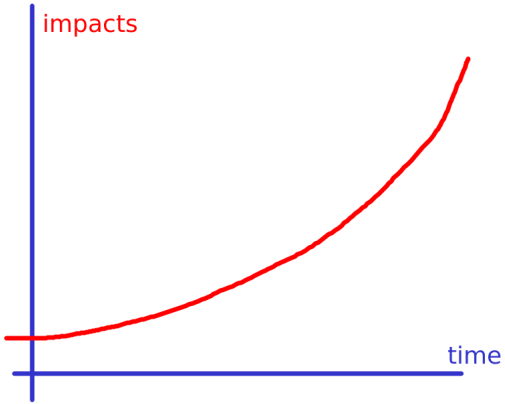

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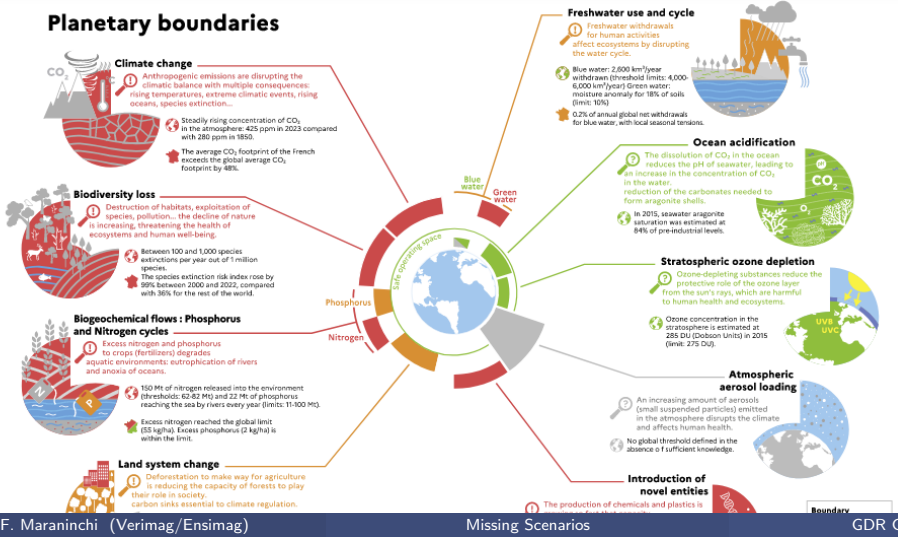
A Few Words On Planetary Boundaries

https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/la-france-face-aux-neuf-limites-planetaires/en



Absolute Sustainability

https://orbit.dtu.dk/en/publications/downscaling-the-planetary-boundaries-in-absolute-environmental-su

JOURNAL ARTICLE

Downscaling the planetary boundaries in absolute environmental sustainability assessments – A review

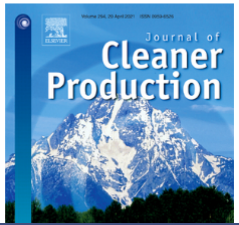
IN Journal of Cleaner Production — 2020, Volume 276, pp. 123287

BY Ryberg, Morten W.[1,2,3]; Andersen, Martin Marchman[3]; Owsianiak, Mikołaj[1,2,3]; Hauschild, Michael Zwicky[1,2,3]

FROM Sustainability[1], Quantitative Sustainability Assessment[2], Department of Technology[3] details

The safe operating space as defined by the Planetary Boundaries framework can be used as an environmental sustainability reference in absolute environmental sustainability assessments (AESAs). In AESAs, the safe operating space must be distributed among human activities so impacts associated with an activity can be related to its assigned share of the safe operating space to assess if the activity can be considered absolute sustainable.

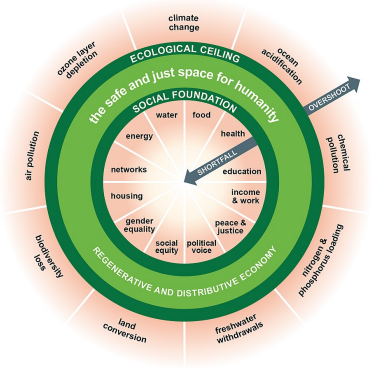
To ensure choices concerning sharing principles in AESA are deliberate, there is a need for understanding the distributive justice theory underlying the sharing principles. This study provides a



Global Limits: ICT In The Donut?[3]

There are already a lot of existing digital technology, we're not sure they "fit" in the donut;

Should we keep hoping for new "greener" objects (i.e., that would fit in the donut), or rather preserve what we can of the existing objects?
The sharing principles are necessarily political



[3] By DoughnutEconomics - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=75695171

The Current Green × ICT Landscape

- **Green ICT**:
  - Measures/estimations/modeling of (mainly) energy consumption
  - Optimization (SW, HW, communication)

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  - New domains (e.g, car-sharing platforms)

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- But how does this address the exponential growth and the necessity to fit in the donut? what about rebound effets?[a] and degrowth/postgrowth?
  What if it's not sufficient, or even counter-productive?

