SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

User Interface Design & Implementation

Introduction

Week 1 – Lecture 1

January – May Term, 2020

People

- Lecturer: Peng SONG
  - Assistant Professor
  - Research area: Computer Graphics, Computational Design
  - Research group: https://sutd-cgl.github.io/
  - Contact: peng_song@sutd.edu.sg

- Lecturer: Leong Hwee TEO
  - Adjunct Assistant Professor
  - Senior Member of Technical Staff, DSO National Laboratories
  - Research area: HCI, Cognitive Modelling
  - Contact: leonghwee_teo@sutd.edu.sg teo@alumni.cmu.edu

People

- Assistant: Junhua LIU
  - PhD Candidate (ISTD)
  - Research area:
    Artificial Intelligence
    Sequence modelling and recommendation
  - Founder & CEO of
    EdTech startup Qlassroom (www.qlassroom.co) and
    QuanTech startup SFT (www.supremacyfuture.com)
  - Contact: junhua_liu@mymail.sutd.edu.sg

People

- Enrolled Students (**55** in total)
  - **45** ISTD + **6** ESD + **4** EPD
  - **46** Senior + **5** Junior + **4** Freshman

- Auditing Students (~**6** in total)

Overview

- Course orientation
- What is user interface?
- What is human computer interaction?
- What is user interface design about?
- Why hard to design user interfaces?
- Learning outcome from this course

General Information

- Time and location
  - Class time:
    - Monday 13:30 - 15:00
    - Tuesday 18:00 - 19:30
    - Thursday 11:00 - 13:00
  - Location: 1.409 TT7 & 1.410 TT8
- 12 Credits
- eDimension
  - Calendar, slides, submissions etc.

Have a break of **10 minutes** at the middle of each lecture class

Urgent Precautionary Measures - novel Coronavirus

	Group 1	Group 2	Group 3	Group 4
Condition	· Instructor did not go to China. · Students did not go to China.	· Instructor went to China and is under quarantine. · Students did not go to China.	· Instructor did not go to China. · Small group of students went to China and is under quarantine.	· Instructor did not go to China. · 50% or more of the students went to China and are under quarantine.
Delivery of Class	· Lessons will be conducted as per normal based on the timetable.	· E-learning lessons will be conducted during the quarantine period of the instructor. · Lessons will resume based on timetable when the quarantine period of the instructor ends.	· Lessons will be conducted as per normal based on the timetable. · Faculty will work with quarantined students for online learning lesson. · Affected quarantined students will take online lessons.	· E-learning lessons will be conducted during the quarantine period of the faculty. · Lessons will resume based on timetable when the quarantine period students end.

For students that are placed on Leave of Absence (LOA):

- All **course material** (i.e., slides) will be on eDimension
- **Online lectures** in the format of recorded videos will be on eDimension
- **Contact** instructors and the TA if you have questions about missing lectures

Course Orientation

- Structure
  - Week 1-6: concepts, principles, guidelines, methodology, evaluation…
  - Week 8-13: design studio
- 1 term-long design project
  - Presentation and report at mid-term
  - Presentation, report, and prototype at end-term
- 1 written exam (end-term)
  - Time: 29 Apr 2020 (Wed), 9.00am – 11.00am

Course Orientation

	Monday (13:30 - 15:00)	**Tuesday** (18:00 - 19:30)	**Thursday** (11:00 - 13:00)
Week 1 (27 Jan)			Introduction
Week 2 (3 Feb)	User in UI Design	UI Design Principles	Usability
Week 3 (10 Feb)	UI Design Process	Interaction Style I: Direct Manipulation	Interaction Style II: Menus and Forms
Week 4 (17 Feb)	UI Design Methods	UI Evaluation	*Project overview, team up, scoping*
Week 5 (24 Feb)	UI Prototyping	Visual Structure	*Project - scoping*
Week 6 (02 Mar)	Interaction Devices	**Mid-term Presentation**	**Mid-term Presentation**
Week 7 (09 Mar)	Recess Week		
Week 8 (16 Mar)	*Project*	Guest Lecture	*Project (Team Presentation)*
Week 9 (23 Mar)	*Project*	Guest Lecture	*Project (Team Presentation)*
Week 10 (30 Mar)	*Project*	*Project*	*Project (Team Presentation)*
Week 11 (6 Apr)	*Project*	*Project*	*Project (Team Presentation)*
Week 12 (13 Apr)	*Project*	*Project*	*Course Q&A*
Week 13 (20 Apr)	**End-term Presentation**	**End-term Presentation**	**End-term Presentation**
Week 14 (27 Apr)	Final Exam Week		

A Lectures

A *Projects*

A **Mid- or end-term presentations**

By Peng Song

By Leong Hwee Teo

By Leong Hwee Teo & Peng Song

By Guest Speakers

Course Topics

Part I: Basics
- The User in UI Design
- Guidelines, Principles, and Theories
- Usability of Interactive Systems

Part II: Interaction Styles
- Direct Manipulations
- Menu selection, Form fill in, and Dialog boxes

Part III: Development Process
- Managing Design Processes
- UI Design Methods
- Evaluating Interface Designs

Part IV: Interface Implementation
- UI Prototyping
- UI Visual Structure
- Interaction Input & Output Devices

	Monday (13:30 - 15:00)	**Tuesday** (18:00 - 19:30)	**Thursday** (11:00 - 13:00)
Week 1 (27 Jan)			Introduction
Week 2 (3 Feb)	User in UI Design	UI Design Principles	Usability
Week 3 (10 Feb)	UI Design Process	Interaction Style I: Direct Manipulation	Interaction Style II: Menus and Forms
Week 4 (17 Feb)	UI Design Methods	UI Evaluation	*Project overview, team up, scoping*
Week 5 (24 Feb)	UI Prototyping	Visual Structure	*Project - scoping*
Week 6 (02 Mar)	Interaction Devices	**Mid-term Presentation**	**Mid-term Presentation**
Week 7 (09 Mar)	Recess Week		
Week 8 (16 Mar)	*Project*	Guest Lecture	*Project (Team Presentation)*
Week 9 (23 Mar)	*Project*	Guest Lecture	*Project (Team Presentation)*
Week 10 (30 Mar)	*Project*	*Project*	*Project (Team Presentation)*
Week 11 (6 Apr)	*Project*	*Project*	*Project (Team Presentation)*
Week 12 (13 Apr)	*Project*	*Project*	*Course Q&A*
Week 13 (20 Apr)	**End-term Presentation**	**End-term Presentation**	**End-term Presentation**
Week 14 (27 Apr)	Final Exam Week		

Course Project

Project overview, team up
- **K** students per team (**K** = 4, 5, 6)
- Form a team before **Feb 17th** (Mon) and **inform TA**
- Otherwise, TA will form a team for you

Project scoping
- Discuss and help each team to scope the project

Mid-term presentation and report
- Task, design method, and implementation plan

Design Studio
- Work on the project on Monday/Tuesday
- Weekly progress presentation on Thursday

End-term presentation and report
- UI design journey, rationale, and evaluation
- Submit UI demos

	Monday (13:30 - 15:00)	**Tuesday** (18:00 - 19:30)	**Thursday** (11:00 - 13:00)
Week 1 (27 Jan)			Introduction
Week 2 (3 Feb)	User in UI Design	UI Design Principles	Usability
Week 3 (10 Feb)	UI Design Process	Interaction Style I: Direct Manipulation	Interaction Style II: Menus and Forms
Week 4 (17 Feb)	UI Design Methods	UI Evaluation	*Project overview, team up, scoping*
Week 5 (24 Feb)	UI Prototyping	Visual Structure	*Project - scoping*
Week 6 (02 Mar)	Interaction Devices	**Mid-term Presentation**	**Mid-term Presentation**
Week 7 (09 Mar)	Recess Week		
Week 8 (16 Mar)	*Project*	Guest Lecture	*Project (Team Presentation)*
Week 9 (23 Mar)	*Project*	Guest Lecture	*Project (Team Presentation)*
Week 10 (30 Mar)	*Project*	*Project*	*Project (Team Presentation)*
Week 11 (6 Apr)	*Project*	*Project*	*Project (Team Presentation)*
Week 12 (13 Apr)	*Project*	*Project*	*Course Q&A*
Week 13 (20 Apr)	**End-term Presentation**	**End-term Presentation**	**End-term Presentation**
Week 14 (27 Apr)	Final Exam Week		

Course Assessment

Mid-term presentation and report Presentation Report	**20%** 10% 10%	Grade based on *team* performance
Final presentation, report, and prototype Presentation Report UI prototype	**40%** 15% 15% 10%	Grade based on *team* performance
Class Participation In-class activity, discussion	**10%** 10%	Grade based on *individual* performance
Final exam	**30%**	Grade based on *individual* performance

Course Assessment: Enrolled Students

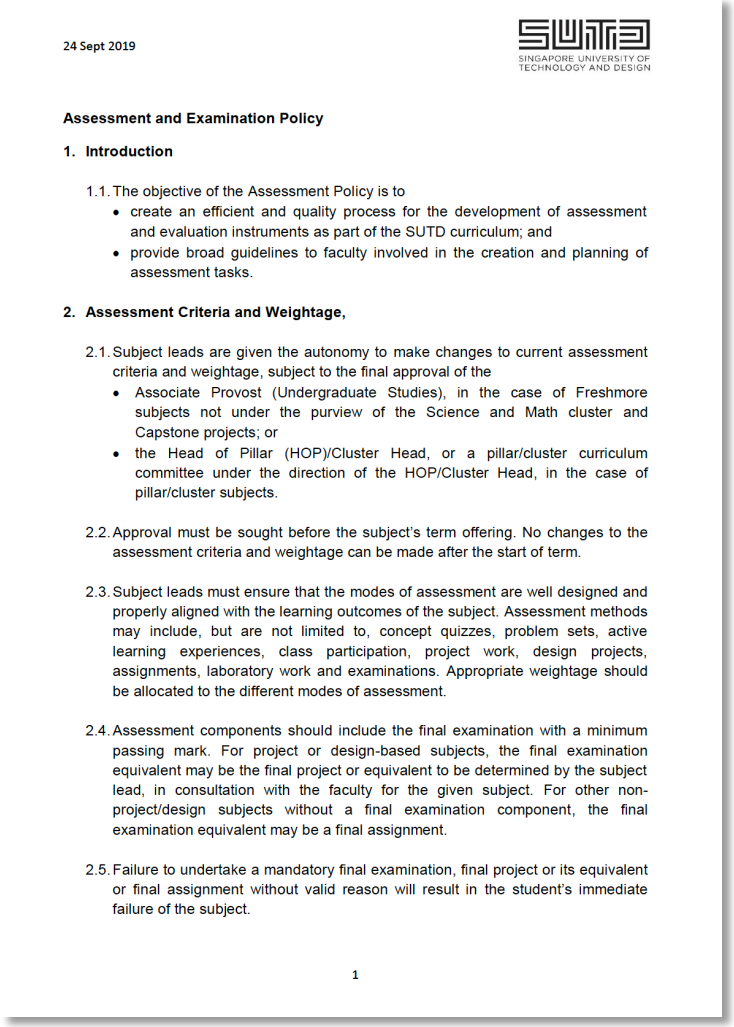
2.5 Failure to undertake a mandatory final examination, final project or its equivalent or final assignment without valid reason will result in the student's immediate failure of the subject.

3.1 Submission deadlines of final projects, final assignments, term papers or presentations shall not fall any later than the Monday of Week 14.

4.5 Students who require an **alternative final examination** date due to reasons other than scheduling conflict will need to seek the approval through MyPortal….Requests for alternative arrangements are to be made at least one month prior to the examination.

This course will have only **one** make-up exam opportunity!

Assessment and Examination Policy



24 Sept 2019

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

Assessment and Examination Policy

1. Introduction

1.1. The objective of the Assessment Policy is to
- create an efficient and quality process for the development of assessment and evaluation instruments as part of the SUTD curriculum; and
- provide broad guidelines to faculty involved in the creation and planning of assessment tasks.

