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Does Synchronous Collaboration Improve Collaborative Computer-Aided Design Output

Results From A Large-Scale Competition

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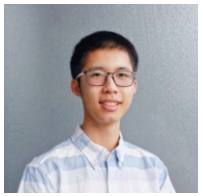

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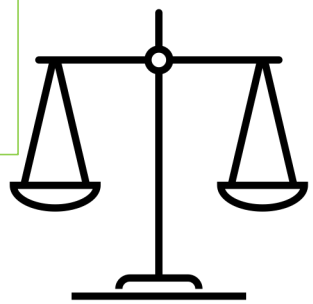
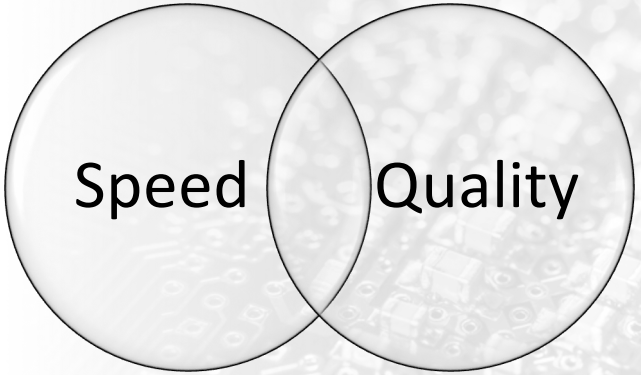
Collaboration: Studied in many contexts, but not at scale with Computer-Aided Design

Benefits from division of labor and learning



Costs of communication and coordination



Collaboration in complex tasks [1]

Collaboration in computer-aided design (CAD) [2]

[1] Mao, A., Mason, W., Suri, S., and Watts, D. J., 2016, "An Experimental Study of Team Size and Performance on a Complex Task," PLoS ONE, **11**(4).
[2] Phadnis, V., Arshad, H., Wallace, D., and Olechowski, A., 2021, "Are Two Heads Better Than One for Computer-Aided Design?," Journal of Mechanical Design, **143**(7), pp. 1–38.

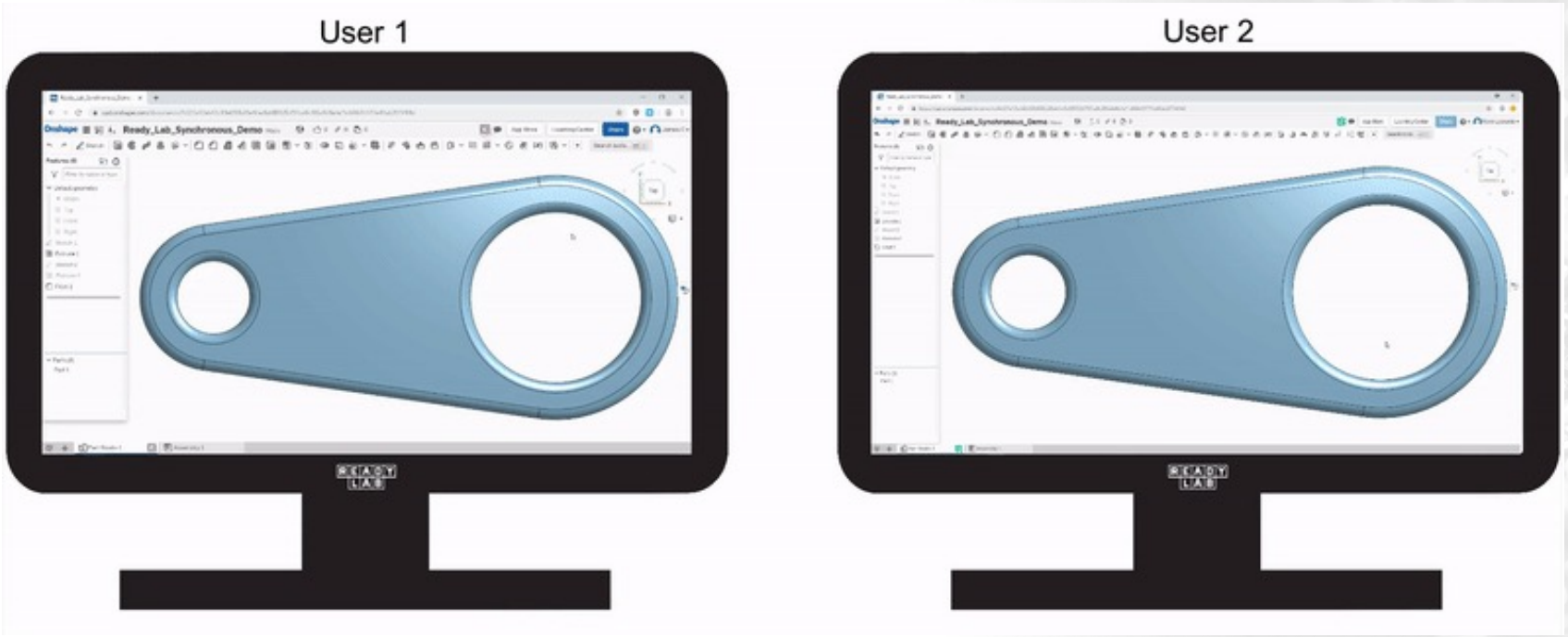
Multi-User Computer-Aided Design (MUCAD)