[a] *https://en.wikipedia.org/wiki/Jevons_paradox*

ICT In The Donut? We Need To Change Perspectives

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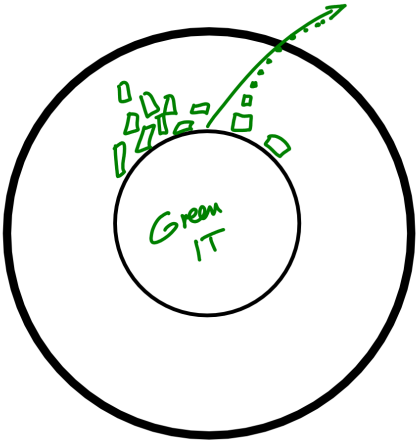

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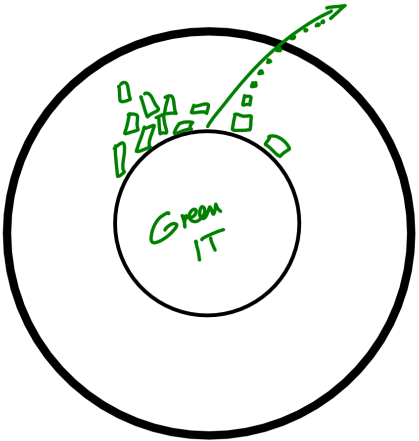

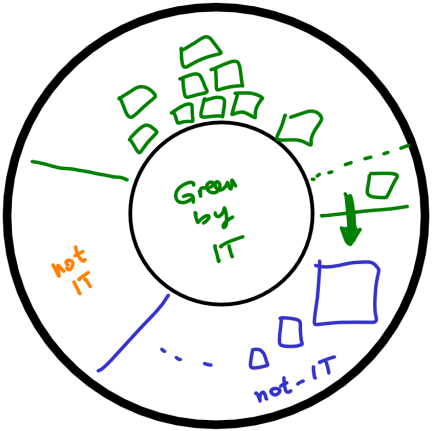

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Green-ICT aims at designing *greener objects*. But we need **absolute sustainability**, not relative sustainability.

Green-by-ICT gives priority to ICT now and promises a better future for other activities.

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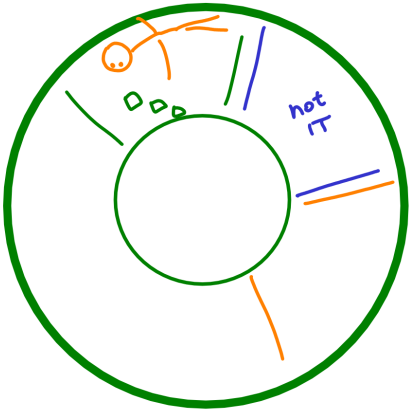

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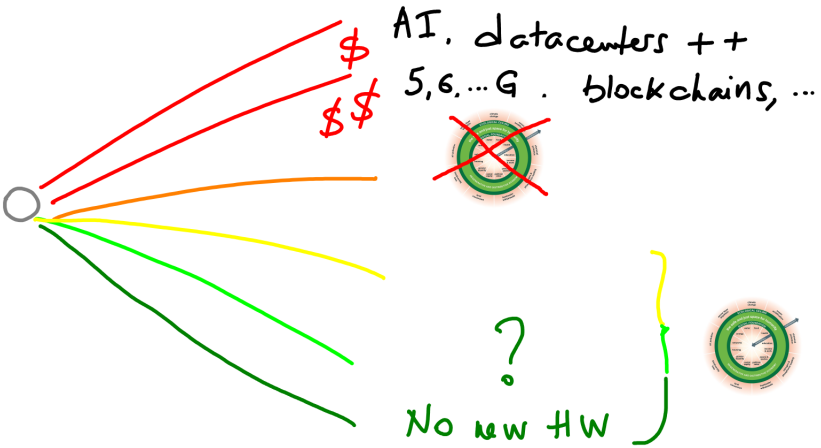
Missing Research, Teaching, and Engineering Work



Research In CS Should Explore More Diverse Paths[4] [5] [6]

[4] https://cacm.acm.org/opinion/let-us-not-put-all-our-eggs-in-one-basket/

[5] https://www.ins2i.cnrs.fr/fr/cnrsinfo/quelle-recherche-en-informatique-pour-un-numerique-inscrit-dans-les-limites-planetaires

[6] https://undonecs.sciencesconf.org/

This Talk: Some Missing Research Topics in CS For The Non-Overly Techno-Optimistic Hypotheses

