CPS: Synergy: Foundations of Cyber-Physical Infrastructure for Creative Design and Making of Cyber-physical Products

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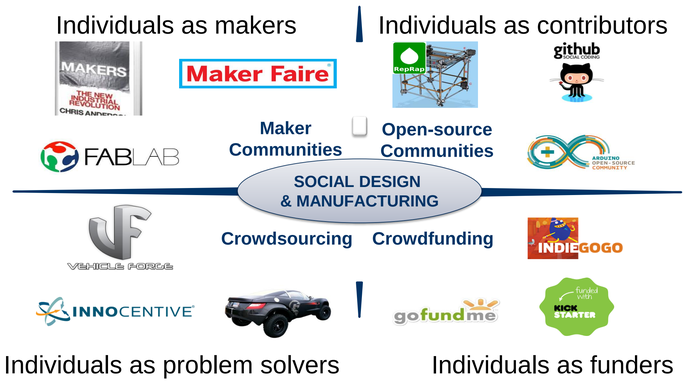
Emerging Models of Innovation



Motivation

Barriers to participation in design and prototyping:

- Makers may lack complete engineering knowledge
- Makers may not have necessary tools and knowledge for physics-based modeling
- Makers may not be willing to reveal information in the early stages of co-design

Project Overview

The **primary objective** of this project is to lay the foundations of a cyber-physical infrastructure for creative design and making of realizable products.

Specific aims:
Aim 1: Reducing barriers to participation through NUIs.
Aim 2: Reducing barriers to model-based engineering.
Aim 3: Overcoming information-related impediments to co-design.

NUI-based Simulation-supported Design Framework

Sketch-based 3D Modeling for Early Stage Design

Intuitive pen-and-touch based modeling interactions

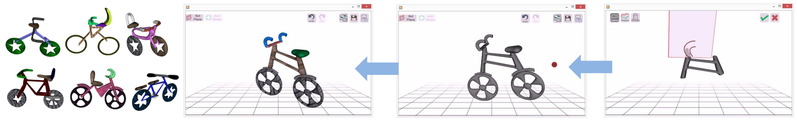
Direct design modeling in 3D space & automatic conversion of simple sketch inputs into 3D geometry

Multi-level shape editing using sketch inputs

Generate multiple design concepts

Color & Texture Application

Creating new shapes in-context of the overall design



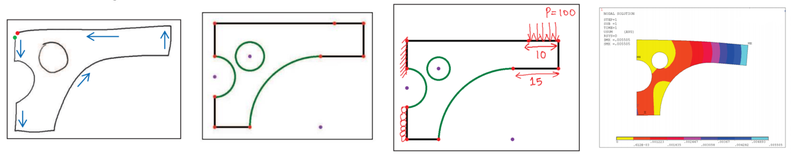
Sketch-based Interface for Early Stage Design Analysis

Raw sketch Input of Design

Beautified Design Model

Sketched Load and Constraints

Analysis Results

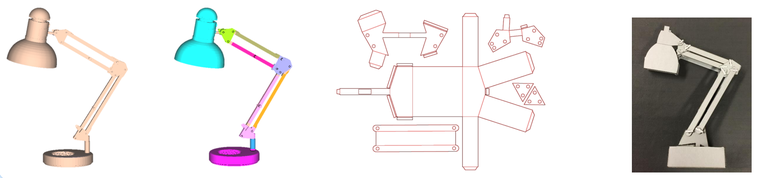


Physical Prototyping using Digital Fabrication

Digital 3D model

Automatic design segmentation & generation of component fabrication plan

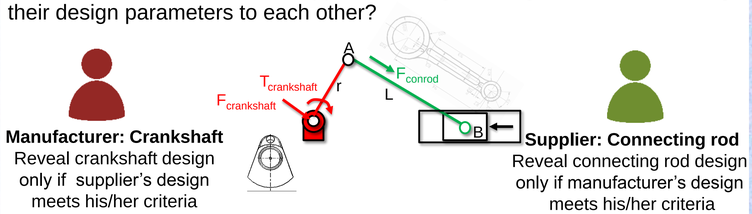
Low cost and quick fabrication of physical prototype



