Design of a Breakaway Utensil Attachment for Enhanced Safety in Robot-Assisted Feeding

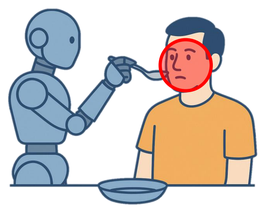
Hau Wen CHANG[2], J-Anne YOW[1,2], Lek Syn LIM[2], Wei Tech ANG[1,2]

[1] Singapore-ETH Centre, Future Health Technologies Programme
[2] Nanyang Technological University Singapore

1 Introduction

Robot-assisted feeding systems lack robust mechanical safety mechanisms

- Robot arms risk applying excessive force near the user's face
- Software-based safety is not always reliable
- Goal: Add a passive mechanical fail-safe



2 Design of Breakaway Attachment

Design Constraints:

- Max force before break = 65N (ISO 15066 safe limit for facial contact) [1]
- Min force to withstand = 25N (based on food acquisition experiments)

Mechanism Selection

- Standard shear pins and electromagnets are too bulky
- We chose simple, compact U- and L-shaped geometries and reduced shaft diameters to introduce **intentional weak points** (Fig. 1), leveraging bending and torsional moments to concentrate stress.
- U-shaped slot design chosen for **predictable failure location**

Figure 1: Finite element analysis (FEA) on the L-shaped (left) and U-shaped (right) designs. Stress concentrations are observed at the intentional weak points, particularly around the reduced shaft diameters, confirming the effectiveness of the geometry in promoting predictable breakage under load.

Fabrication and Tuning via 3D Printing

- Breakaway force is tunable via (1) Slot depth *d* (2) Wall loops *w*
- Clean break achieved by aligning 3D print layers with break line

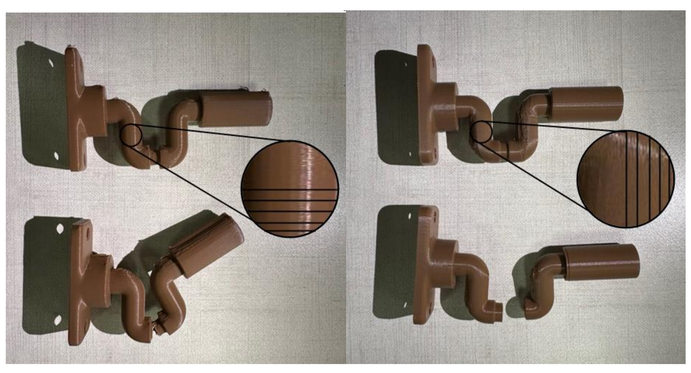


Figure 2: 3D printing orientations. (Left) Layer lines perpendicular to the breaking line for strength, resulting in an unclean break. (Right) Layer lines parallel to the breaking line, producing a clean break

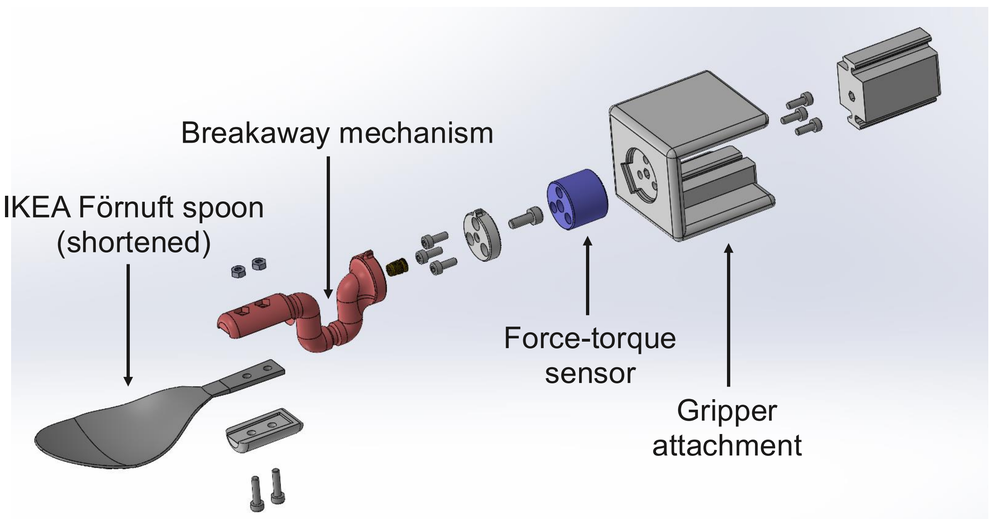


Figure 3: Utensil attachment design with force-torque sensor. The breakaway mechanism is highlighted in red.

3 Experiments and Results

Experiments

- Drop test rig to simulate impact; force measured by load cell
- Motion capture synchronized at 200Hz to record position, velocity and acceleration

Results

- Optimal configuration: d = 1mm, w = 3 (breaks near ISO 15066 safe limit)
- Clean, consistent failure at slot (Fig. 5)
- Breakaway force customizable based on user comfort threshold

Table I: Effect of slot depth *d* and wall loop *w* on breakaway force

Slot Depth *d* (mm)	Wall loops *w*	Force (N)
1.0	6	75.6
1.0	3	65.0
2.0	6	53.1
2.0	3	45.0

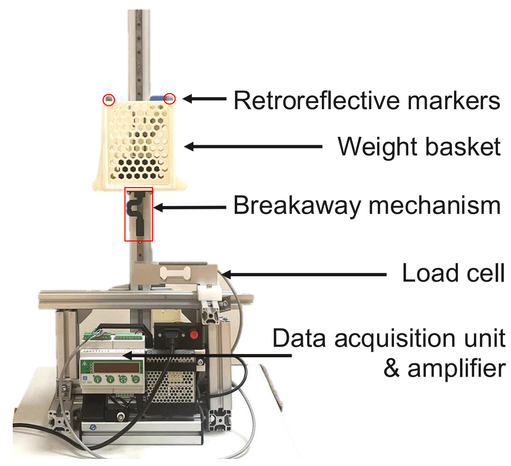


Figure 4: Drop test rig to measure breakaway force



Figure 5: Consistent failure point at the slot of the breakaway mechanism

5 Conclusion & Future Work

- We developed 3D-printable breakaway utensil attachment that reliably detaches under excessive force, enhancing safety in robot-assisted feeding.

Future work:

- Incorporate user-specific customization (e.g., based on comfort or pain thresholds)
- Evaluate breakaway performance with angled impacts and real robot use

Please refer to our paper for more details:

Reference:
[1] *ISO 15066 Robots and robotic devices* — Collaborative robots, International Organization for Standardization, 2016.

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NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE