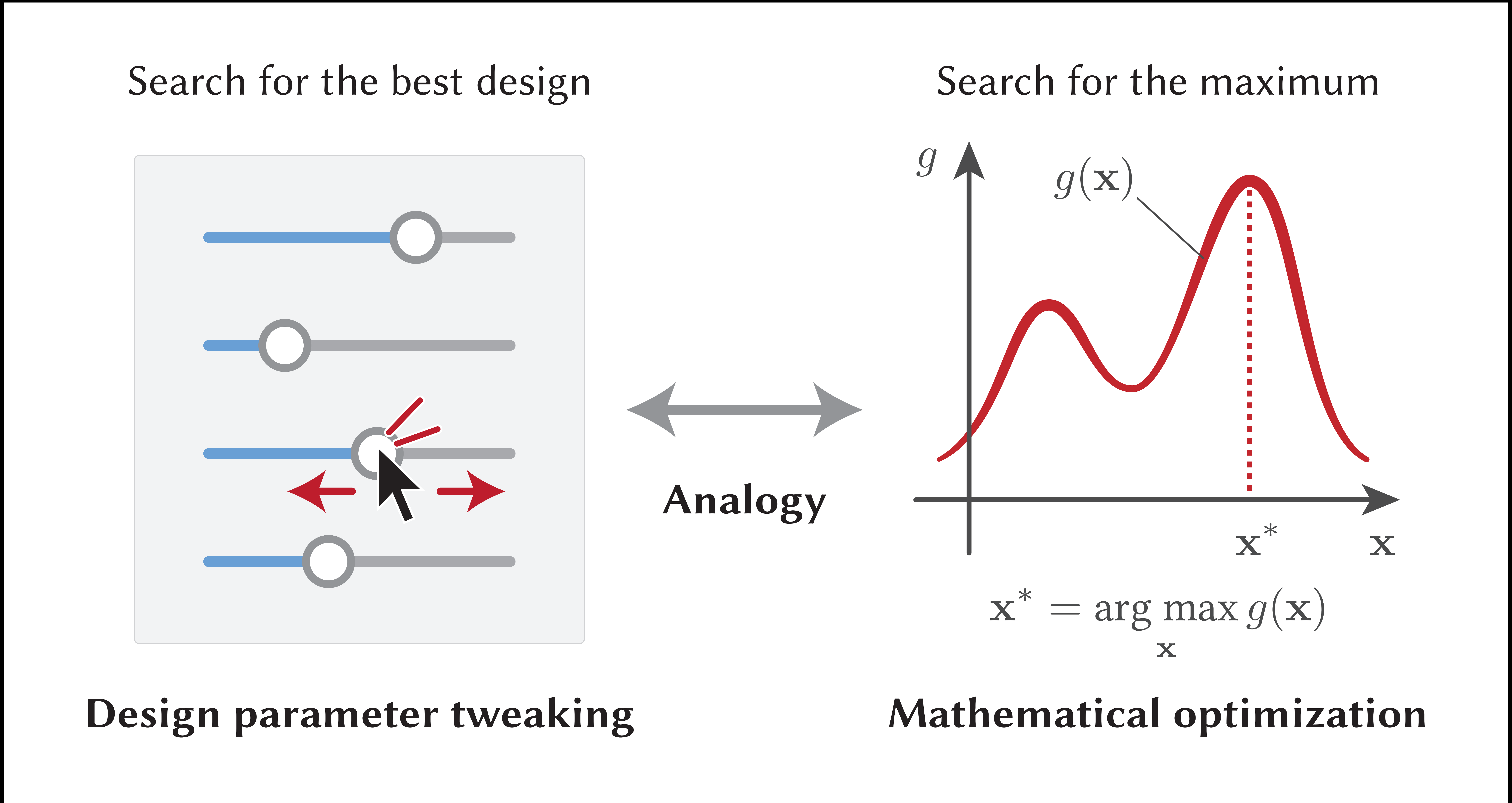
Introduction to Computational Design

Part 3: Summary and Discussion

Presenter: Yuki Koyama (AIST, Japan)

2021-05-12 | CHI 2021 Courses | Online



Computational design: a paradigm in which design problems are formulated as optimization problems and solved by computational techniques.

A Definition of "Computational Design"

A general definition:

Computational design is a paradigm in which design problems are formulated mathematically and solved by computational techniques.

A more focused (narrower) definition:

Computational design is a paradigm in which design problems are formulated as optimization problems and solved by computational techniques.

Computational Design Research

Approach:

- Formulate design processes that have been traditionally dependent on individual skills as mathematical optimization problems, and
- Support or augment design processes by devising new ways of utilizing computing power and mathematical tools

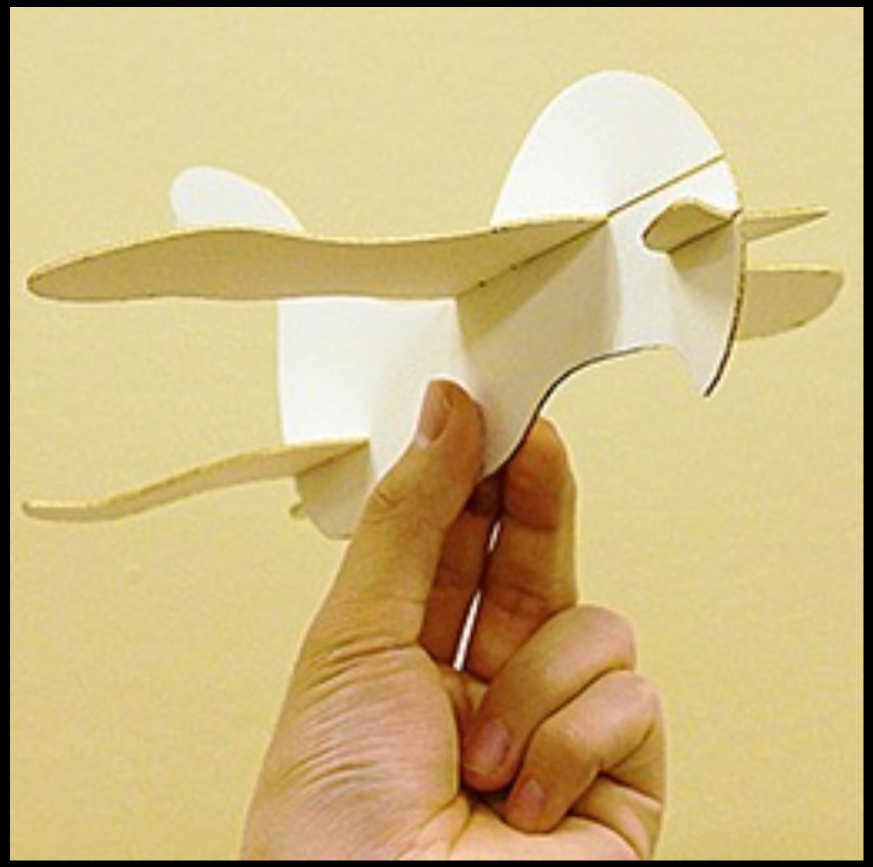
Goal:

- Enable efficient design workflow or sophisticated design outcomes that are impossible in traditional approaches relying purely on the human brain

[Recap]

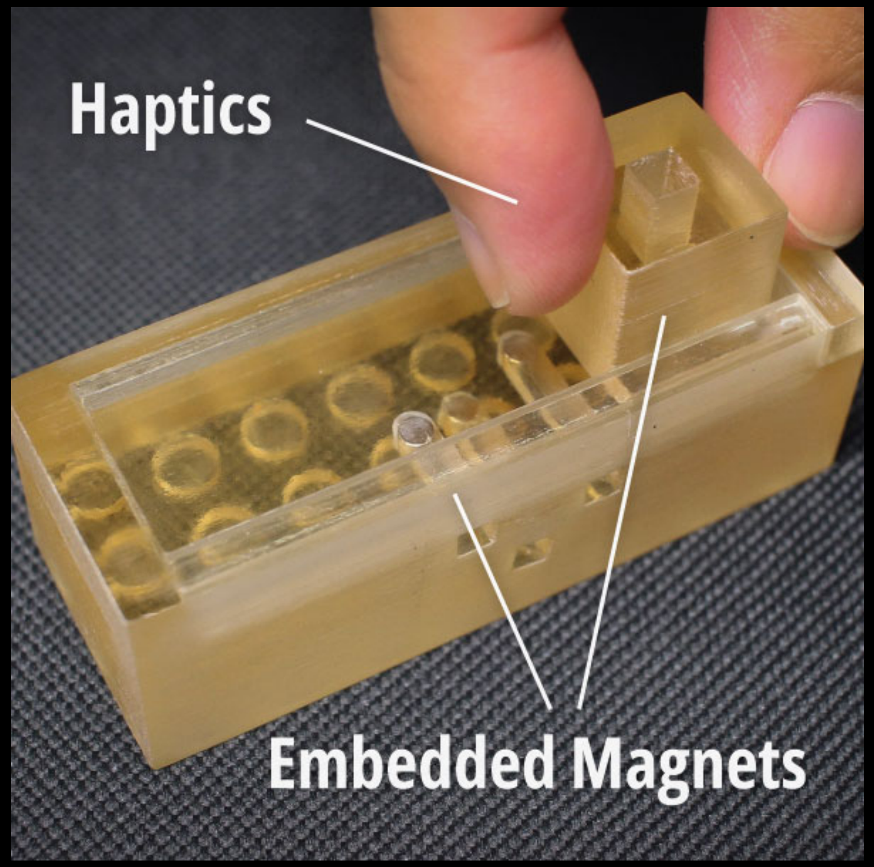
Computational design:

SIGGRAPH 2014



Fly-ability

CHI 2021



Haptics

Pacific Graphics 2016

Fly-ability

SIGGRAPH Asia 2015

Connect-ability

VRST 2017

Haptics

The design goal (objective) is the functionality of the designed object

Design Goals (Objectives)

[Recap]