2. Assessment Criteria and Weightage,

2.1. Subject leads are given the autonomy to make changes to current assessment criteria and weightage, subject to the final approval of the
- Associate Provost (Undergraduate Studies), in the case of Freshmore subjects not under the purview of the Science and Math cluster and Capstone projects; or
- the Head of Pillar (HOP)/Cluster Head, or a pillar/cluster curriculum committee under the direction of the HOP/Cluster Head, in the case of pillar/cluster subjects.

2.2. Approval must be sought before the subject's term offering. No changes to the assessment criteria and weightage can be made after the start of term.

2.3. Subject leads must ensure that the modes of assessment are well designed and properly aligned with the learning outcomes of the subject. Assessment methods may include, but are not limited to, concept quizzes, problem sets, active learning experiences, class participation, project work, design projects, assignments, laboratory work and examinations. Appropriate weightage should be allocated to the different modes of assessment.

2.4. Assessment components should include the final examination with a minimum passing mark. For project or design-based subjects, the final examination equivalent may be the final project or equivalent to be determined by the subject lead, in consultation with the faculty for the given subject. For other non-project/design subjects without a final examination component, the final examination equivalent may be a final assignment.

2.5. Failure to undertake a mandatory final examination, final project or its equivalent or final assignment without valid reason will result in the student's immediate failure of the subject.

1

Course Assessment: Auditing Students

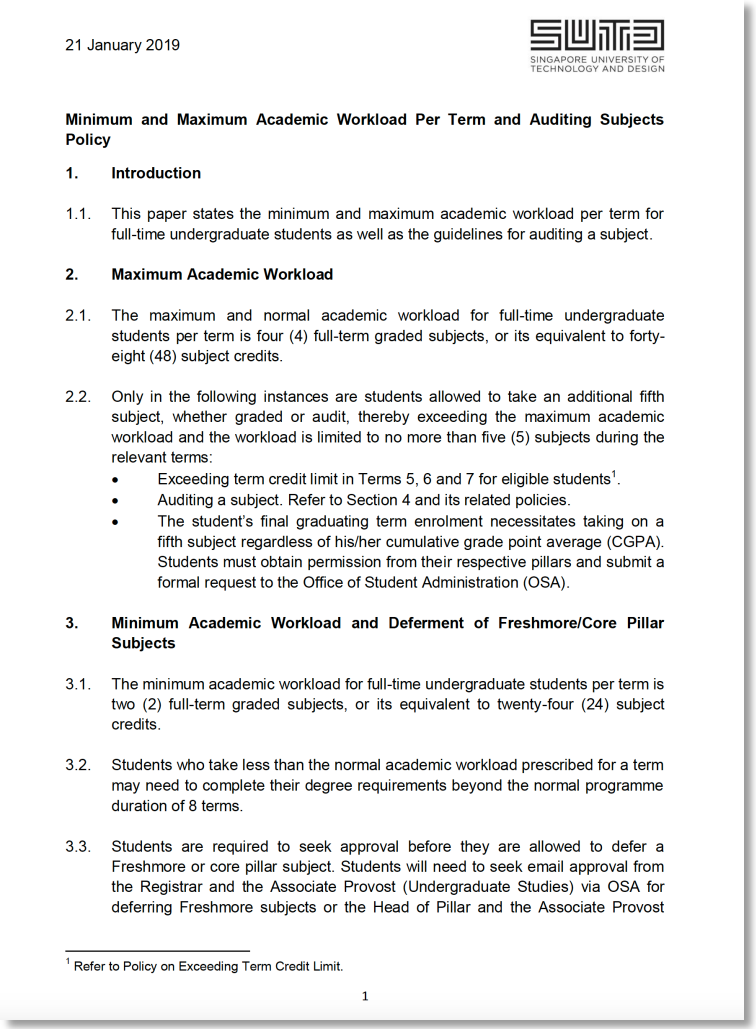
4.1 Auditing a subject allows the student to attend class without earning a letter grade or credits. As such, audit subjects do not fulfill degree or minor requirements but are typically taken out of interest or self-enrichment.

4.5 …The Faculty has the final say on whether to grant permission (or not) to audit requests and at the end of the term, the Faculty will decide if the student has participated sufficiently for the audit grade.

4.7 After receiving the necessary approvals and information, students can then approach the OSA to register for the audit subject.

4.8 The subject will appear on the academic transcript with the non-letter grade "AU" upon successful audit.

Minimum and Maximum Academic Workload Per Term and Auditing Subjects Policy



21 January 2019

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

Minimum and Maximum Academic Workload Per Term and Auditing Subjects Policy

1. Introduction

1.1. This paper states the minimum and maximum academic workload per term for full-time undergraduate students as well as the guidelines for auditing a subject.

2. Maximum Academic Workload

2.1. The maximum and normal academic workload for full-time undergraduate students per term is four (4) full-term graded subjects, or its equivalent to forty-eight (48) subject credits.

2.2. Only in the following instances are students allowed to take an additional fifth subject, whether graded or audit, thereby exceeding the maximum academic workload and the workload is limited to no more than five (5) subjects during the relevant terms:

- Exceeding term credit limit in Terms 5, 6 and 7 for eligible students[1].
- Auditing a subject. Refer to Section 4 and its related policies.
- The student's final graduating term enrolment necessitates taking on a fifth subject regardless of his/her cumulative grade point average (CGPA). Students must obtain permission from their respective pillars and submit a formal request to the Office of Student Administration (OSA).

3. Minimum Academic Workload and Deferment of Freshmore/Core Pillar Subjects

3.1. The minimum academic workload for full-time undergraduate students per term is two (2) full-term graded subjects, or its equivalent to twenty-four (24) subject credits.

3.2. Students who take less than the normal academic workload prescribed for a term may need to complete their degree requirements beyond the normal programme duration of 8 terms.

3.3. Students are required to seek approval before they are allowed to defer a Freshmore or core pillar subject. Students will need to seek email approval from the Registrar and the Associate Provost (Undergraduate Studies) via OSA for deferring Freshmore subjects or the Head of Pillar and the Associate Provost

[1] Refer to Policy on Exceeding Term Credit Limit.

1

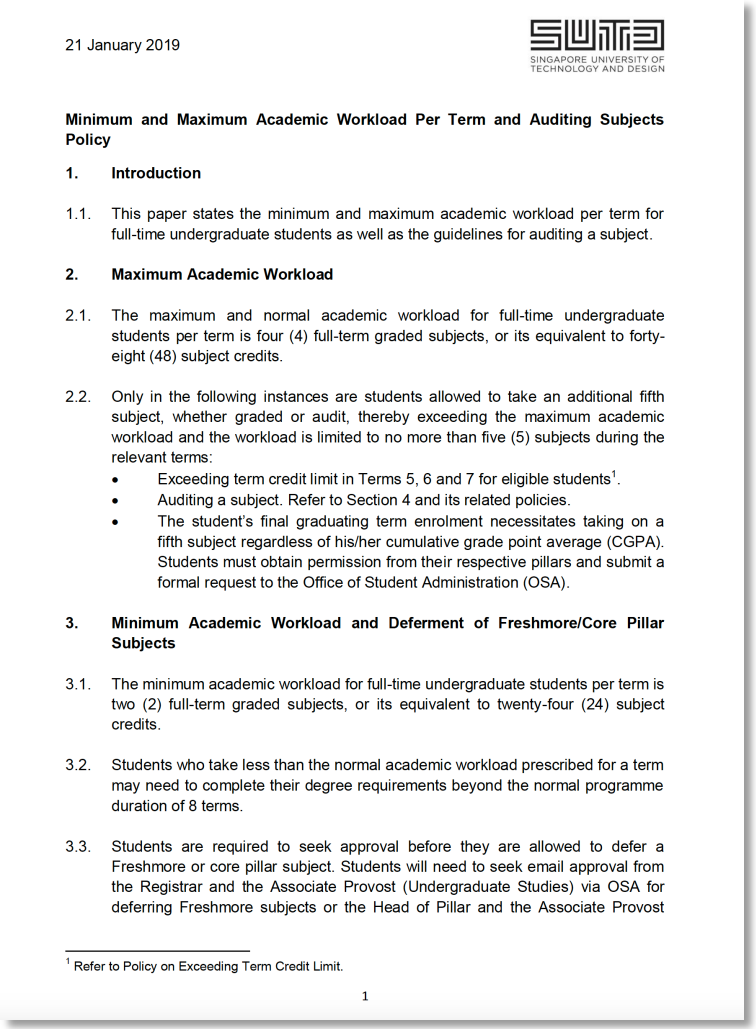
Course Assessment: Auditing Students

4.1 Auditing a subject allows the student to attend class without earning a letter grade or credits. As such, audit subjects do not fulfill degree or minor requirements but are typically taken out of interest or self-enrichment.

4.5 …The Faculty has the final say on whether to grant permission (or not) to audit requests and at the end of the term, the Faculty will decide if the student has participated sufficiently for the audit grade.

- Auditing students are **not required** to take the exam and do the course project
- The first half of the course (i.e., lectures) are mostly useful for auditing students
- Auditing students will be **assessed** based on the lectures during week 1-6.

Minimum and Maximum Academic Workload Per Term and Auditing Subjects Policy



21 January 2019

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

Minimum and Maximum Academic Workload Per Term and Auditing Subjects Policy

1. Introduction

1.1. This paper states the minimum and maximum academic workload per term for full-time undergraduate students as well as the guidelines for auditing a subject.

2. Maximum Academic Workload

2.1. The maximum and normal academic workload for full-time undergraduate students per term is four (4) full-term graded subjects, or its equivalent to forty-eight (48) subject credits.

2.2. Only in the following instances are students allowed to take an additional fifth subject, whether graded or audit, thereby exceeding the maximum academic workload and the workload is limited to no more than five (5) subjects during the relevant terms:

- Exceeding term credit limit in Terms 5, 6 and 7 for eligible students[1].
- Auditing a subject. Refer to Section 4 and its related policies.
- The student's final graduating term enrolment necessitates taking on a fifth subject regardless of his/her cumulative grade point average (CGPA). Students must obtain permission from their respective pillars and submit a formal request to the Office of Student Administration (OSA).

3. Minimum Academic Workload and Deferment of Freshmore/Core Pillar Subjects

3.1. The minimum academic workload for full-time undergraduate students per term is two (2) full-term graded subjects, or its equivalent to twenty-four (24) subject credits.

3.2. Students who take less than the normal academic workload prescribed for a term may need to complete their degree requirements beyond the normal programme duration of 8 terms.

3.3. Students are required to seek approval before they are allowed to defer a Freshmore or core pillar subject. Students will need to seek email approval from the Registrar and the Associate Provost (Undergraduate Studies) via OSA for deferring Freshmore subjects or the Head of Pillar and the Associate Provost

[1] Refer to Policy on Exceeding Term Credit Limit.

1

Literature

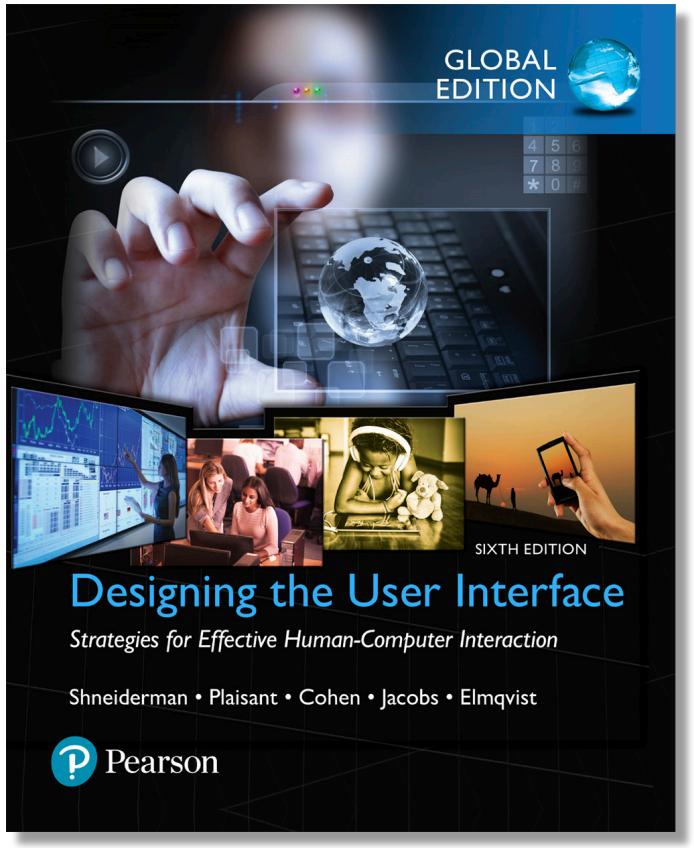
Recommended Textbook

“Designing the User Interface: Strategies for Effective Human-Computer Interaction”

6th Edition, 2016

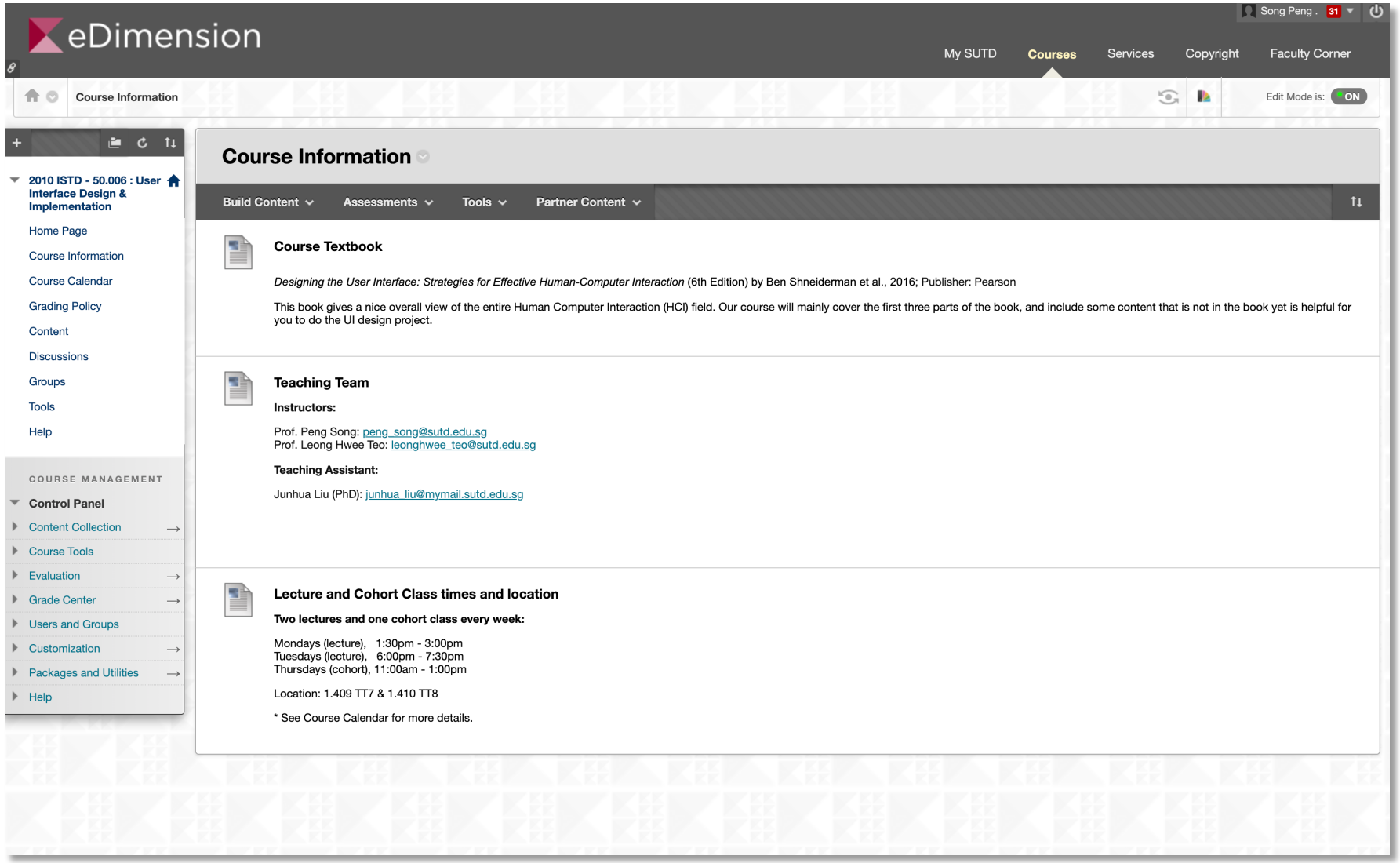
Authors: Ben Shneiderman et al.

Publisher: Pearson



Link

eDimension



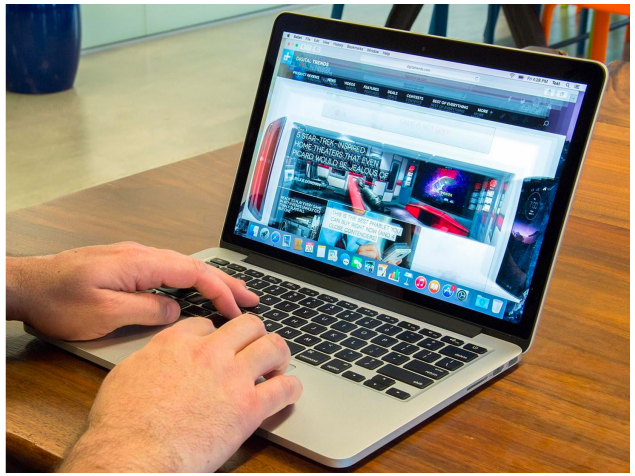
Link

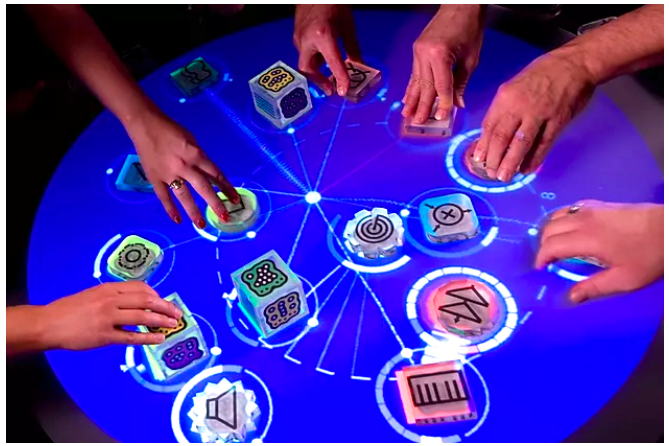
User Interface

A **user interface** is a system that helps users communicate with the computer system and/or the application system

- what the system looks like
- how the system accepts input from the user
- how the system responds to user input
- how the system outputs the results of processing