Integration

Application: Manufacturer- Supplier Scenario

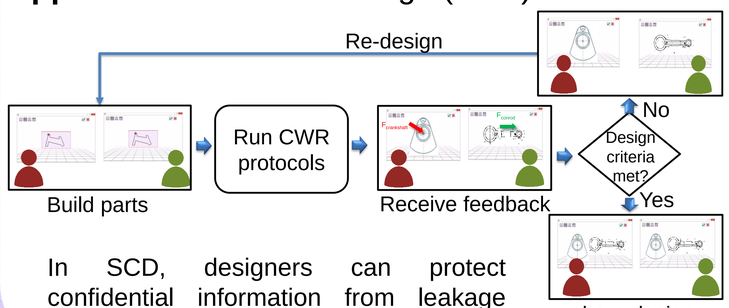
How can a manufacturer and supplier co-design an engine without revealing their design parameters to each other?



Manufacturer: Crankshaft
Reveal crankshaft design only if supplier's design meets his/her criteria

Supplier: Connecting rod
Reveal connecting rod design only if manufacturer's design meets his/her criteria

Approach: Secure Co-design (SCD) framework



In SCD, designers can protect confidential information from leakage through their collaborators.

Significance

- Quick externalization and evaluation of design ideas
- In-depth exploration of design space during early stages
- Win-Win situation to all the collaborators
- Protection against misuse (purpose control)
- Remote shredding

References

- Murugappan, S., Piya, C., Yang, M., Ramani, K., "FEASY: A Sketch-based Tool for Finite Element Analysis", Journal of Computing and Information Science in Engineering 16(3), September 2016.
- Wang, S., Bhandari, S., Chaduvula S. Chaitanya, Panchal J. H., Atallah M., and Ramani, K., 2016, "*Secure Collaboration in Engineering Systems Design*", Journal of Computing and Information Science in Engineering, In Review.
- Dachowicz A., Chaduvula S. Chaitanya, Panchal J. H., and Atallah M., 2016, "*Confidentiality Management in Collaborative Design*", ASME 2016 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC/CIE 2016).

Confidentiality preservation in co-design

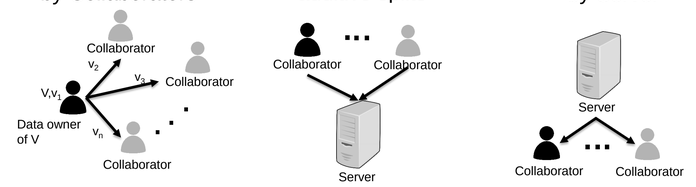
Research Question:
How collaborators can determine their desired outputs without revealing their inputs?

Approach: Computing Without Revealing (CWR) involves the following three steps:

Step 1: Additive splits by Collaborators

Step 2: Morph additive splits

Step 3: Additive splits by Server



$v = v_1 + v_2 \ldots + v_n$

Every collaborator similarly splits his/her inputs

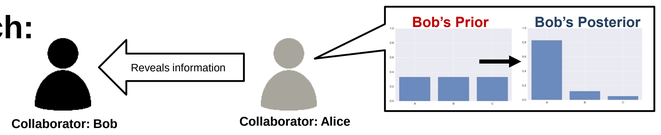
Server receives morphed additive splits and performs the computation over morphed splits

Server additively splits the output among collaborators

CWR based protocols are developed for primitive operations such as arithmetic, logical operations. Higher level operations such as matrix factorization are constructed using these primitives

Research Question:
How collaborators can quantify confidentiality loss associated with revealed information?

Approach:



Alice models Bob's learning using Bayesian inference
Alice measures the distance between distributions using K-L divergence

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