Functionality

We can compute the “goodness” of a design by predictive simulation

Aesthetic preference

We cannot compute the “goodness” of a design as it is **perceptual**

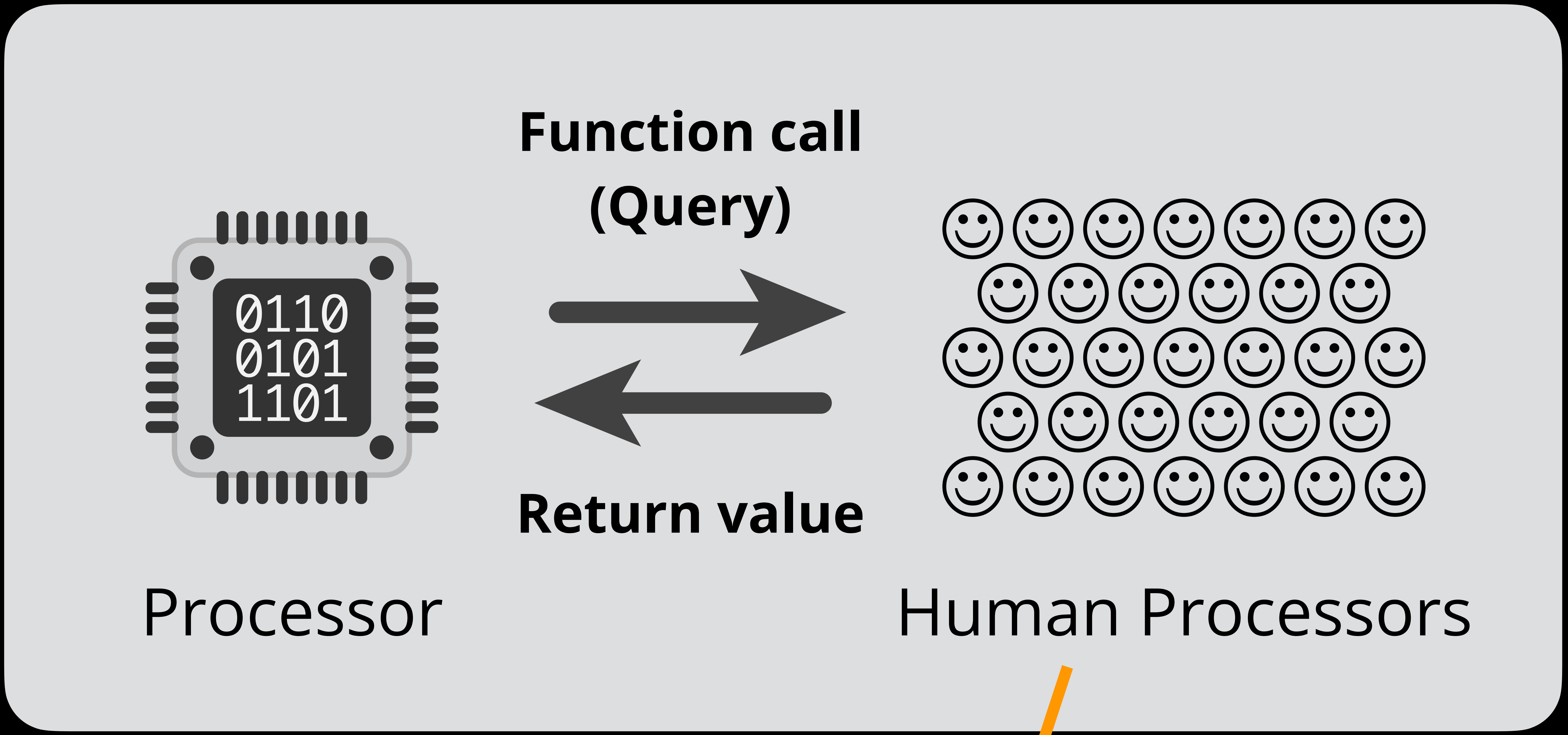
Human assessment is necessary

A Systematic Approach to Input Human Assessment

[Recap]

Human Computation:

“[...] *a paradigm for utilizing human processing power to solve problems that computers cannot yet solve.*” [von Ahn 05]



Either crowd workers or the single user

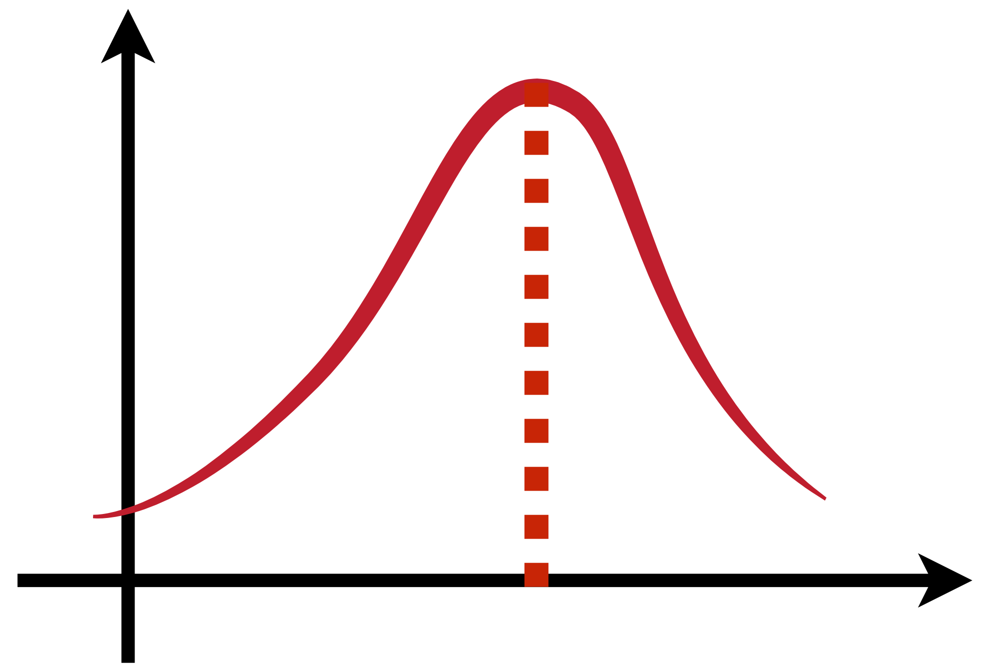
A. J. Quinn and B. B. Bederson. 2011. Human computation: a survey and taxonomy of a growing field. In Proc. CHI '11. 1403-1412.

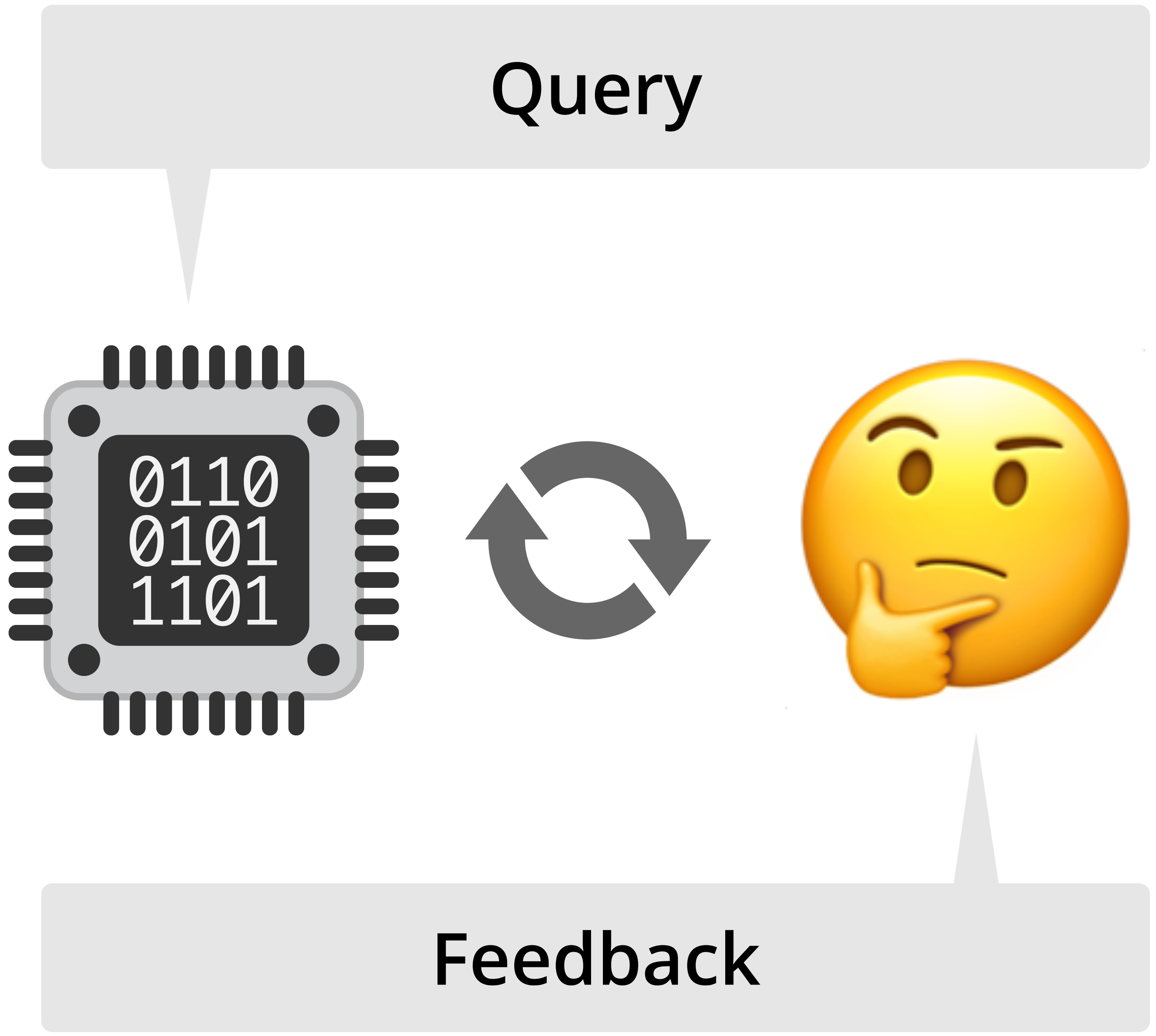
von Ahn, L. Human Computation. Doctoral Thesis. UMI Order Number: AAI3205378, CMU, (2005).