Link

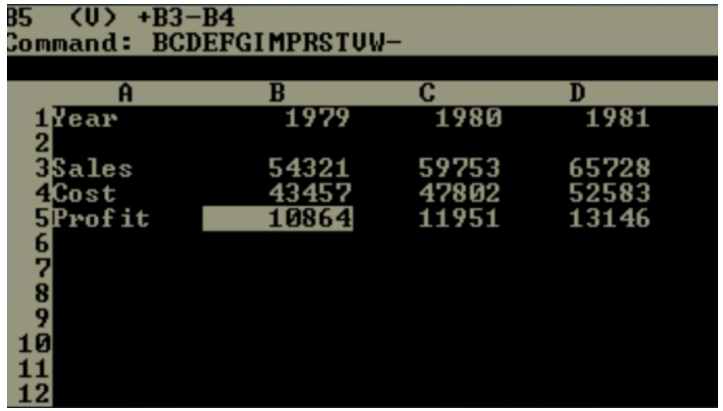




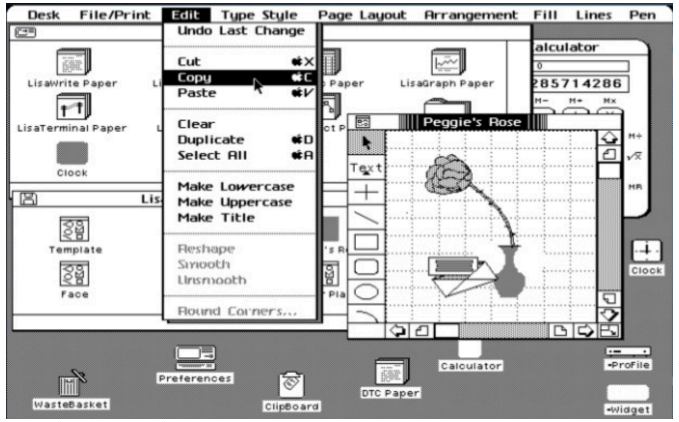
User Interface: History

1962 Computer Game Spacewar

1964 The Mouse

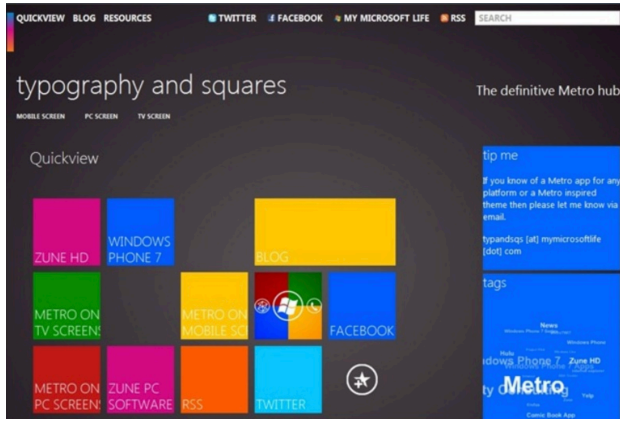


1970s Command line interface



1980s GUI – Apple Lisa

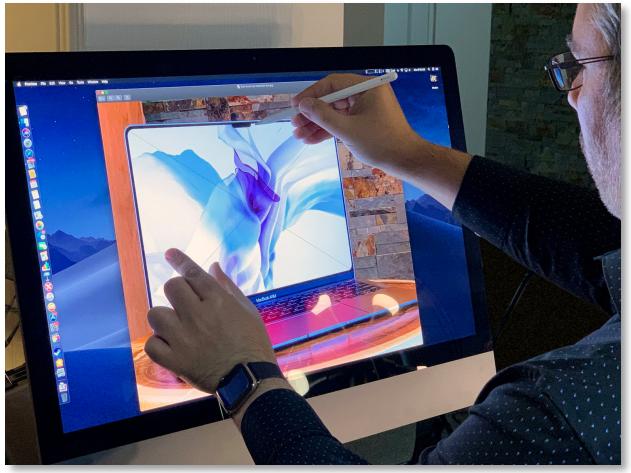
2000s UI Widgets



2010+ Modern GUI

User Interface: Nowadays

Multi-touch phone



Pen + Touch

Tangible device

Large multi-touch display

Mid-air gestural interaction

User Interface: Nowadays

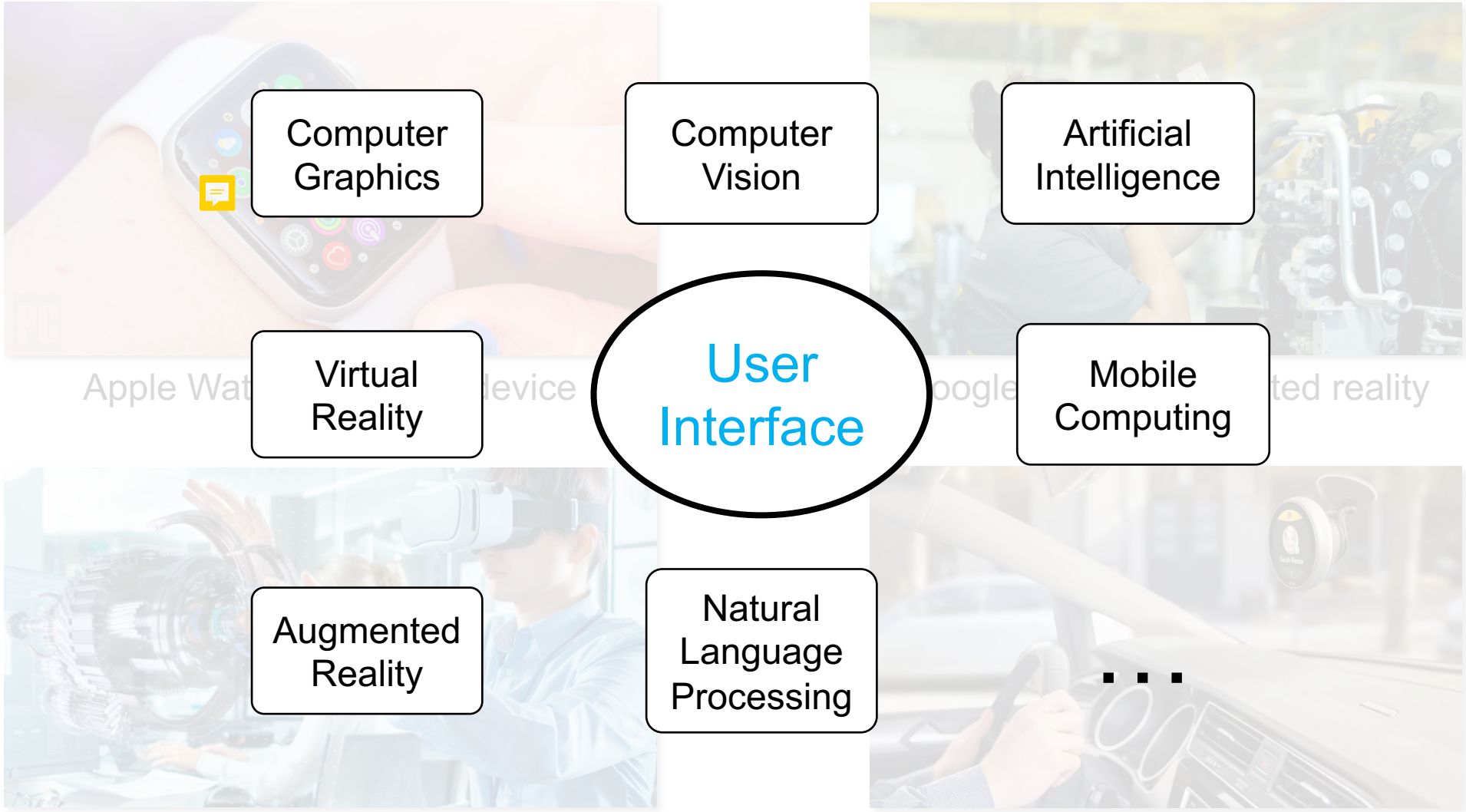
Apple Watch, wearable device

Google glass, augmented reality

3D VR glass, virtual reality

Chris, voice Interface

User Interface: Nowadays

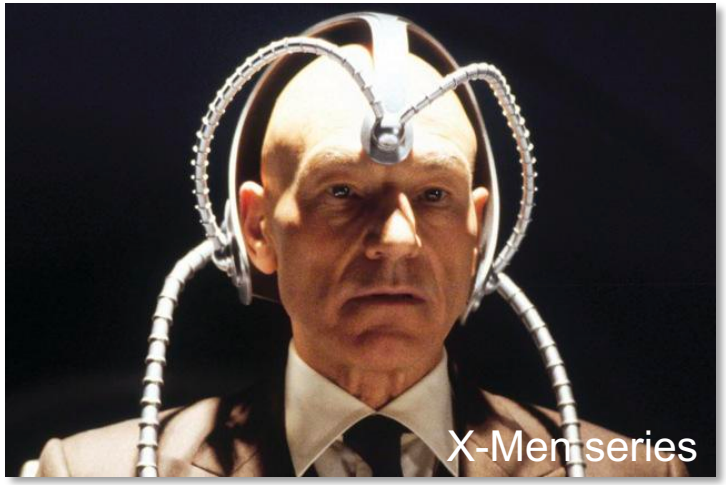


User Interface: Future

Tangible VR interface

Eye-tracking interface

Device-free AI interface



Brain-machine interface

Human Computer Interaction

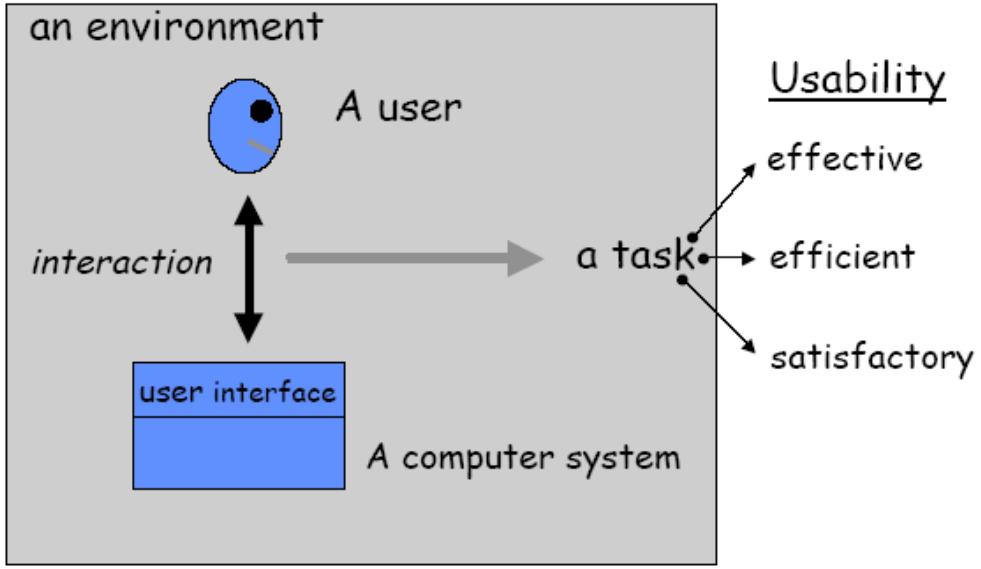
Human-computer interaction (HCI): "*is a discipline concerned with the design, evaluation and implementation of interactive systems for human use and with study of major phenomena surrounding them.*"

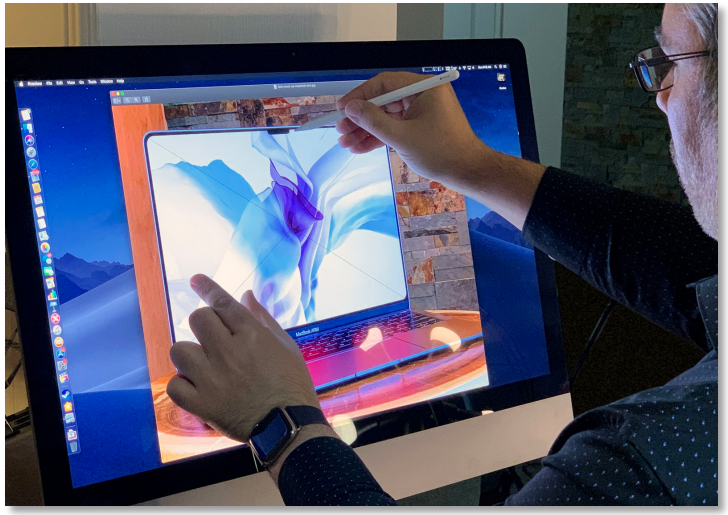
(ACM SIGCHI, 1992, p. 6)

- HCI is the study of interaction between people (users) and computers.
- Interaction between users and computers **occurs at the user interface**
- **User interface design** is a sub-topic in **HCI**

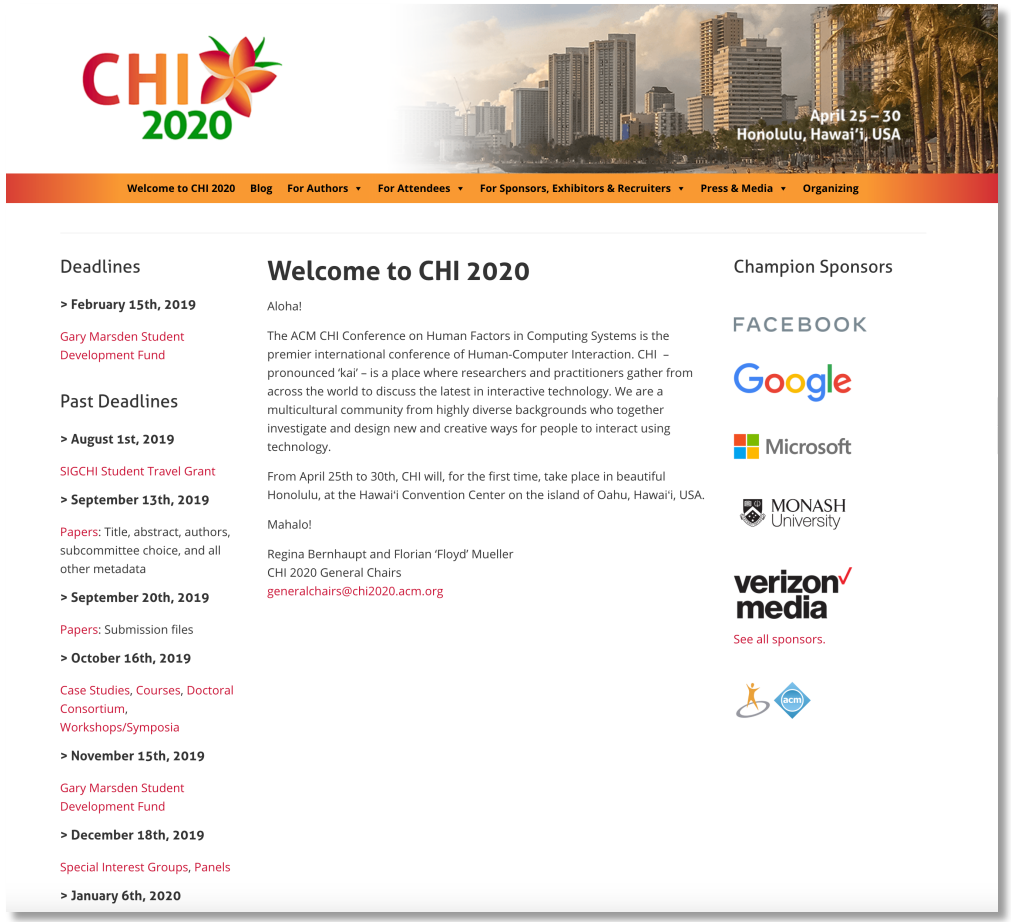
Human Computer Interaction

- **Human**
  - Users, single, group working together
  - User tries to complete a task
- **Computer**
  - Technology, not just Desktop computer
  - Systems: Process control, Embedded
- **Interaction**
  - Communication, direct/indirect
  - Dialogue + feedback/batch
  - Task oriented



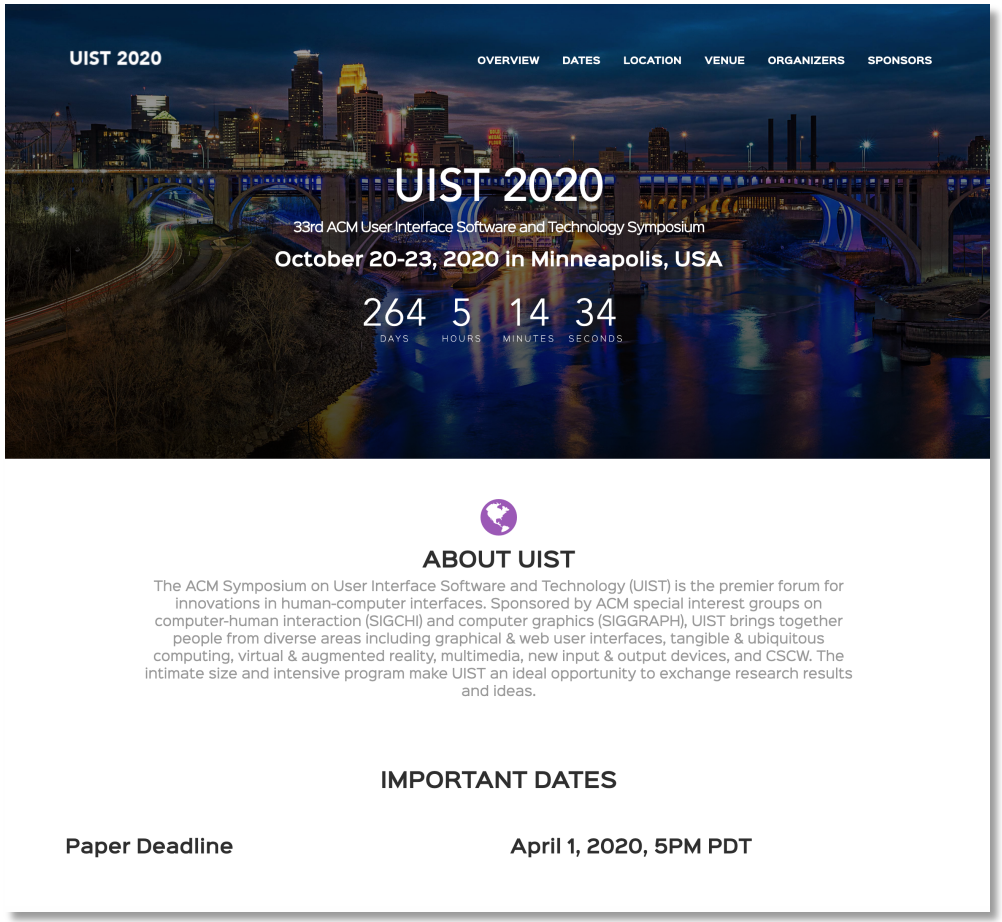


Conferences in HCI



CHI 2020: https://chi2020.acm.org/

Hosted by ACM **SIGCHI**

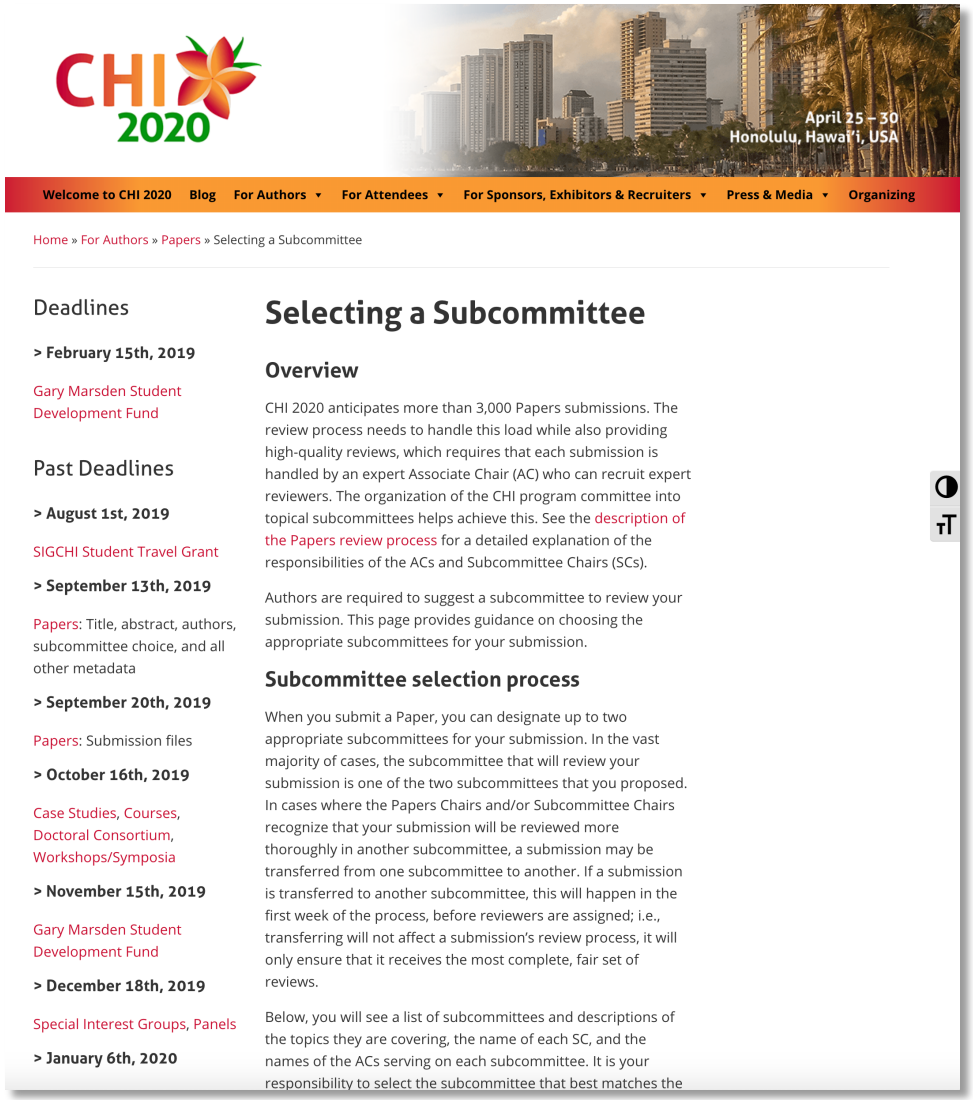


UIST 2020: http://uist.acm.org/uist2020/

Sponsored by ACM **SIGCHI** and **SIGGRAPH**

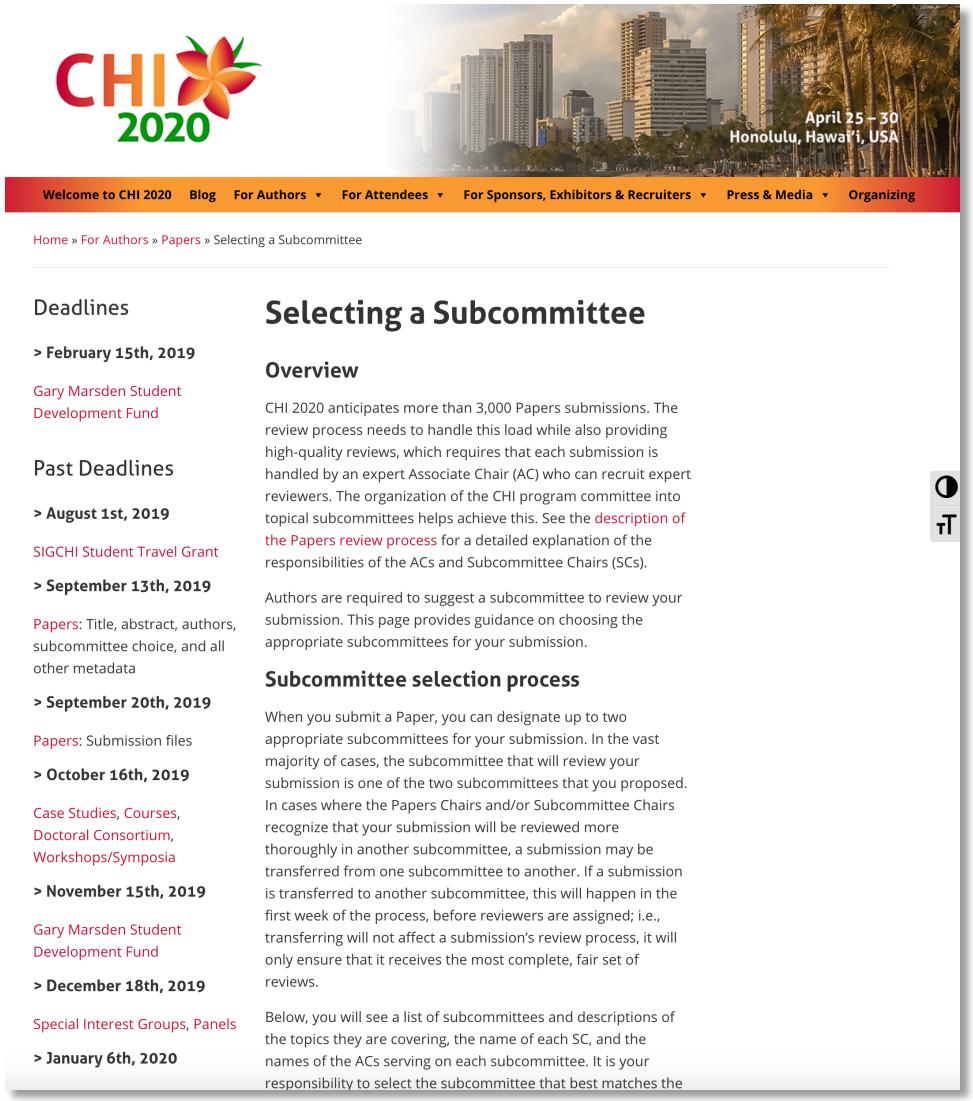
Conferences in HCI

- List of the subcommittees in CHI 2020
  - User Experience and Usability
  - Specific Application Areas
  - Learning, Education and Families
  - Interaction Beyond the Individual
  - Games and Play
  - Privacy, Security
  - Visualization
  - Health
  - Accessibility and Aging
  - Design
  - Interaction techniques, Devices and Modalities
  - Understanding People: Theory, Concepts, Methods
  - Engineering Interactive Systems and Technologies



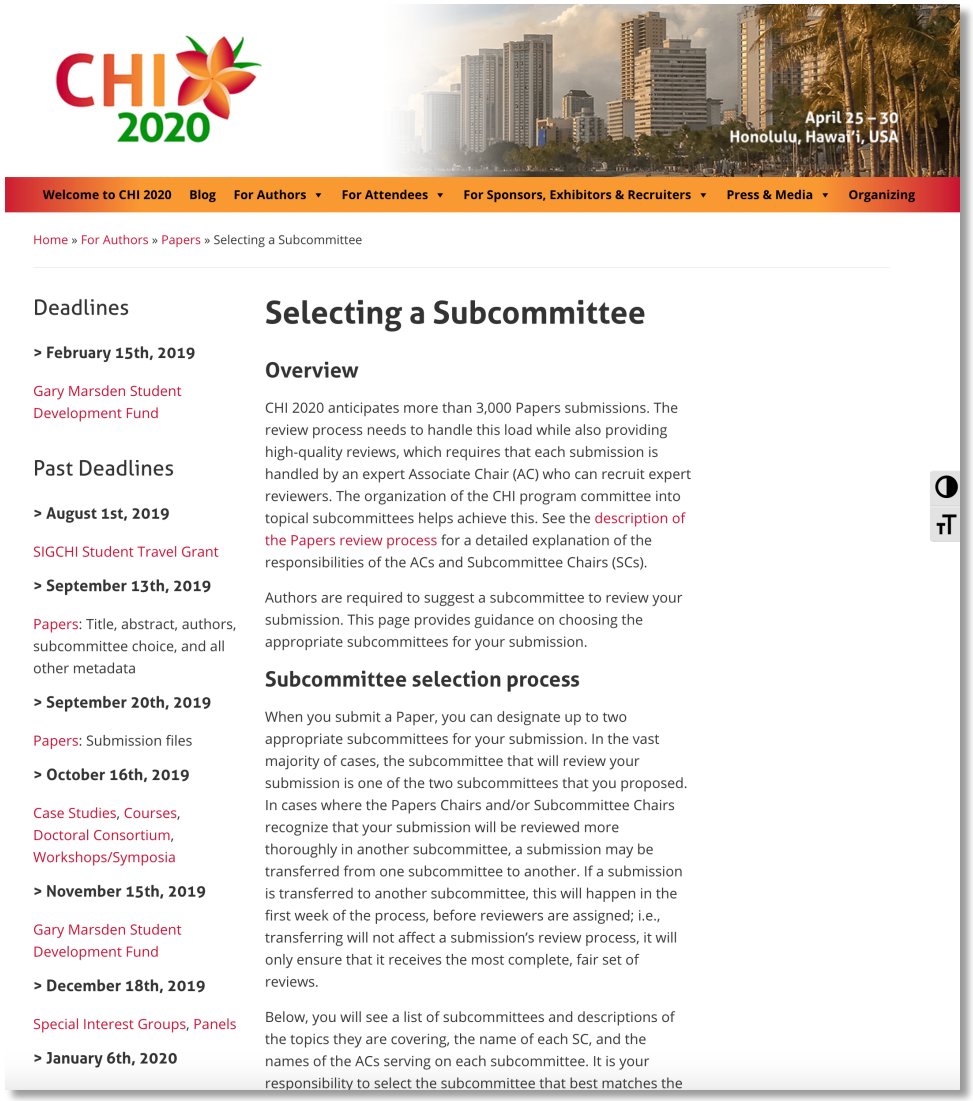
Conferences in HCI

- List of the subcommittees in CHI 2020
  - User Experience and Usability
  - Specific Application Areas
  - Learning, Education and Families
  - Interaction Beyond the Individual
  - Games and Play
  - Privacy, Security
  - Visualization
  - Health
  - ✓ Accessibility and Aging
  - Design
  - Interaction techniques, Devices and Modalities
  - ✓ Understanding People: Theory, Concepts, Methods
  - Engineering Interactive Systems and Technologies



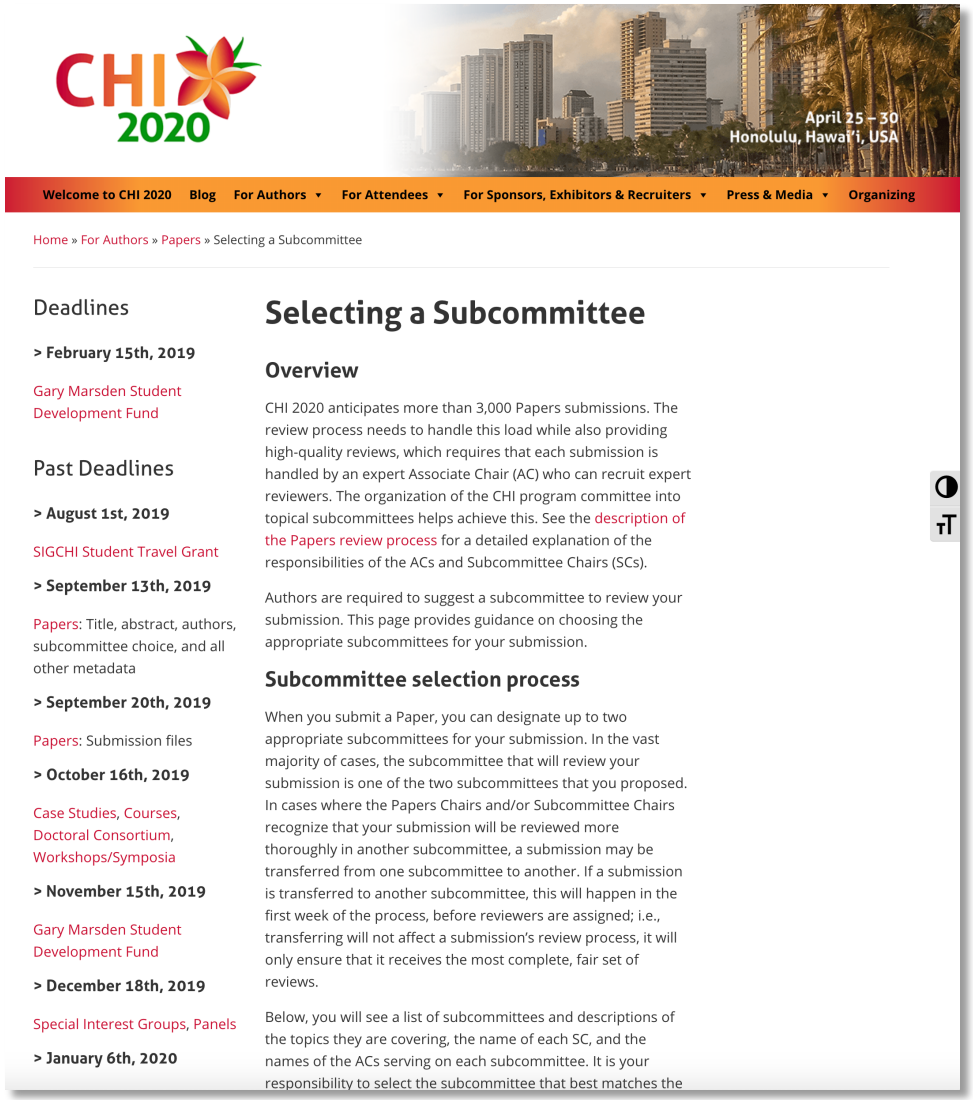
Conferences in HCI

- List of the subcommittees in CHI 2020
  - User Experience and Usability
  - Specific Application Areas
  - Learning, Education and Families
  - Interaction Beyond the Individual
  - Games and Play
  - ✓ Privacy, Security
  - ✓ Visualization
  - Health
  - Accessibility and Aging
  - Design
  - Interaction techniques, Devices and Modalities
  - Understanding People: Theory, Concepts, Methods
  - Engineering Interactive Systems and Technologies



Conferences in HCI

- List of the subcommittees in CHI 2020
  - ✓ User Experience and Usability
  - Specific Application Areas
  - Learning, Education and Families
  - ✓ Interaction Beyond the Individual
  - Games and Play
  - Privacy, Security
  - Visualization
  - Health
  - Accessibility and Aging
  - ✓ Design
  - ✓ Interaction techniques, Devices and Modalities
  - Understanding People: Theory, Concepts, Methods
  - ✓ Engineering Interactive Systems and Technologies



Who Contributes to HCI

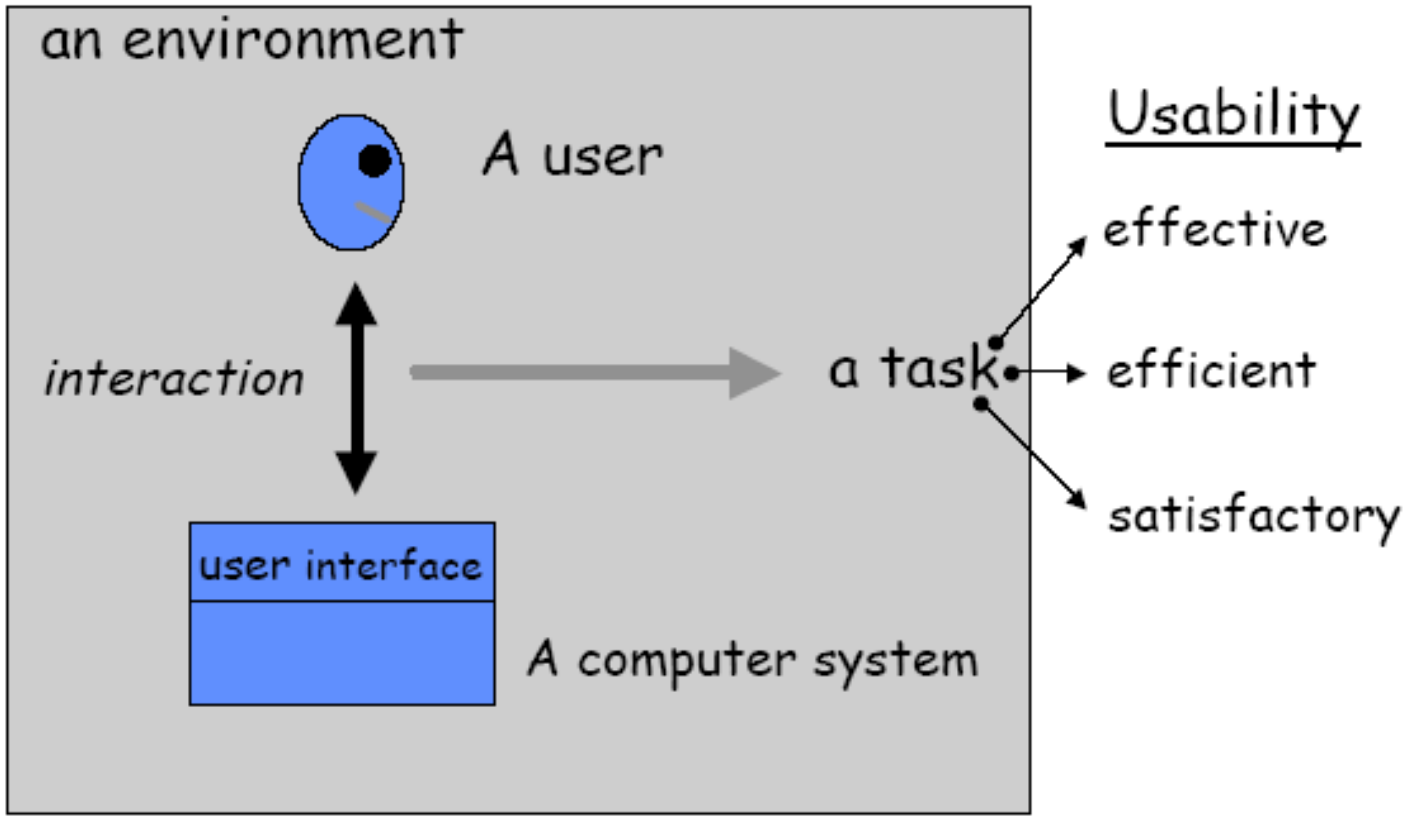
- **Computer scientists**
  - Modelling, specifying & analysing interaction
- **Software engineers**
  - Interaction design is part of overall system development
  - Knowledge of users, tasks necessary to capture and understand requirements
- **Artificial intelligence researchers**
  - Interactive systems exhibiting (or simulating) intelligence
  - Behaviour

Who Contributes to HCI

- **Linguists**
  - Interaction as communicative and conceptual activity
- **Sociologists**
  - Interaction as social activity
- **Ergonomists**
  - Interaction is physical as well as conceptual
- **Psychologists**
  - User as perceiver, thinker

User Interface Design

Produce a user interface which makes it easy, efficient, and enjoyable to operate a machine in the way which produces the desired result.



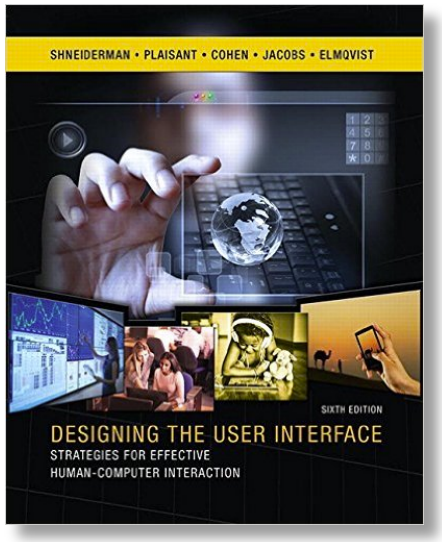
User Interface Design

- User interface design is an **iterative process** involving close liaisons between users and designers
- The three core activities in this process are
  - **User analysis**. Understand what the users will do with the system
  - **System prototyping**. Develop a series of prototypes for experiment
  - **Interface evaluation**. Experiment with these prototypes with users

User Interface Design

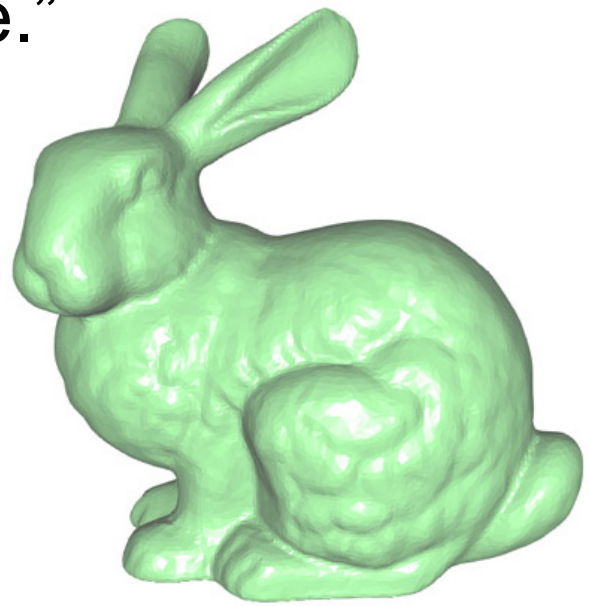
"Good designs generate **positive feelings of success, competence, mastery, and clarity** in the user community. The users are not encumbered by the computer, and can predict what will happen in response to each of their actions. When it is well designed, the **interface almost disappears**, enabling users to concentrate on their work, exploration, or pleasure."