Cloud-based parametric CAD, but allows simultaneous editing from multiple users with instant updates

- Distributed collaboration
- Real-time synchronous collaboration
- Instant file access and reference

Question: does synchronous collaboration in MUCAD improve design output?

Onshape – Environment for Synchronous Multi-tenant CAD Editing

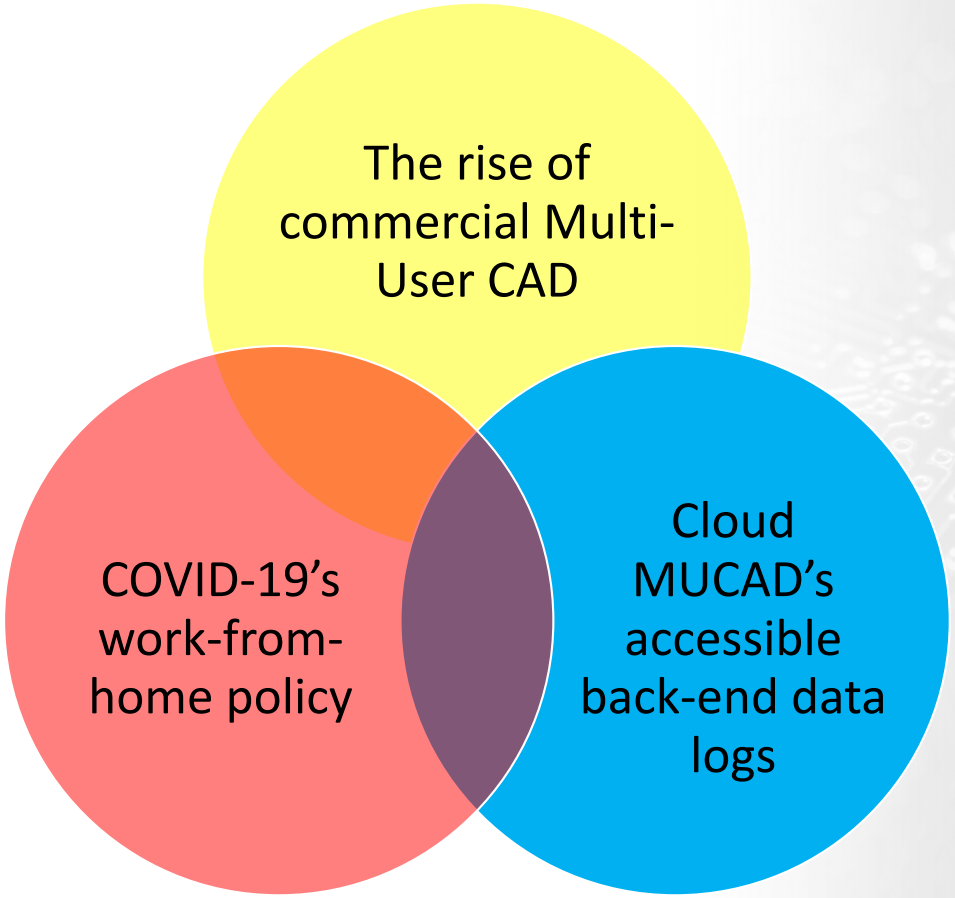


2020 Robots to the Rescue (RttR) Competition

- A virtual design challenge held by PTC Inc. for *FIRST*® Robotics
- A 41-day competition that challenged to solve real-world problems through designing robots in Onshape