Human-in-the-Loop Optimization

[Recap]

"I don't know the objective function, but I want to find the maximizer..."





Iterative search process

Human-in-the-loop optimization is used for solving problems with **"subjective" objective functions** (e.g., preference)

Summary

- **Computational design** is a paradigm in which design problems are formulated as **mathematical optimization** and solved using **computational techniques**
  - **HCI topics**: Functional fabrication, haptics, user interface, visual design, etc.
- **Human-in-the-loop optimization** can be used for solving problems with **perceptual objective functions** (e.g., preference)
  - **Tight integration between algorithm design and interface design** would be the key to achieve **higher efficiency**

Discussion

Discussion: Exploratory Design

"Exploratory modeling is open-ended: the user begins the design process with ***an under-specified goal****, and the precise form of the final model is established through experimentation* [...]"

Jerry O. Talton, Daniel Gibson, Lingfeng Yang, Pat Hanrahan, and Vladlen Koltun. 2009. Exploratory modeling with collaborative design spaces. ACM Trans. Graph. 28, 5 (December 2009), 1–10. DOI:https://doi.org/10.1145/1618452.1618513

Discussion: Exploratory Design

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$$\mathbf{x}^* = \arg\max_{\mathbf{x} \in \mathcal{X}} \underbrace{f(\mathbf{x})}$$

The objective function is unknown at the beginning, and it can even change during the design process

Adaptive techniques (e.g., online machine learning) should be used

Jerry O. Talton, Daniel Gibson, Lingfeng Yang, Pat Hanrahan, and Vladlen Koltun. 2009. Exploratory modeling with collaborative design spaces. ACM Trans. Graph. 28, 5 (December 2009), 1–10. DOI:https://doi.org/10.1145/1618452.1618513

Discussion: "Optimization-in-the-Loop" Design Iteration

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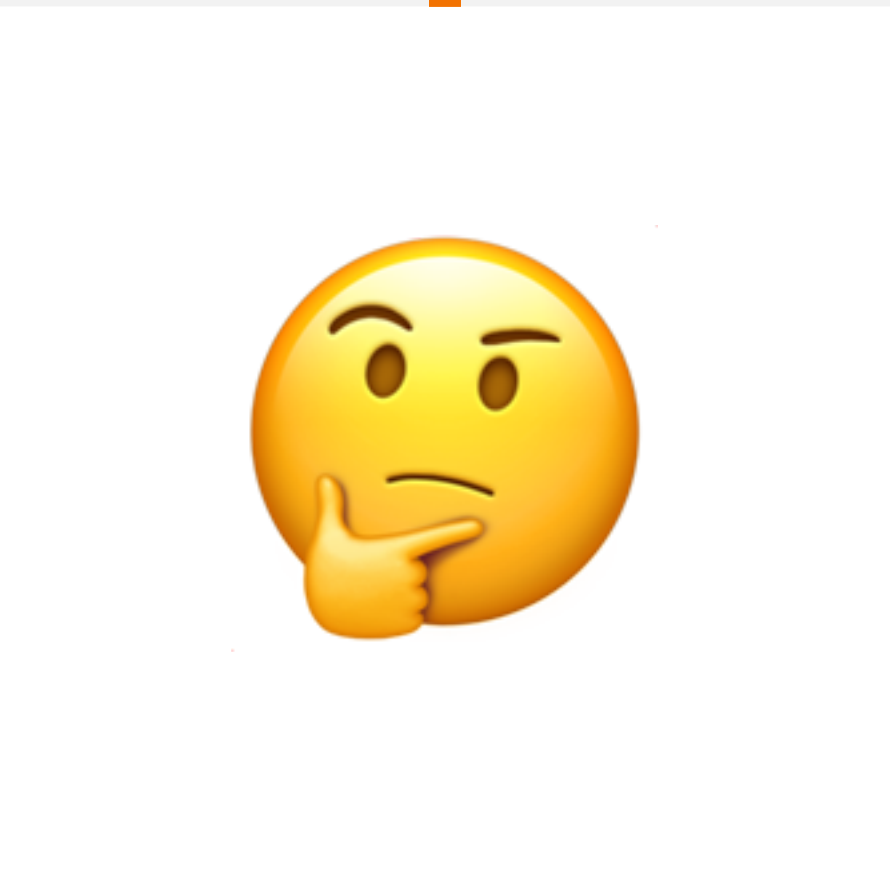
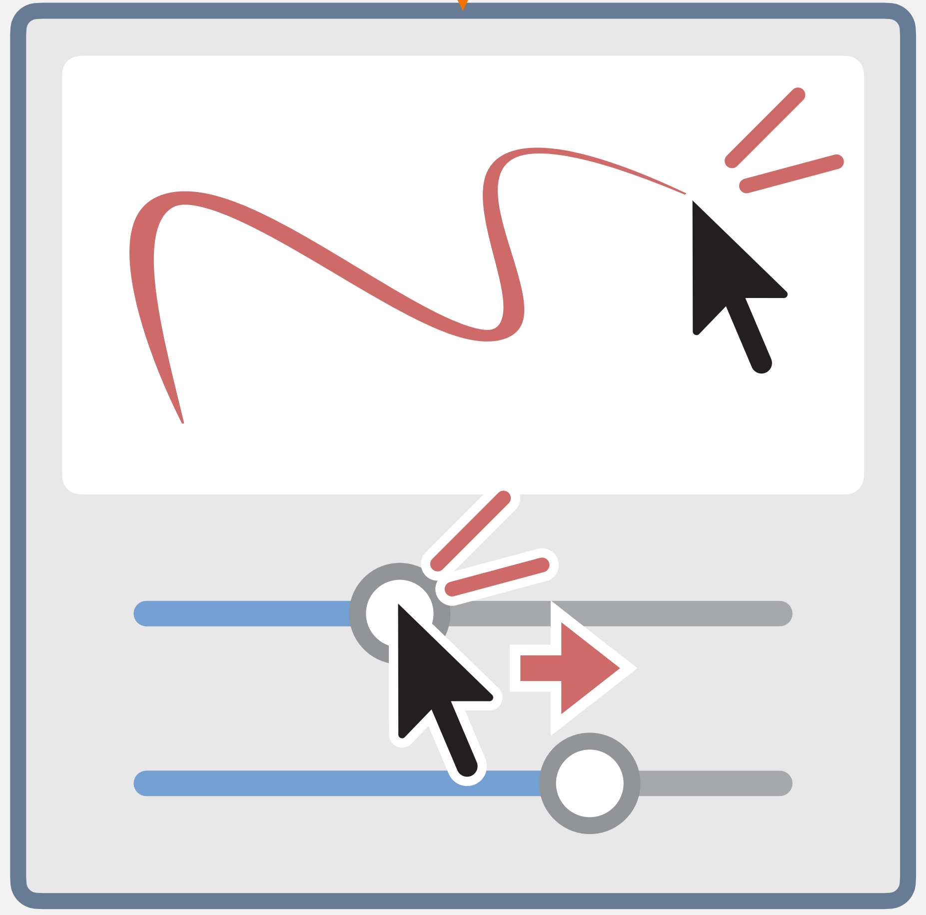