- Ben Shneiderman
University of Maryland



User Interface Design

"Good designs generate **positive feelings of success, competence, mastery, and clarity** in the user community. The users are not encumbered by the computer, and can predict what will happen in response to each of their actions. When it is well designed, the **interface almost disappears**, enabling users to concentrate on their work, exploration, or pleasure."



Example Task:

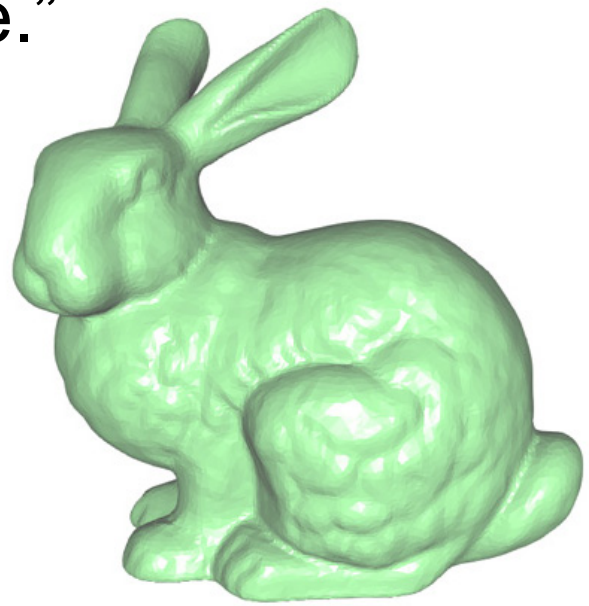
Manipulate a 3D virtual object

User Interface Design

"Good designs generate **positive feelings of success, competence, mastery, and clarity** in the user community. The users are not encumbered by the computer, and can predict what will happen in response to each of their actions. When it is well designed, the **interface almost disappears**, enabling users to concentrate on their work, exploration, or pleasure."

Example Task:

Manipulate a 3D virtual object



Interface Options:

- Command line
- Manu selection
- Natural language
- Direct manipulation ✓

Why Study UI Design?

- Interacting with technology has become an essential part of everyday life for the majority of people.
- The average user of a computer system is now less likely to understand the technology. Since, there are different types of technology they have to use.
- People are busy and may spend little or no time actually learning a new system.
- Therefore, computer systems should be easy to use, easy to learn, and with no errors.

Why Study UI Design?

- Major part of work for “real” software
  - UI design
  - takes approximately 50% of time & resources
- At a company you work on “real” software
  - intended for users other than “us”
  - You are not the user!
- Bad UIs cost
  - dissatisfaction user results is substantially lower profits
  - Depending on application . . can cost lives

Why Hard to Design UIs?

- **No silver bullet** (straightforward solution to have extreme effectiveness, for productivity, quality and control)
- User Interface design is a **creative** process
- Designers have **difficulty** thinking like users
  - Can't "unlearn" something

After you know what is there,
it is hard to remember *how* "not" to see it!

Why Hard to Design UIs?

- **No silver bullet** (straightforward solution to have extreme effectiveness, for productivity, quality and control)
- User Interface design is a **creative** process
- Designers have **difficulty** thinking like users
  - Can't "unlearn" something
- **"It is easy to make things hard. It is hard to make things easy."**

Why Hard to Design UIs?

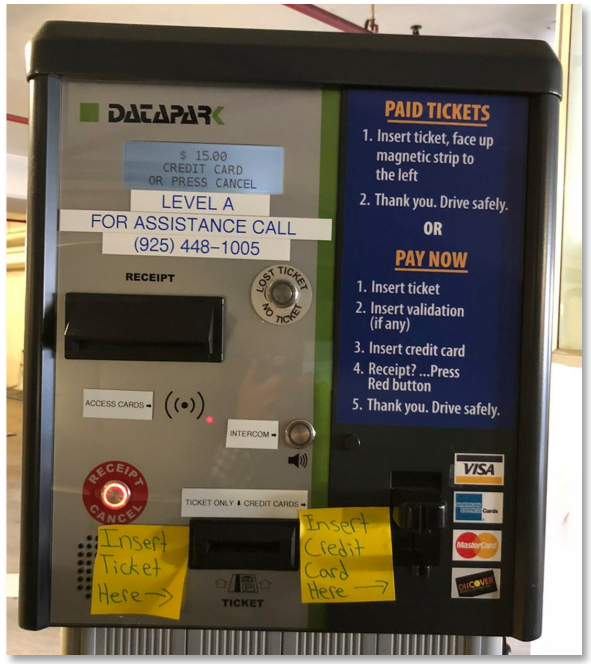
- All UI design involves **tradeoffs**:
  - Standards (style guides, related products)
  - Graphic design (artistic)
  - Technical writing (Documentation)
  - Internationalization
  - Performance
  - Multiple platforms (hardware, browsers, etc.)
  - High-level and low-level details
  - External factors (social issues)
  - Legal issues
  - Time to develop and test (“time to market”)

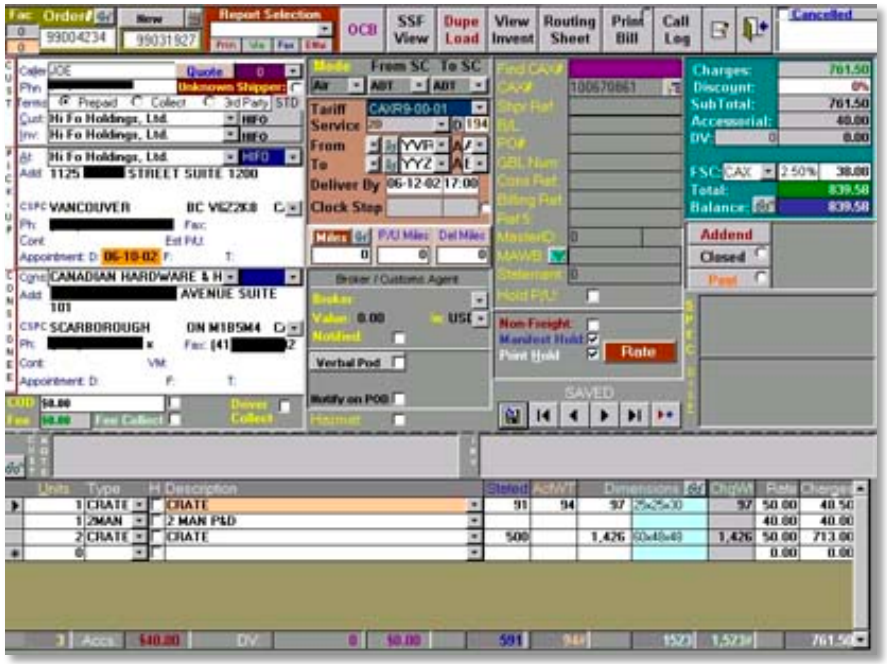
Goals of this Course

- Goal of this course is to give you an overview of UI Design
  - To help you think about UI Design matters!
  - To understand the principles of UI Design
  - To understand methods for user-studies and feedback
  - To learn the “vocabulary” of UI Design researchers
  - To enable you to appreciate what is involved in designing complex interactive systems
  - To make you want you to learn more about UI Design . .
- This course will focus on UI design of software systems
  - user interface is not limited to computers
  - user interface is about any machines and application systems