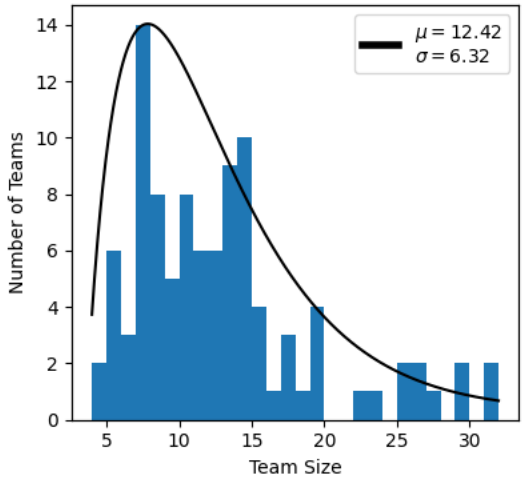
The winner of the competition with this robot designed to identify and repair potholes on roads in real time (https://www.onshape.com/en/robots-to-the-rescue/)

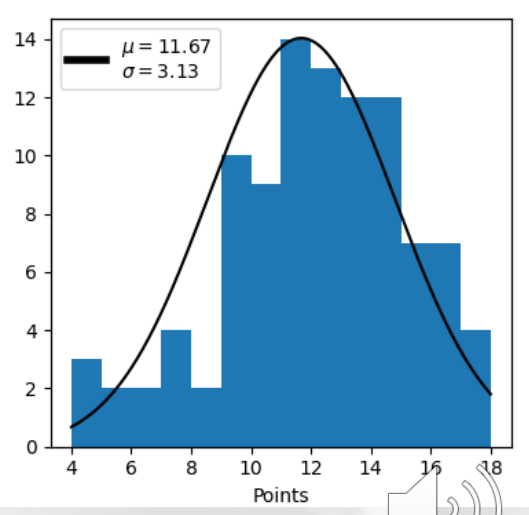
The unique context of this work



Research Data

- Participants: 101 high school student teams, composed of 1254 individuals → 1,627,764 entries of back-end analytic data (~ user clicks in the CAD program)
- Performance: Each robot design was graded by three judges based on four criteria (each on a one to five scale, summed as 'Points'):
  - Completeness and complexity of design
  - Ability to solve the problem
  - Feasibility
  - Utilization of *FIRST*® components





Variables of interest

- Total Actions: control
- Team Size
- Complexity of design: Bill of Material
- **Collaboration Occurrence Ratio:**

  the proportion of occurrences of overall document “opens” when one person opened the CAD document, one or more teammates were already working in the document.

Hierarchical Regression on Point Score

	A	B	C	D	E
(Constant)	10.3 ***	9.14 ***	9.14 ***	9.43 ***	9.56 ***
Total Actions	4e-4 **	2e-4	2e-4	2e-4	
Team Size		0.14 **	0.14 **	0.21 **	0.25 ***
BOM Size			-1e-5	-1e-4	
Collab. Occ. Ratio				-2.96 *	-2.86 *
R^2	.113	.174	.174	.213	.182
Adjusted R^2	.104	.157	.148	.180	.165
F-statistic	12.6	10.3	6.81	6.48	10.9

*, **, *** indicate $p < .05$, $p < .01$, and $p < .001$, respectively.

$$Points = f(\beta_0 + \beta_1 \cdot TeamSize - \beta_2 \cdot CollaborationOccurrenceRatio)$$

Discussion

- The first to examine the affordance of a MUCAD platform from a large-scale competition through a non-intrusive approach
- Inform the best practices of employing a MUCAD platform for large and complex CAD designs
  - Larger teams had better performance → potential efficiencies on division of labour, learning, and benefits of diversity
  - More occurrence of synchronous collaboration (collaboration occurrence ratio) associated with worse performance → further research required on the synchronous work process

Future Work

- Understand precisely what is happening during synchronous time
- Difference in collaboration for different design activities
- Measure the extent and strategies of collaboration for each occurrence
- Time-series analysis over the design process
- Real-world professional engineers vs. high-school students
- Exploring and defining the affordances within MUCAD

Thank you!

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