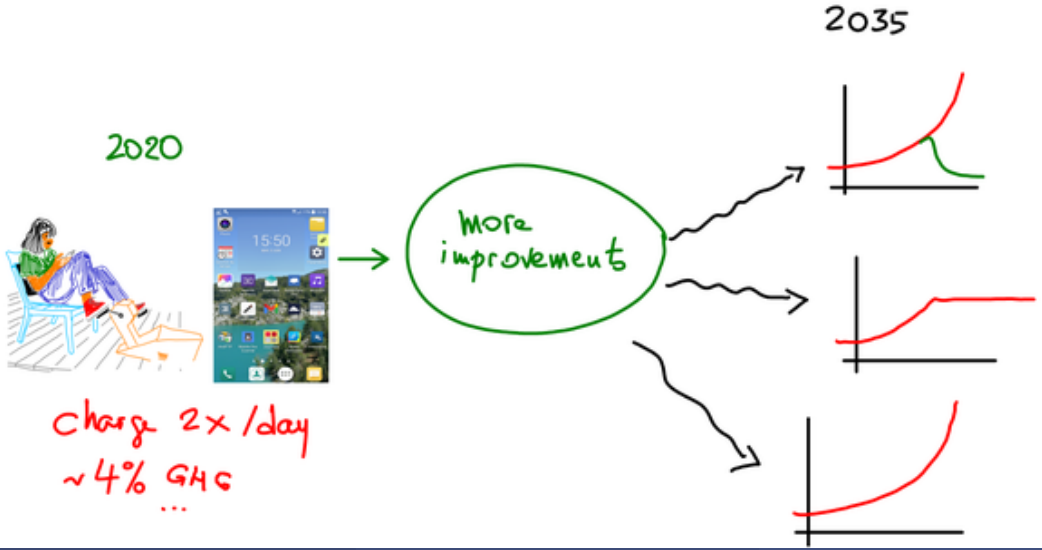
1. A Tale Of Three Futures (the Example of Mobile Communications 2005-2020)
2. Anti-Limits in CS and Implicit Futures
3. Example CS Research Topics For The "Fading ICT" Scenario
4. This is Not a Conclusion

Typical Situation in 2005

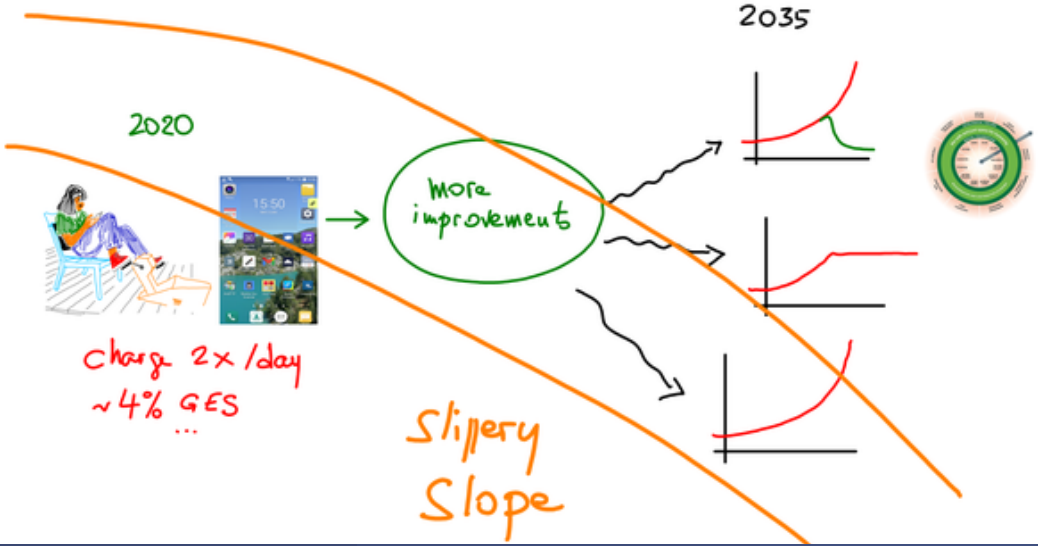
Typical Situation in 2020

What Future For 2020 Did We Have in Mind Back In 2005?

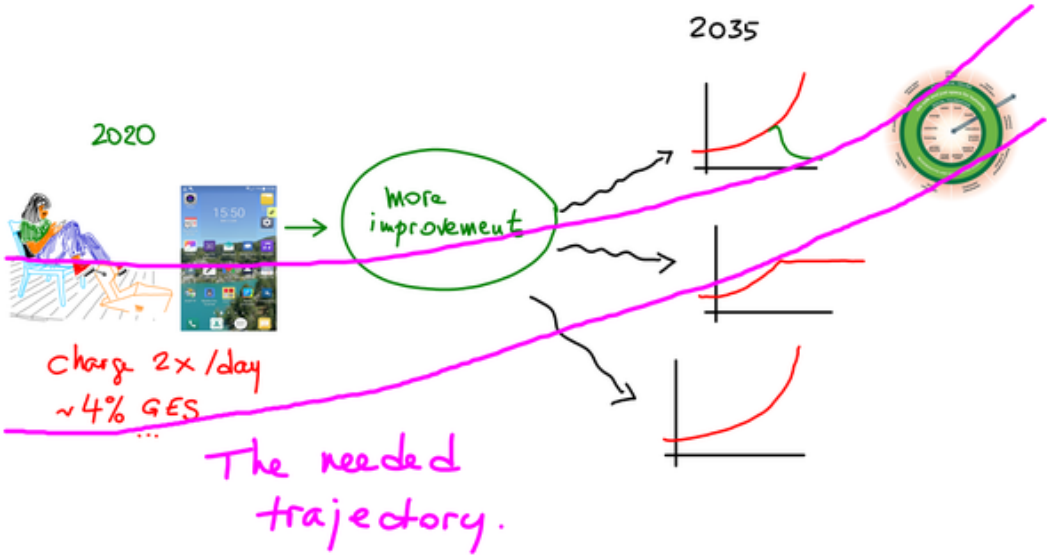
How Do We See The Future, say in 2035?



The Slippery Slope: Towards Increased Impacts



How To Set ICT On The Needed Trajectory?



Rebound Effects

Not logged in Talk Contributions Create account Log

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The Free Encyclopedia

Article Talk | Read Edit View history | Search Wikipedia

Jevons paradox

From Wikipedia, the free encyclopedia

Main page
Contents
Current events
Random article
About Wikipedia
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Learn to edit
Community portal
Recent changes
Upload file

Tools
What links here
Related changes

In economics, the **Jevons paradox** (/ˈdʒɛvənz/; sometimes **Jevons effect**) occurs when technological progress or government policy increases the efficiency with which a resource is used (reducing the amount necessary for any one use), but the falling cost of use increases its demand, negating reductions in resource use.[1] The Jevons' effect is perhaps the most widely known paradox in environmental economics.[2] However, governments and environmentalists[needs update] generally assume that efficiency gains will lower resource consumption, ignoring the possibility of the effect arising.[3]

In 1865, the English economist William Stanley Jevons observed that technological improvements that increased the efficiency of coal use led to the increased consumption of coal in a wide range of industries. He argued that, contrary to common intuition, technological progress could not be relied upon to reduce fuel consumption.[4][5]

The issue has been re-examined by modern economists studying consumption rebound effects from improved energy efficiency. In addition to reducing the amount needed for a given use, improved efficiency also lowers the relative cost of using a resource, which increases the quantity demanded. This counteracts (to some extent) the reduction in use from improved efficiency. Additionally,

Coal-burning factories in 19th-century Manchester, England. Improved technology allowed coal to fuel the Industrial Revolution, greatly increasing the consumption of coal.

Social Questions vs Computer Science Research Topics

Individual Behaviors or Regulations? Should we keep the videos of cats? How to choose democratically? ...

Even if we don't agree on the need to keep digital technologies within limits, even if we don't agree on what to keep/remove, we can and should ask:
intrinsic computer science questions on the mere feasibility of staying within limits; do we even know how not to grow?

Anti-Limits *(from the CACM paper)*

An Anti-Limit is both a promise and a deliberate hypothesis that resources will grow as needed. There is an anti-limit if a digital system:

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An Anti-Limit is both a promise and a deliberate hypothesis that resources will grow as needed. There is an anti-limit if a digital system:

- ...
- Promises immediate service delivery, whatever the number of clients and usages (most of the cloud services)
- Promises unlimited storage in both space and time (Gmail in 2006), twitter, ...
- Is designed to allow for unlimited functional extensions
- ...

Anti-Limits And The Corresponding Limits

Each anti-limit leads to interesting socio-political or technical questions:

- Unlimited storage in both space and time (more examples later):
  Mastodon vs Twitter: choose an expiration delay vs tweets are there forever
  Do you have disk/email quotas at work?
  Do you archive your conversations on social networks?

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- Unlimited and concentrated cloud services:
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- Extensible systems (more details later):
  Is extensibility always a desirable property?
  What about ad-hoc, non-extensible systems, by-design?
- ...

One More Anti-Limit: Digital Cartography

https://write.tedomum.net/flomaraninchi/penser-le-numerique-dans-les-limites-planetaires-une-metaphore-visuelle-et

https://geoservices.ign.fr/lidarhd

???

- IGN Lidar 50cm-precision
- Micro-mapping and now Panoramax (replacement for Google StreetView) in Open Street Map
- Real-time information (e.g., waze)

Is there a limit? And if yes, where?

A Quest For The Map Of The World At The Scale 1-1

https://fr.wikipedia.org/wiki/De_la_rigueur_de_la_science

En aquel Imperio, el Arte de la Cartografía logró tal Perfección que el mapa de una sola Provincia ocupaba toda una Ciudad, y el mapa del Imperio, toda una Provincia. Con el tiempo, estos Mapas Desmesurados no satisficieron y los Colegios de Cartógrafos levantaron un Mapa del Imperio, que tenía el tamaño del Imperio y coincidía puntualmente con él. Menos Adictas al Estudio de la Cartografía, las Generaciones Siguientes entendieron que ese dilatado Mapa era Inútil y no sin Impiedad lo entregaron a las Inclemencias del Sol y los Inviernos. En los desiertos del Oeste perduran despedazadas Ruinas del Mapa, habitadas por Animales y por Mendigos; en todo el País no hay otra reliquia de las Disciplinas Geográficas.

Suárez Miranda, Viajes de Varones Prudentes, Libro Cuarto, Cap. XLV, Lérida, 1658.
Jorge Luis Borges.

Where Do We Stop?

If a new technology allowing for a precision of 1cm is developed, will we use it?

We already have a huge set of data, to be preserved forever, which grows with no visible limit because of all the things that people may want to include in maps, ...

What if the next "useful info" is real-time data about the whole territory?

The Implicit Scenario We Use To Justify The Quest

The implicit context for the usefulness of this precise (and real-time) information: people are alone in the wild, there's no public authority in charge of installing road signs and broadcasting real-time information, no one can help, or you don't trust them...

What does it tell us on our pre-conceptions of the public space?

The Case Of Windows 11 Recall

https://arstechnica.com/gadgets/2024/05/microsofts-new-recall-feature-will-record-everything-you-do-on-your-pc/

Recall uses Copilot+ PC advanced processing capabilities to take images of your active screen every few seconds, (...) The snapshots are encrypted and saved on your PC's hard drive. You can use Recall to locate the content you have viewed on your PC using search or on a timeline bar that allows you to scroll through your snapshots.

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To use Recall, users will need to purchase one of the new "Copilot Plus PCs" powered by Qualcomm's Snapdragon X Elite chips, which include the necessary neural processing unit (NPU). There are also minimum storage requirements for running Recall, with a minimum of 256GB of hard drive space and 50GB of available space. The default allocation for Recall on a 256GB device is 25GB, which can store approximately three months of snapshots. Users can adjust the allocation in their PC settings, with old snapshots being deleted once the allocated storage is full. me: Really?

The *My Life Bits* Experiment 2001-2024

https://en.wikipedia.org/wiki/MyLifeBits

Remember the experiment My Life Bits by Gordon Bell (started in 2001)?

MyLifeBits

Article Talk Read Edit V

From Wikipedia, the free encyclopedia

MyLifeBits is a life-logging experiment begun in 2001.[1] It is a Microsoft Research project inspired by Vannevar B Memex computer system. The project includes full-text search, text and audio annotations, and hyperlinks. The "s subject" of the project is computer scientist Gordon Bell, and the project will try to collect a lifetime of storage on Gemmell of Microsoft Research and Roger Lueder were the architects and creators of the system and its software

MyLifeBits is an attempt to fulfill Vannevar Bush's vision of an automated store of the documents, pictures (includ automatically), and sounds an individual has experienced in his lifetime, to be accessed with speed and ease. For documents he had read or produced, CDs, emails, and so on. He continued to do so through his death in 2024, ga browsed, phone and instant messaging conversations and the like more or less automatically. The book *Total Rec* vision and implications for a personal, lifetime e-memory for recall, work, health, education, and immortality.[2] In was published in paperback.[3] As of 2016, Bell was no longer using the wearable camera associated with the pro the rise of the smartphone as largely fulfilling Bush's vision of the Memex.[4]

2. Anti-Limits in CS and Implicit Futures
   - Anti-Limits
   - One More Anti-Limit: Digital Cartography
   - One More Anti-Limit: Total Recall
   - Questioning Implicit Scenarios And Their Effects On Digital Systems

Implicit Futures: Usages vs Core Development Principles

There are implicit infinite-growth futures (not so) hidden in the promises and subsequent uses of digital technologies: store without limits, until you lose any hope of finding anything significant (or you buy the idea that you need AI for that purpose).

There are also implicit futures hidden in the core design principles of digital systems. Example: extensibility.

Implicit Futures Hidden in The Definitions Of Extensibility

Extensibility is a software engineering and systems design principle that provides for future growth. Extensibility is a measure of the ability to extend a system and the level of effort required to implement the extension[a].

[a] https://en.wikipedia.org/wiki/Extensibility

Software extensibility encapsulates the software's innate ability to absorb fresh features, capabilities, or alterations, all without requiring an extensive reconstruction of its core architecture. Think of this as building with a "future-proof" mindset (...)[a].

[a] https://www.codium.ai/glossary/software-extensibility/

Extensibility is almost always considered a desirable property.
But what futures do we have in mind?

(goto slide 53)

1. A Tale Of Three Futures (the Example of Mobile Communications 2005-2020)
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3. Example CS Research Topics For The "Fading ICT" Scenario
   - What Is "Fading" ICT?
   - Self-Obviating Systems
   - Limits-First Design
   - + Non-Extensible Systems/Shrinkability Principle
   - + Tools for Deconstructing ICT
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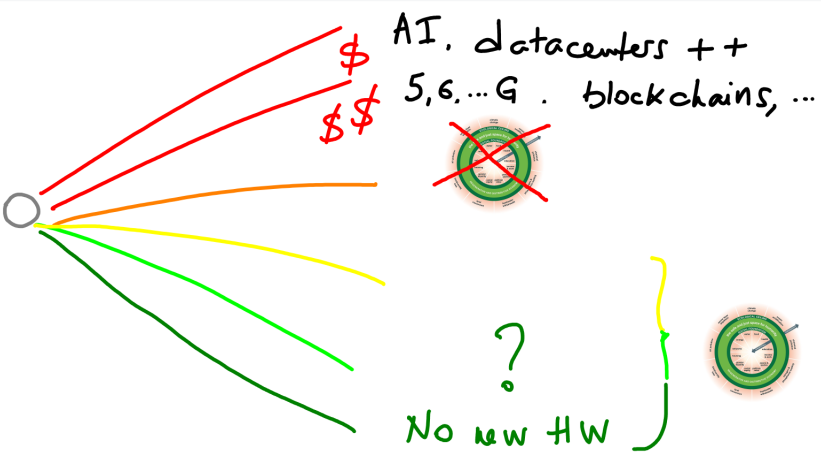
$
$$
AI. datacenters ++
5,6,...G . blockchains, ...
?
No new HW

ICT in Prospective Scenarios (A. Bugeau et A.-L. Ligozat)

https://ensimag.grenoble-inp.fr/fr/l-ecole/conferences-et-ateliers-le-numerique-dans-les-limites-planetaires-quelles-nouvelles-formations-po

https://hal.science/hal-04486589

Conference Papers | Year : 2024

Analysing ICT in prospective scenarios to help reveal undone computer science

Aurélie Bugeau (1, 2, 3) , Anne-Laure Ligozat (4, 5, 6)

Show details

1 IUF - Institut universitaire de France
2 LaBRI - Laboratoire Bordelais de Recherche en Informatique
3 UB - Université de Bordeaux
4 ENSIIE - Ecole Nationale Supérieure d'Informatique pour l'Industrie et l'Entreprise
5 LISN - Laboratoire Interdisciplinaire des Sciences du Numérique
6 STL - Sciences et Technologies des Langues - LISN

Abstract en

Computer science is often mentioned as a solution to solve climate change (e.g. [Rolnick et al., 2019]). But at the same time, it is now acknowledged that ICT has it own environmental impacts. Several authors have tried to estimate future information and communication technologies (ICT) energy

Keywords en

future of ICT prospective scenario sustainable ICT

future of ICT | prospective scenario

Fading ICT: An Hypothesis and A Scenario

What if, at some point in the future, **we stopped manufacturing new HW?**
We should explore this hypothesis, just in case...

- Scenario: how to get there? the "fading-ICT" scenario
- Several existing research topics are relevant for this hypothesis: fighting SW obsolescence; Self-Obviating Systems; Limits-First Design; Permacomputing; ...
- I propose to add: Non-Extensible Systems/Shrinkability Principle; Tools for Deconstructing ICT

Studying this hypothesis and its consequences is also a way to change perspectives.

goto Slide 10.

3. Example CS Research Topics For The "Fading ICT" Scenario
   - What Is "Fading" ICT?
   - Self-Obviating Systems
   - Limits-First Design
   - + Non-Extensible Systems/Shrinkability Principle
   - + Tools for Deconstructing ICT

Use The Current ICT Abundance To Build Non ICT-Dependent Solutions ("Back To The Trees" Project)

LIMITS '23, June 14–15, 2023,

Back to the trees: Identifying plants with Human Intelligence

Simon Castellan
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France
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Jos Käfer
Université de Lyon, Université Lyon 1, CNRS, Laboratoire de Biométrie et Biologie Evolutive UMR 5558, Villeurbanne, France; DIADE, Université de Montpellier, IRD, CIRAD, Montpellier, France; ISEM, Univ Montpellier, CNRS, IRD, Montpellier
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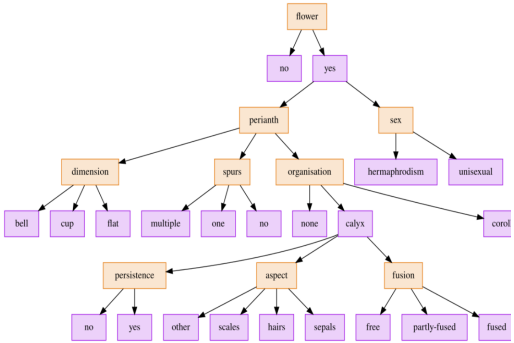
jos.kafer@cnrs.fr

Eric Tannier
Inria, Centre de Lyon ; Université de Lyon, Université Lyon 1, CNRS, Laboratoire de Biométrie et Biologie Evolutive UMR 5558, Villeurbanne
France
eric.tannier@inria.fr

ABSTRACT

We investigate a way to build a *convivial* plant identification tool halfway between the complex determination keys of botanists and the more recent but poorly explainable approaches based on AI image recognition. Our approach consists of a formal language to organize morphological traits and a Bayesian technique to de-

2001] for instance) as precise tools to identify an unknown plant, despite some limits: (1) they require an expertise in plant morphology; (2) they suppose the ability to answer questions concerning all the organs (and in particular the flower) even if these organs are not observable (because of seasonality for example) on the considered plant; and (3) they leave little place for errors or uncertainties, both



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7 https://assets.pubpub.org/v16f148a/61686158341995.pdf

Valérie d'Acremont: Digital Technologies for Health

https://steep.inria.fr/comprendreagir/technologies-et-sante-quels-compromis-entre-ethique-environnement-et-climat-actions-et-questionnements-basees-sur-lexperience-terrain/

Technologies et santé : Quels compromis entre éthique, environnement et climat ? Analyse réflexive et expérience de terrain

Date : 27 septembre 2021

3. Example CS Research Topics For The "Fading ICT" Scenario
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Offline-First Design[8] [9]

Designing Offline-First Web Apps

by **Alex Feyerke** · December 04, 2013

Published in Application Development, Mobile/Multidevice, Responsive Design

When it comes to building apps, we often assume our users are very much like us. We picture them with the latest devices, the most recent software, and the fastest connections. And while we may maintain a veritable zoo of older devices and browsers for testing, we spend most of our time building from the comfort of our modern, always-online desktop devices.