The designer decides
what to do next

Design iteration

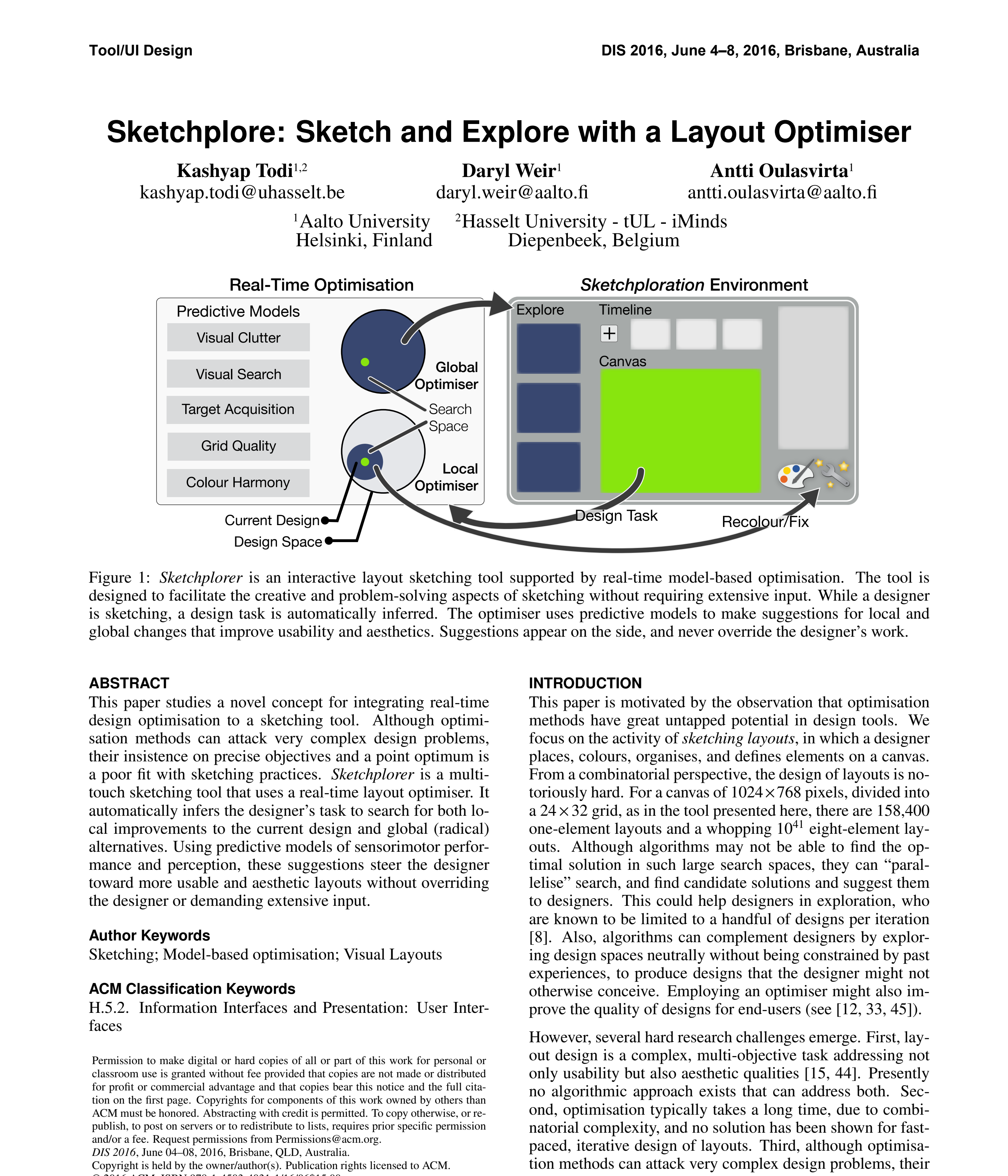


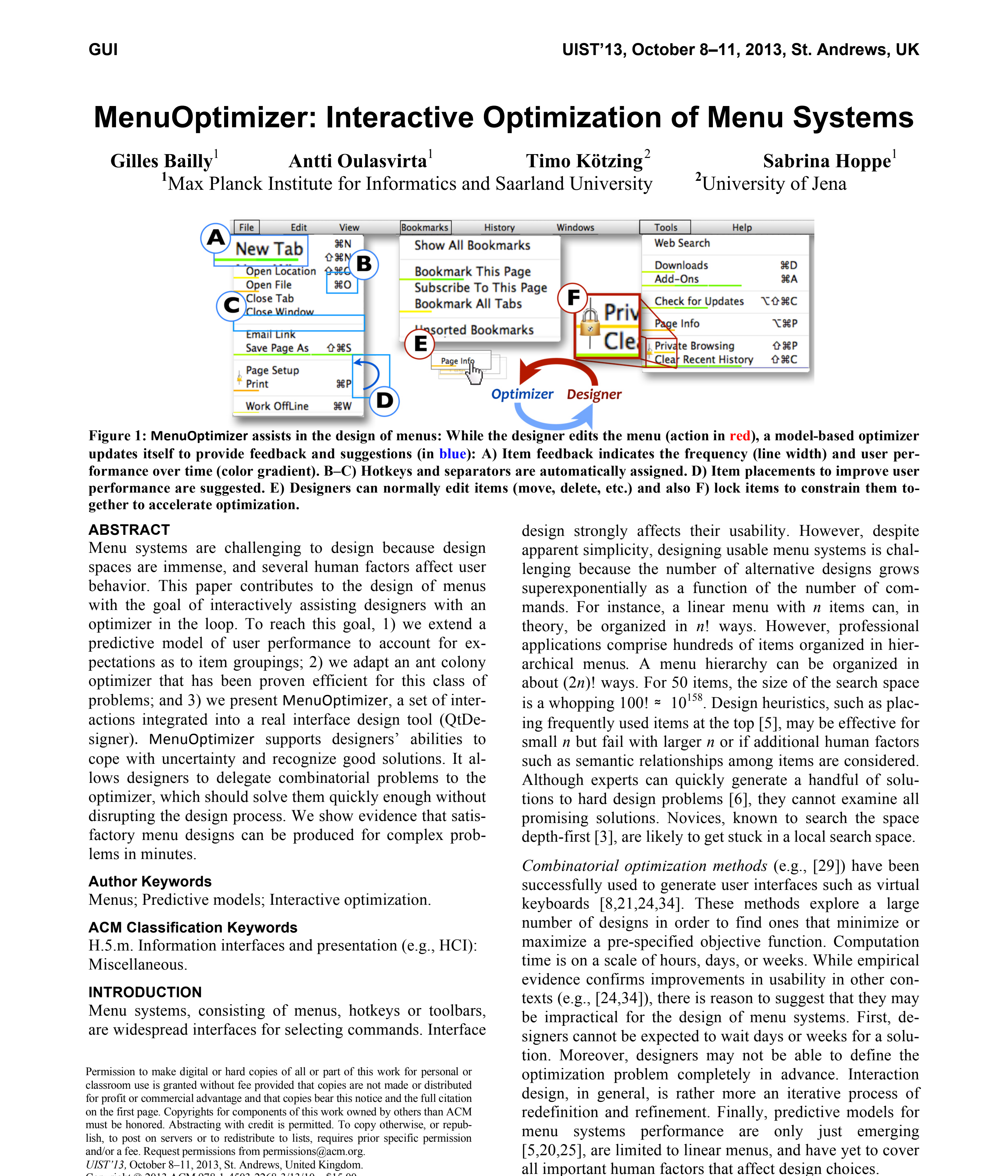
Manual
content edit

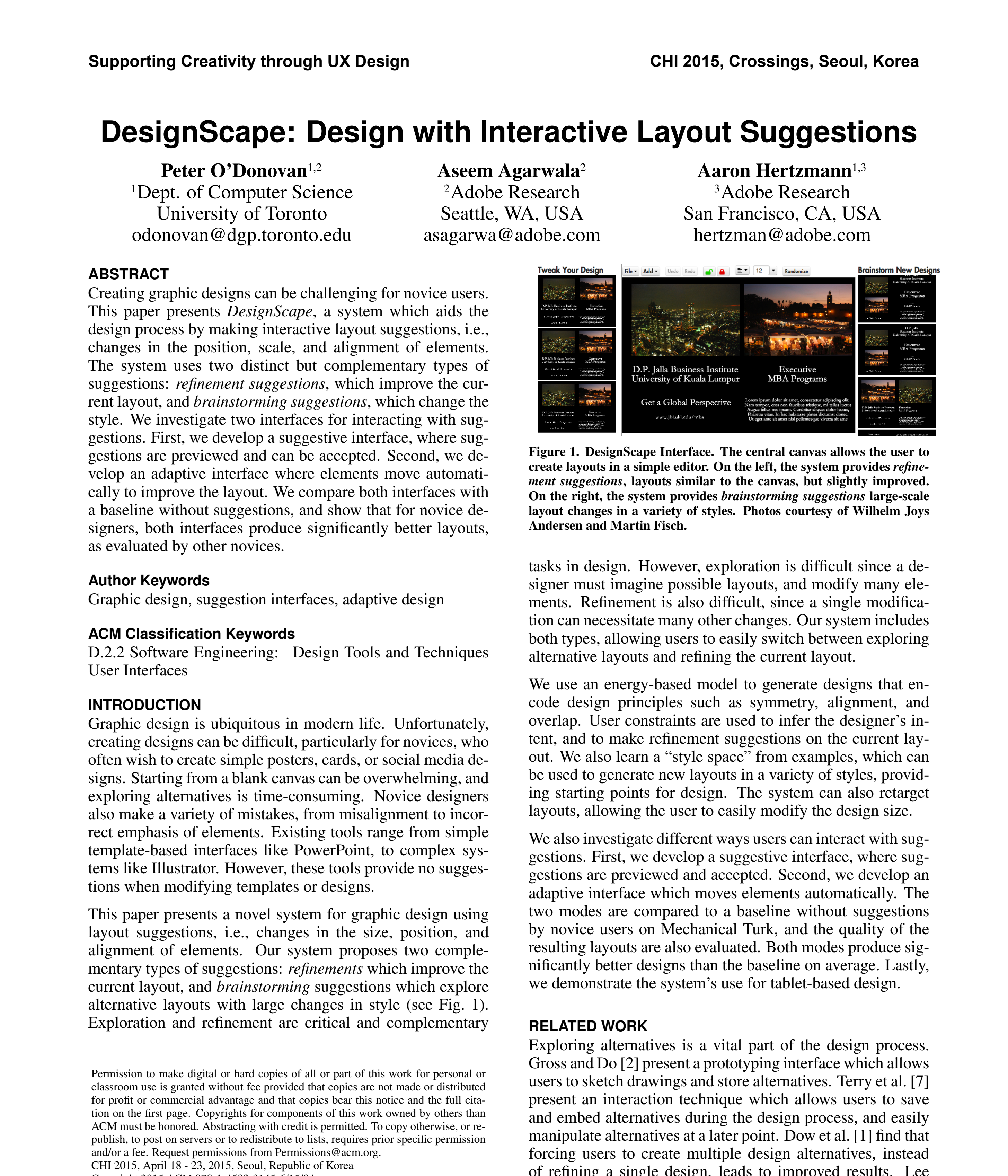
Automatic
