Shells and Stages for Actuated TUIs: Reconfiguring and Orchestrating Dynamic Physical Interaction

By Ken Nakagaki, PhD thesis, 2021.

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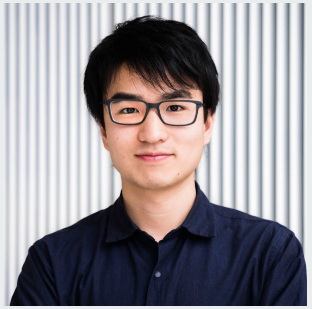

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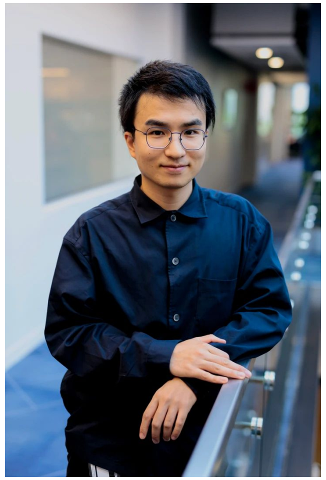

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研究方向 :

HCI、Actuated TUI、TEI

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Outline

- Abstract
- Introduction
- Background
- Mechanical Shell
- TRANS-DOCK
- HERMITS
- Stages: Physical Platforms
- Dis(Appearables)
- Discussion, Challenge and Future Work
- Conclusion

Abstract

Research on Actuated and Shape-Changing Tangible User Interfaces (TUIs) in the field of Human Computer Interaction (HCI) has been explored widely to design embodied interactions using digital computation has been explored widely. While advanced technical approaches, such as robotics and material science, have led to many concrete instances of Actuated TUIs, a single actuated hardware system, in reality, is inherently limited by its fixed configuration, thus limiting the reconfigurability, adaptability, and expressibility of its interactions.

In my thesis, I introduce novel hardware augmentation methods, Shells and Stages, for Actuated TUI hardware to expand and enrich their interactivity and expressibility for dynamic physical interactions. Shells act as passive mechanical attachments for Actuated TUIs that can extend, reconfigure and augment the interactivity and functionality of the hardware. Stages are physical platforms that allow Actuated TUIs to propel on a platform to create novel physical expression based on the duality of front stage and back stage. These approaches are inspired by theatrical performances, computational and robotic architecture, biological systems, physical tools and science fiction. While Shells and Stages can individually augment the interactivity and expressibility of the Actuated TUI system, the combination of the two enhances advanced physical expression based on combined shell-swaping and stage-transitioning. By introducing these novel modalities of Shells and Stages, the thesis expands and contributes to a new paradigm of Inter-Material / Device Interaction in the domain of Actuated TUIs.

- 在致動器(驅動器)的TUI 相關研究已經越來越多
- 但也因致動器受限的硬體被受限了互動方式
- 本論文提出 Actuated TUI (A-TUI) 新型態的互動方式
- 分別用Shells 與 Stages 兩個面向來探討
- Shells 扮演被動機械元件被依附於 Actuated TUI
- Stages 扮演物理平台，允許 Actuated TUI在平台上進行，並根據前台與後台的方式來創造新穎的物理表達。
- 兩個還可以合併成 shell-swaping與 stage-transitioning
- 這些新的TUI創造了一種Inter-Material (Device) 有助於 Actuated TUI 的範例研究

Abstract

The thesis demonstrates the concepts of Shells and Stages based on existing Actuated TUI hardware, including pin-based shape displays and self-propelled swarm user interfaces. Design and implementation methods are introduced to fabricate mechanical shells with different properties, and to orchestrate a swarm of robots on the stage with arbitrary configurations. To demonstrate the expanded interactivity and reconfigurability, a variety of interactive applications are presented via prototypes, ranging from digital data interaction, reconfigurable physical environment, storytelling, and tangible gaming. Overall, my research introduces a new A-TUI design paradigm that incorporates the self-actuating hardware (Actuated TUIs) and passively actuated mechanical modules (Shells) together with surrounding physical platforms (Stages). By doing so, my research envisions the future in which computational technology is coupled seamlessly with our physical environment. This next generation of TUIs, by interweaving multiple HCI research streams, aims to provide endless possibilities for reconfigurable tangible and embodied interactions enabled by fully expressive and functional movements and forms.