[8] https://alistapart.com/article/offline-first/

[9] https://aaltodoc.aalto.fi/items/653b4059-85f0-4a4e-a321-80783da1fe51

Designing for Slow Devices or Slow Connections[10] [11] [12]

URL	Size MB	C	Load time in seconds FIOS	Cable	LTE	3G	2G	Dial	Bad	😱
http://bellard.org	0.01	5	0.40	0.59	0.60	1.2	2.9	1.8	9.5	7.6
http://danluu.com	0.02	2	0.20	0.20	0.40	0.80	2.7	1.6	6.4	7.6
news.ycombinator.com	0.03	1	0.30	0.49	0.69	1.6	5.5	5.0	14	27
danluu.com	0.03	2	0.20	0.40	0.49	1.1	3.6	3.5	9.3	15
http://jvns.ca	0.14	7	0.49	0.69	1.2	2.9	10	19	29	108
jvns.ca	0.15	4	0.50	0.80	1.2	3.3	11	21	31	97
fgiesen.wordpress.com	0.37	12	1.0	1.1	1.4	5.0	16	66	68	FAIL
google.com	0.59	6	0.80	1.8	1.4	6.8	19	94	96	236
joelonsoftware.com	0.72	19	1.3	1.7	1.9	9.7	28	140	FAIL	FAIL
bing.com	1.3	12	1.4	2.9	3.3	11	43	134	FAIL	FAIL
reddit.com	1.3	26	7.5	6.9	7.0	20	58	179	210	FAIL
signalvnoise.com	2.1	7	2.0	3.5	3.7	16	47	173	218	FAIL
amazon.com	4.4	47	6.6	13	8.4	36	65	265	300	FAIL
steve-yegge.blogspot.com	9.7	19	2.2	3.6	3.3	12	36	206	188	FAIL
blog.codinghorror.com	23	24	6.5	15	9.5	83	235	FAIL	FAIL	FAIL

[10] https://danluu.com/slow-device/

[11] https://danluu.com/web-bloat/

[12] https://tonsky.me/blog/js-bloat/

Self-Imposing Limits In Advance

What kind of limit can we define/self-impose to fight the growth of digital cartography?

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Open/Extensible Systems Are Meant For Growth Scenarios That (Almost) Never Realize

- There are perfectly ad-hoc digital systems that have been running unchanged for more than 30 years (examples in nuclear power-plants)
- But the most versatile HW/SW object ever (the smartphone) has to be replaced every 2-5 years

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About "technological" objects in general:

- SW is expected to make things extensible/reusable/... but 10 years is already considered very long!
- 300-year-old Stradivarius violins are still usable

To Stay Within Limits We Might Need Closed/Shrinkable Systems

Closed (Ad-Hoc) Systems:

We could design digital systems from early precise specifications and a few *planned extensions*, not for unexpected extensions.

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Shrinkable: If you do not know what the future will be, plan for smaller (instead of bigger) systems. Hence design for shrinkability rather than extensibility.

Tentative Definitions of Shrinkability

(See slide 37)

Shrinkability is a software engineering and systems design principle that provides for future degrowth. It is a measure of the ability to reduce or reconfigure the functionalities if the resources available decrease, and the level of effort required to implement this functional reduction.

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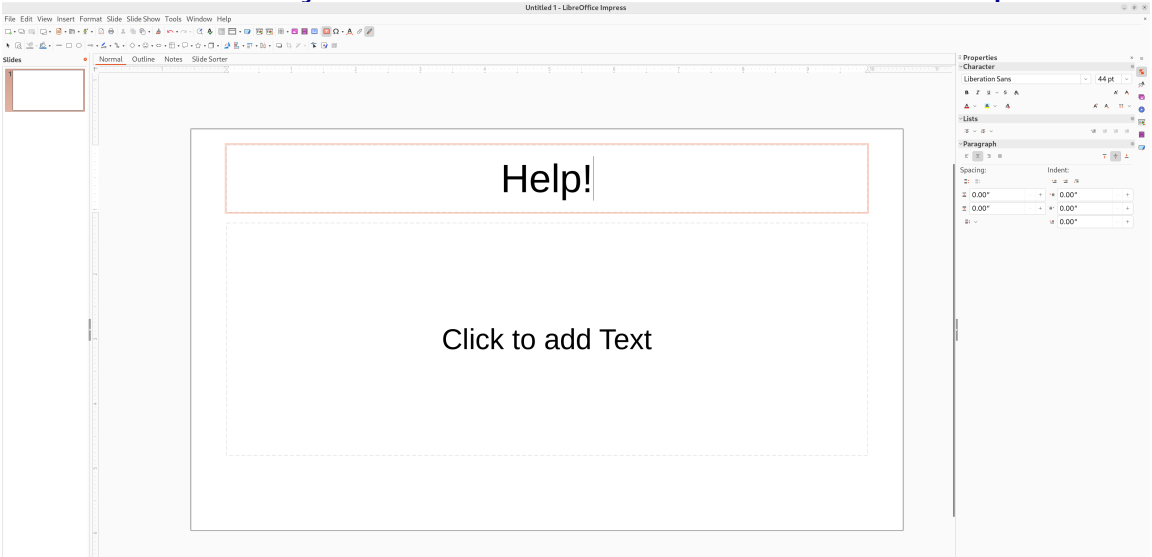
Software shrinkability encapsulates the software's innate ability to be simplified by removing features or capabilities, all without requiring an extensive reconstruction of its core architecture. Think of this as building with a "future-proof" mindset.