By the end of the course, you will…

… **understand** why it's hard to design user interfaces



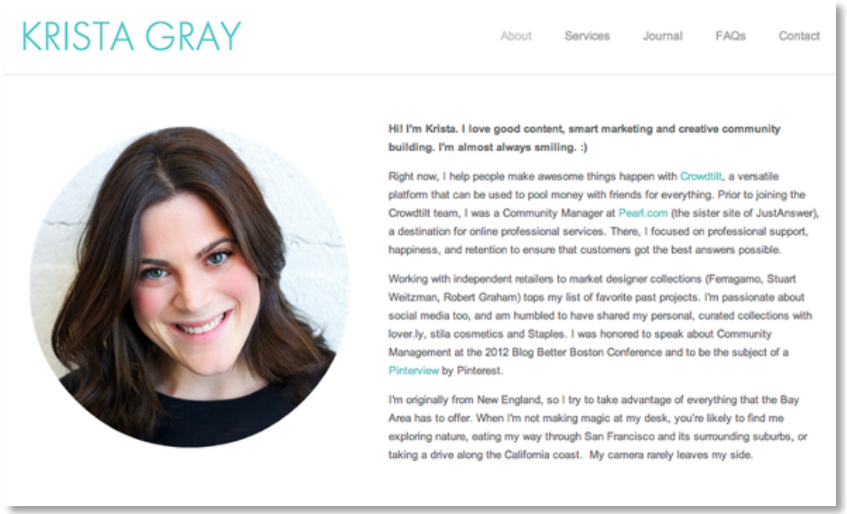


By the end of the course, you will…

… be able to **evaluate** how good/bad a UI is

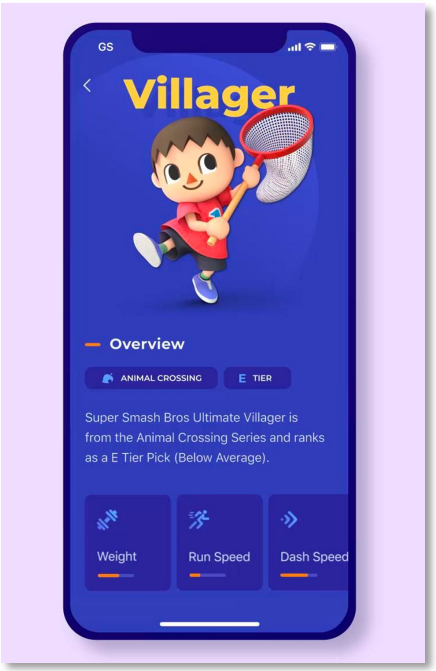
By the end of the course, you will…

… be able to **design** a usable and considerate UI



Personal webpage

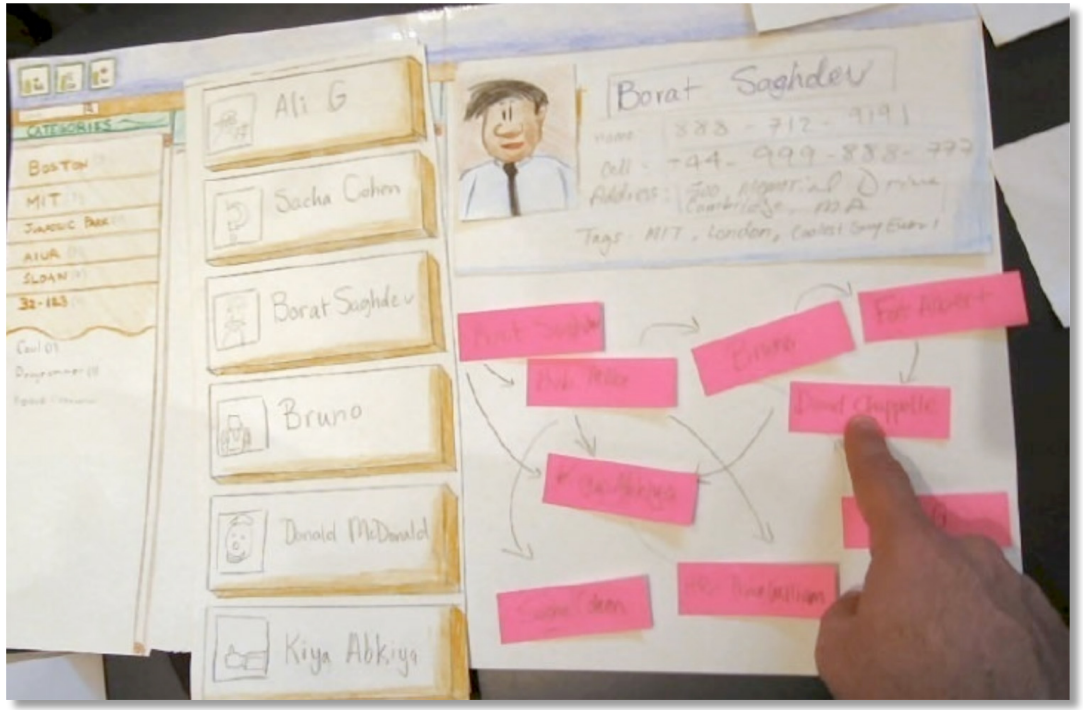
Desktop software

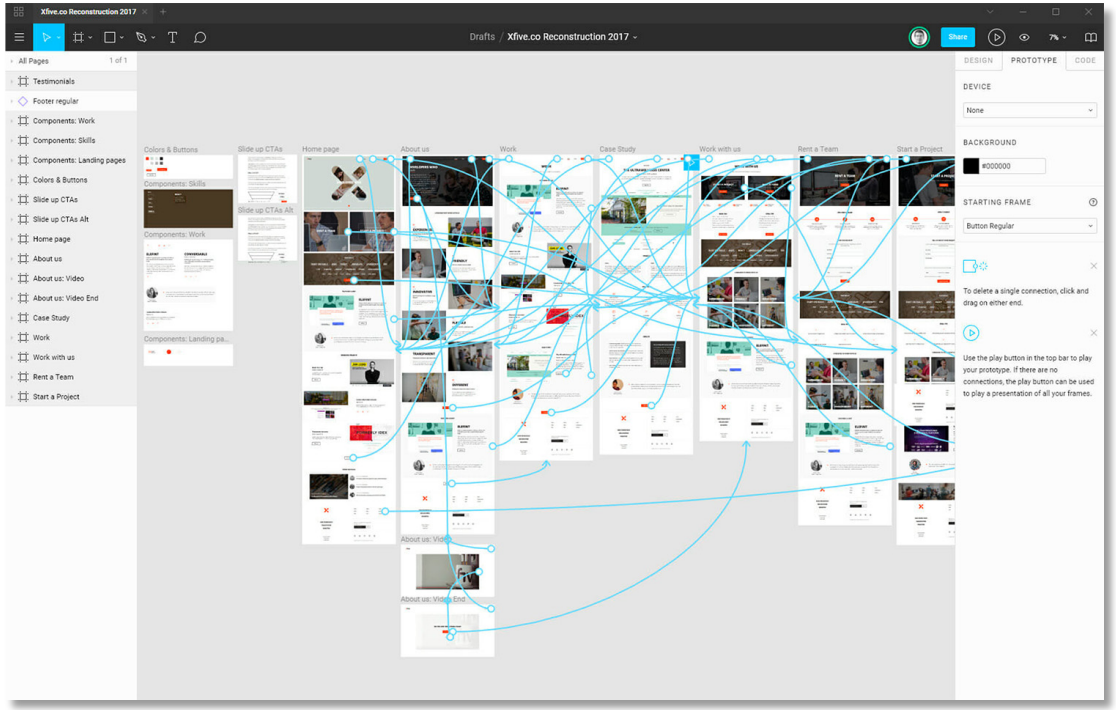


Phone App

By the end of the course, you will…

… be able to **prototype** designed UI efficiently



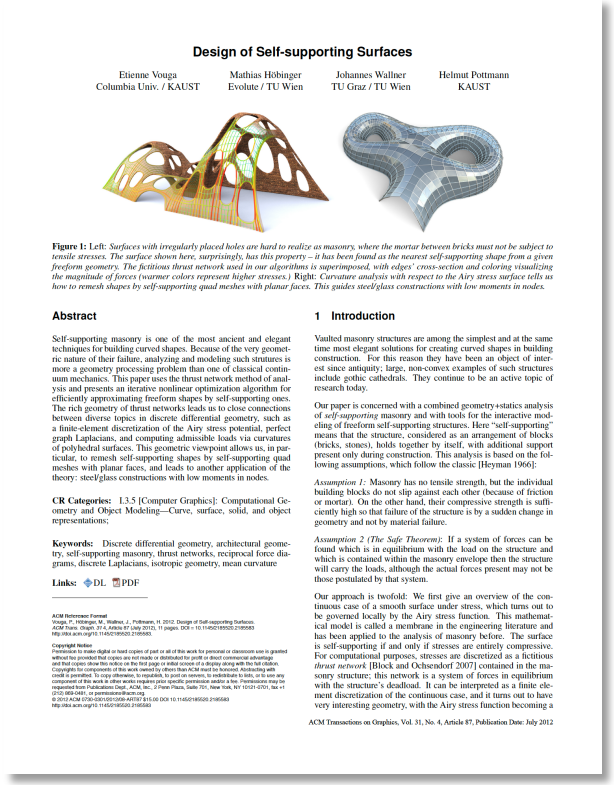


By the end of the course, you will…

… obtain visual **literacy**

UI Design

Presentation



Design of Self-supporting Surfaces

Etienne Vouga, Columbia Univ. / KAUST
Mathias Höbinger, Evolute / TU Wien
Johannes Wallner, TU Graz / TU Wien
Helmut Pottmann, KAUST

Figure 1: Left: *Surfaces with irregularly placed holes are hard to realize as masonry, where the mortar between bricks must not be subject to tensile stresses. The surface shown here, surprisingly, has this property – it has been found as the nearest self-supporting shape from a given freeform geometry. The fictitious thrust network used in our algorithms is superimposed, with edges' cross-section and coloring visualizing the magnitude of forces (warmer colors represent higher stresses.)* Right: *Curvature analysis with respect to the Airy stress surface tells us how to remesh shapes by self-supporting quad meshes with planar faces. This guides steel/glass constructions with low moments in nodes.*

Abstract

Self-supporting masonry is one of the most ancient and elegant techniques for building curved shapes. Because of the very geometric nature of their failure, analyzing and modeling such structures is more a geometry processing problem than one of classical continuum mechanics. This paper uses the thrust network method of analysis and presents an iterative nonlinear optimization algorithm for efficiently approximating freeform shapes by self-supporting ones. The rich geometry of thrust networks leads us to close connections between diverse topics in discrete differential geometry, such as a finite-element discretization of the Airy stress potential, perfect graph Laplacians, and computing admissible loads via curvatures of polyhedral surfaces. This geometric viewpoint allows us, in particular, to remesh self-supporting shapes by self-supporting quad meshes with planar faces, and leads to another application of the theory: steel/glass constructions with low moments in nodes.

CR Categories: I.3.5 [Computer Graphics]: Computational Geometry and Object Modeling—Curve, surface, solid, and object representations;

Keywords: Discrete differential geometry, architectural geometry, self-supporting masonry, thrust networks, reciprocal force diagrams, discrete Laplacians, isotropic geometry, mean curvature

Links: DL PDF

1 Introduction

Vaulted masonry structures are among the simplest and at the same time most elegant solutions for creating curved shapes in building construction. For this reason they have been an object of interest since antiquity; large, non-convex examples of such structures include gothic cathedrals. They continue to be an active topic of research today.

Our paper is concerned with a combined geometry+statics analysis of *self-supporting* masonry and with tools for the interactive modeling of freeform self-supporting structures. Here "self-supporting" means that the structure, considered as an arrangement of blocks (bricks, stones), holds together by itself, with additional support present only during construction. This analysis is based on the following assumptions, which follow the classic [Heyman 1966]:

Assumption 1: Masonry has no tensile strength, but the individual building blocks do not slip against each other (because of friction or mortar). On the other hand, their compressive strength is sufficiently high so that failure of the structure is by a sudden change in geometry and not by material failure.

Assumption 2 (The Safe Theorem): If a system of forces can be found which is in equilibrium with the load on the structure and which is contained within the masonry envelope then the structure will carry the loads, although the actual forces present may not be those postulated by that system.

Our approach is twofold: We first give an overview of the continuous case of a smooth surface under stress, which turns out to be governed locally by the Airy stress function. This mathematical model is called a membrane in the engineering literature and has been applied to the analysis of masonry before. The surface is self-supporting if and only if stresses are entirely compressive. For computational purposes, stresses are discretized as a fictitious *thrust network* [Block and Ochsendorf 2007] contained in the masonry structure; this network is a system of forces in equilibrium with the structure's deadload. It can be interpreted as a finite element discretization of the continuous case, and it turns out to have very interesting geometry, with the Airy stress function becoming a

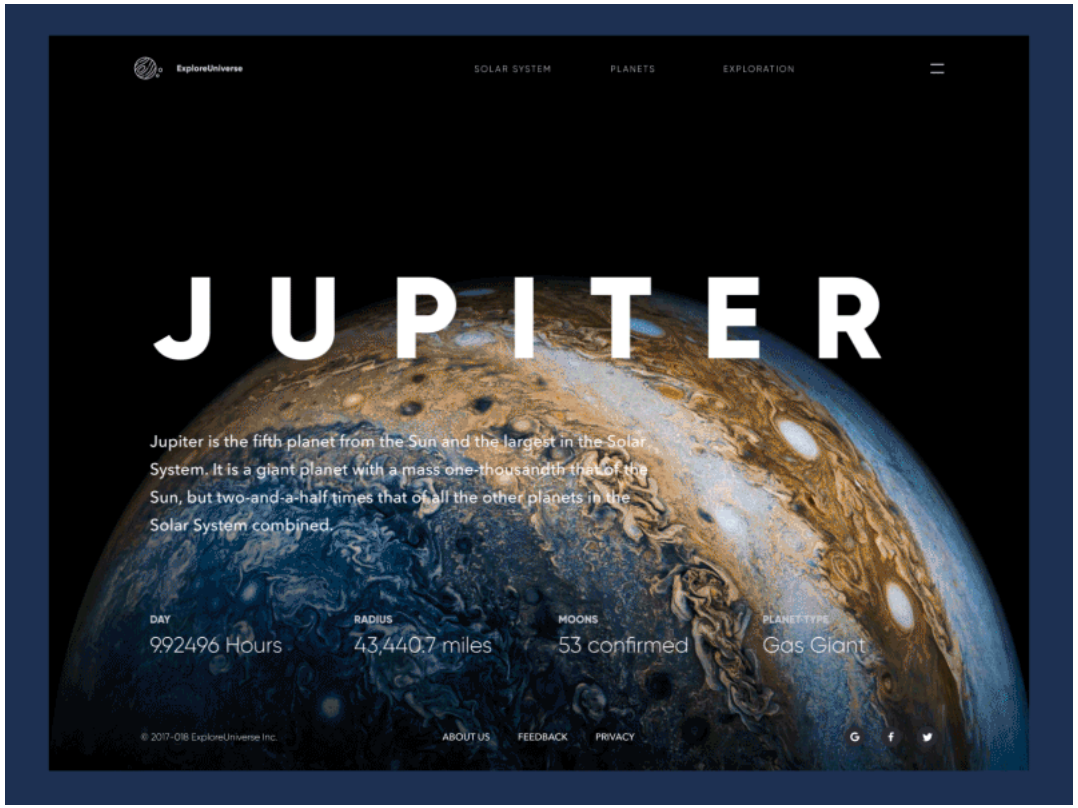
ACM Transactions on Graphics, Vol. 31, No. 4, Article 87, Publication Date: July 2012

Paper/report

By the end of the course, you will…

… (hopefully) appreciate the beauty of user interface

Museum App



Explore Universe Website

Coming Up

Next Monday: **User in UI Design**

– Instructed by *Leong Hwee Teo*

– 13:30 - 15:00 in 1.409 TT7 & 1.410 TT8