optimization

Discussion: "Optimization-in-the-Loop" Design Iteration

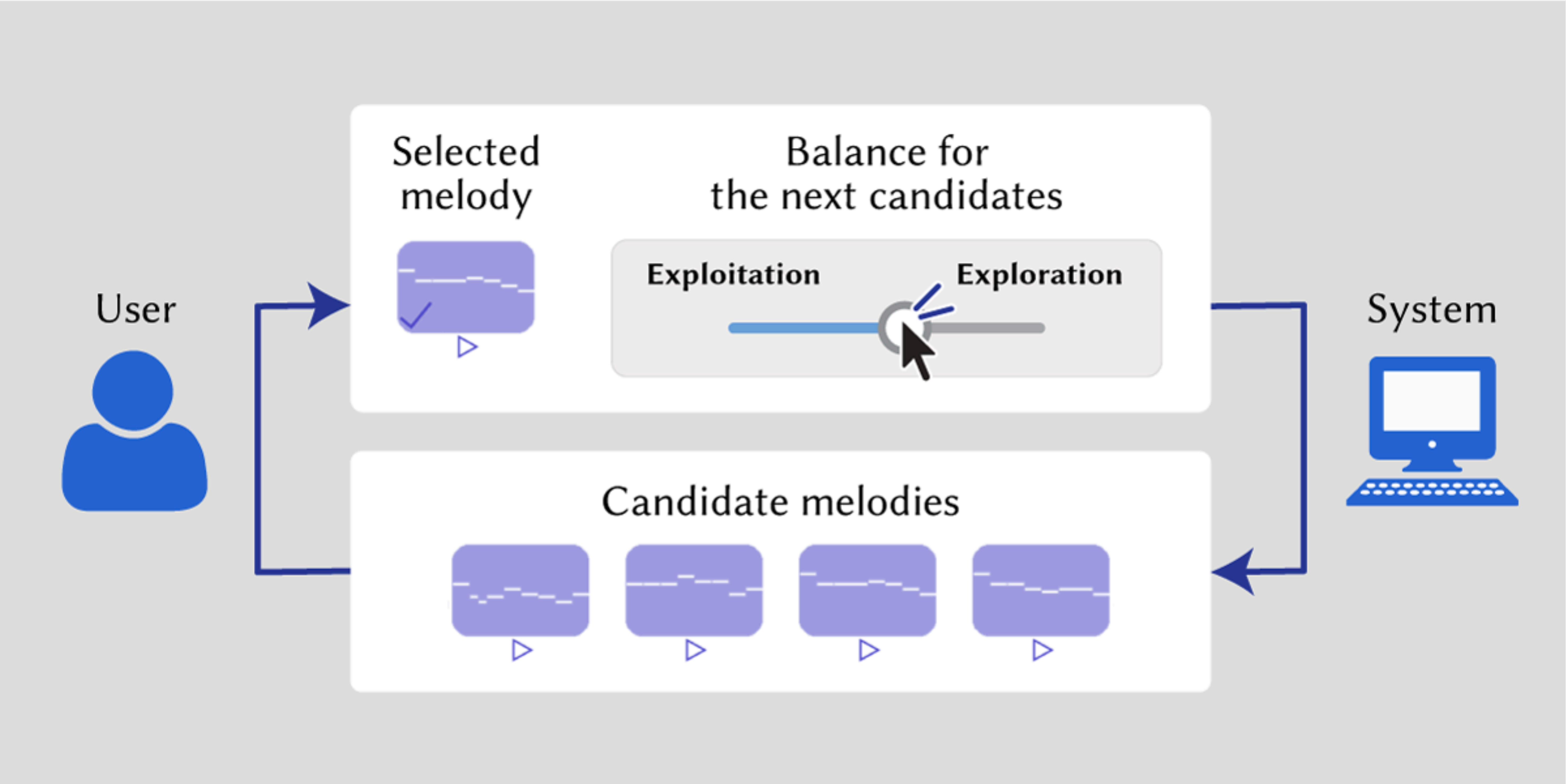
Sketchplore (DIS 2016)	MenuOptimizer (UIST 2013)	DesignScape (CHI 2015)







Discussion: UX of Human-in-the-Loop Optimization