I Would Definitely Vote For A Shrinkable Libreoffice Impress



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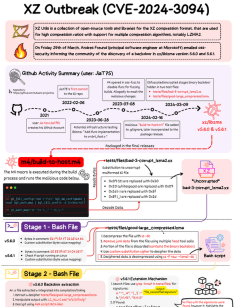
Why Dismantle Complex Digital Systems?

https://research.swtch.com/xz-timeline

https://www.editionsdivergences.com/livre/a-bout-de-flux

Recent `libxz` SW supply-chain attack



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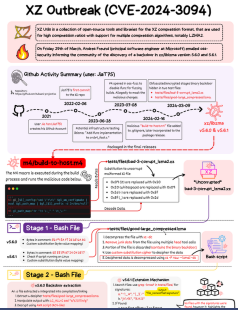
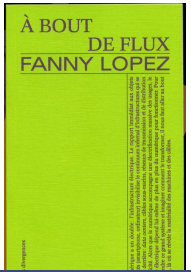


Digital world ⇄ Electrical infrastructure



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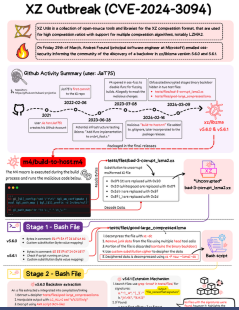

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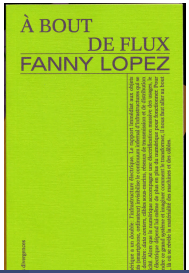
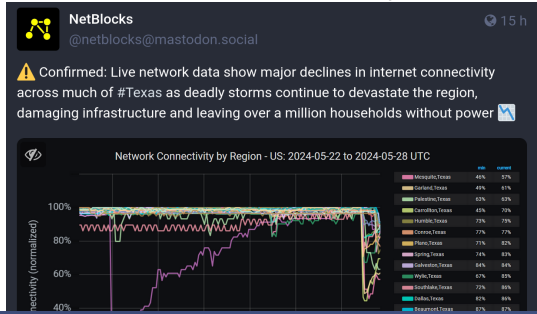


`@netblocks@mastodon.social`: *major declines in internet connectivity across much of Texas as deadly storms continue to devastate the region, damaging infrastructure and leaving over a million households without power*



How To Dismantle Complex (Digital) Systems?

Analysing the impact of removing one "component" somewhere, towards:

- — Less dependencies / coupling
- — More redundancy / technodiversity
- — Simpler versions of useful components
- — Non-optimal systems
- — Reduced dependency on ICT

Low-Tech? Right-Tech? Less Tech!

Take-Home Messages

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- Limiting ICT requires social and political changes, computer scientists/engineers are not particularly legitimate to drive them, but...
- Even if we don't agree on the need to reduce ICT, even if we don't agree on what to keep/remove, we should ask **do we even know how not to grow? Let us stop feeding the growth.**

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Computer Science Research for the "Fading ICT" Scenario

Starting event: at some point in time we stop manufacturing new HW
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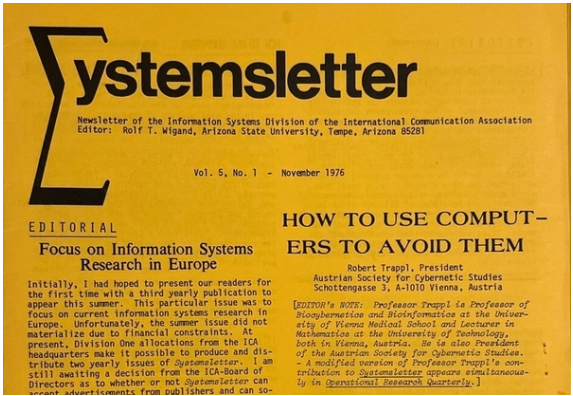
Collateral benefits:
— it would make the whole ICT infrastructure more robust
— IMHO it's more interesting than the "wait-for-a-bigger-machine" attitude

All Of This Is Quite Old! (1976)[13]



Systemsletter

Newsletter of the Information Systems Division of the International Communication Association
Editor: Rolf T. Wigand, Arizona State University, Tempe, Arizona 85281

Vol. 5, No. 1 - November 1976

EDITORIAL

Focus on Information Systems Research in Europe

Initially, I had hoped to present our readers for the first time with a third yearly publication to appear this summer. This particular issue was to focus on current information systems research in Europe. Unfortunately, the summer issue did not materialize due to financial constraints. At present, Division One allocations from the ICA headquarters make it possible to produce and distribute two yearly issues of *Systemsletter*. I am still awaiting a decision from the ICA-Board of Directors as to whether or not *Systemsletter* can accept advertisements from publishers and can so-

HOW TO USE COMPUTERS TO AVOID THEM

Robert Trappl, President
Austrian Society for Cybernetic Studies
Schottengasse 3, A-1010 Vienna, Austria

[*EDITOR's NOTE: Professor Trappl is Professor of Biocybernetics and Bioinformatics at the University of Vienna Medical School and Lecturer in Mathematics at the University of Technology, both in Vienna, Austria. He is also President of the Austrian Society for Cybernetic Studies. - A modified version of Professor Trappl's contribution to Systemsletter appears simultaneously in Operational Research Quarterly.*]

However, there is one significant difference between these two problems: contrary to the energy problem we can use information processing machines to reduce the necessity to use them. We should therefore concentrate our efforts upon using them to develop or improve strategies which help us deal with problems without the use of computers.

[13] https://uniqueatpenn.wordpress.com/2024/03/13/the-international-communication-association-and-the-history-of-communication-studies/

The End. Thank you.
Questions ?