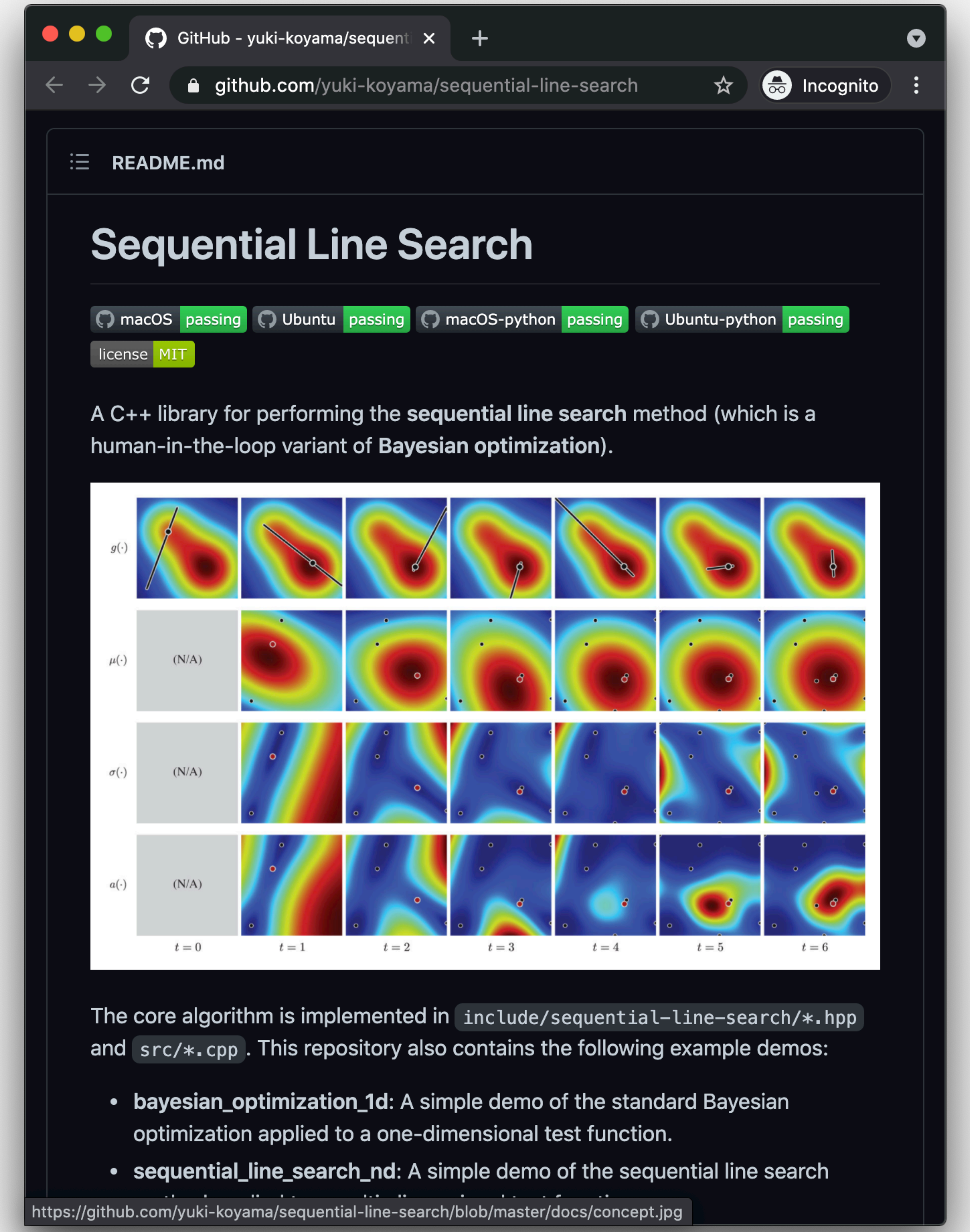
[Zhou+, IUI 2021]
This paper investigates how the user feels when the variation of the candidates (exploration vs. exploitation) can be manually controlled

C.f., Human-AI collaboration

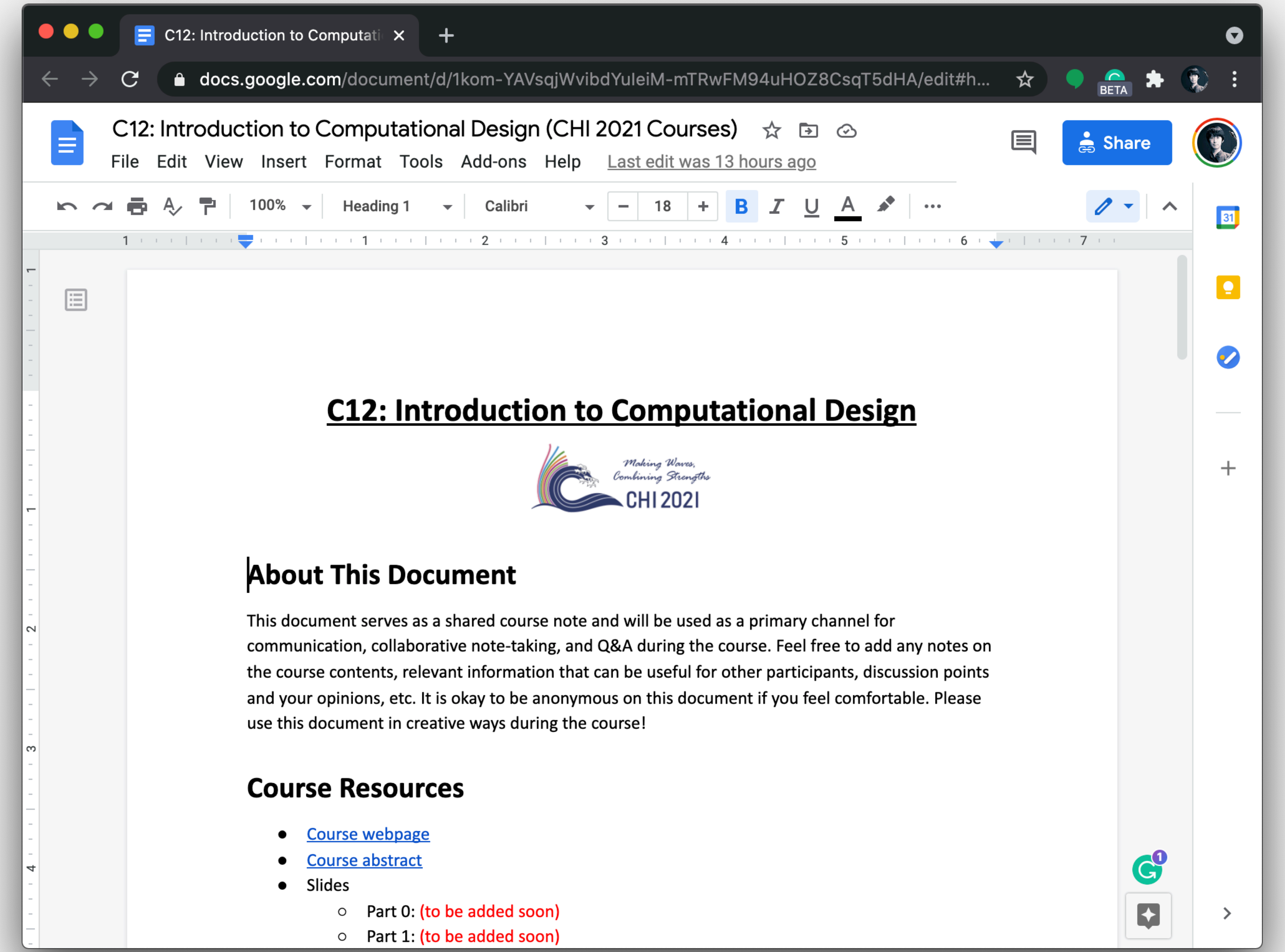
Yijun Zhou, Yuki Koyama, Masataka Goto, and Takeo Igarashi. 2021. Interactive Exploration-Exploitation Balancing for Generative Melody Composition. In Proceedings of the 26th International Conference on Intelligent User Interfaces (IUI '21), pp.43–47. DOI:https://doi.org/10.1145/3397481.3450663

C++ Implementation & Python Bindings Available on GitHub

- https://github.com/yuki-koyama/mathtoolbox
  - Bayesian optimization (BO)
- https://github.com/yuki-koyama/sequential-line-search
  - Preferential Bayesian optimization (PBO)
  - Sequential line search
- https://github.com/yuki-koyama/sequential-gallery
  - Sequential gallery



Questions / Comments



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