- 除了搭建Shell與Stages兩個基礎的Actuated TUI硬體，還包括 pin-based shape 顯示 與 self-propelled swarm 使用者介面
- 建構新的A-TUI設計典範以自驅動硬體、被驅動的機械模組
- 運用Actuated TUI讓下一代的TUI介面可透過多種HCI的研究方式建構有形與無形互動介面

1. Introduction

動機 Motivation

However, such research has been constrained by the limitations of the inherent physical hardware capability, as any physical devices have limitations in terms of actuation capabilities and hardware congurations (ex. degree of freedom, scalability, resolution or texture).

While one of the primary motivations for shape changing actuated interfaces is about developing generic platforms that can provide a versatile interactivity through motion and transformation, they still are limited by their form factor and device conguration built into the initial device.

- HCI的研究範疇受限於螢幕、物理限制、硬體能力限制等因素，像是自由度、可擴展性、解析度或材質，在各方面都有所限制。
- Actuated Interface 除了可以改變外型，更可以提供通用平台的方式進行互動，使原始的樣貌可以通過動態方式或轉化方式被改變。

目標 Goal

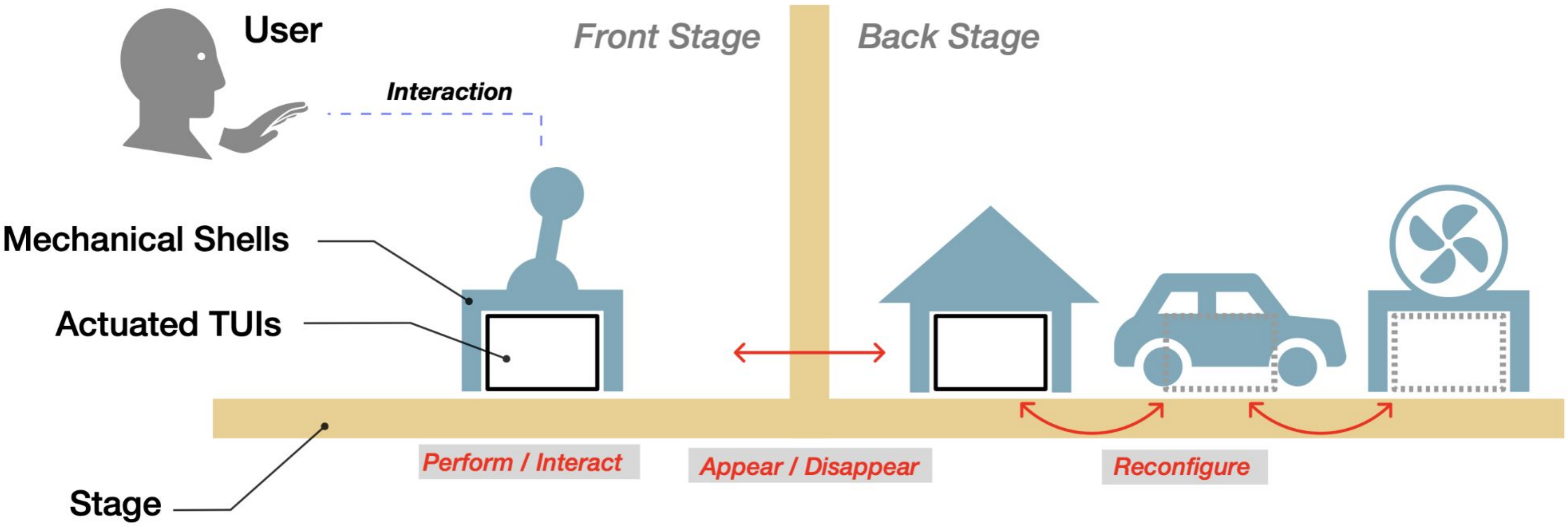
In this thesis, I propose and demonstrate novel hardware augmentation methods for Actuated TUIs including:

Mechanical Shells, external passive mechanical attachments, and Stages, physical surrounding platforms.

Stages are physical platforms for the Actuated TUIs to locomote on and to transition in-between Front and Back Stages.

- 創造一個Actuated TUI的增強型新硬體。
- Mechanical Shells是一個額外擴充的被動式元件可在Stages上存在。
- Stages是一個在Actuated TUI的物理平台，用於前台與後台之間的轉換。

1. Introduction



本身這一個框架(Framework)包括Stage與Mechanical

Stage 包含了Front Stage與 Back Stage

Mechanical Shells本身可以變換成不同樣子，像是房

子、搖桿、電扇...等

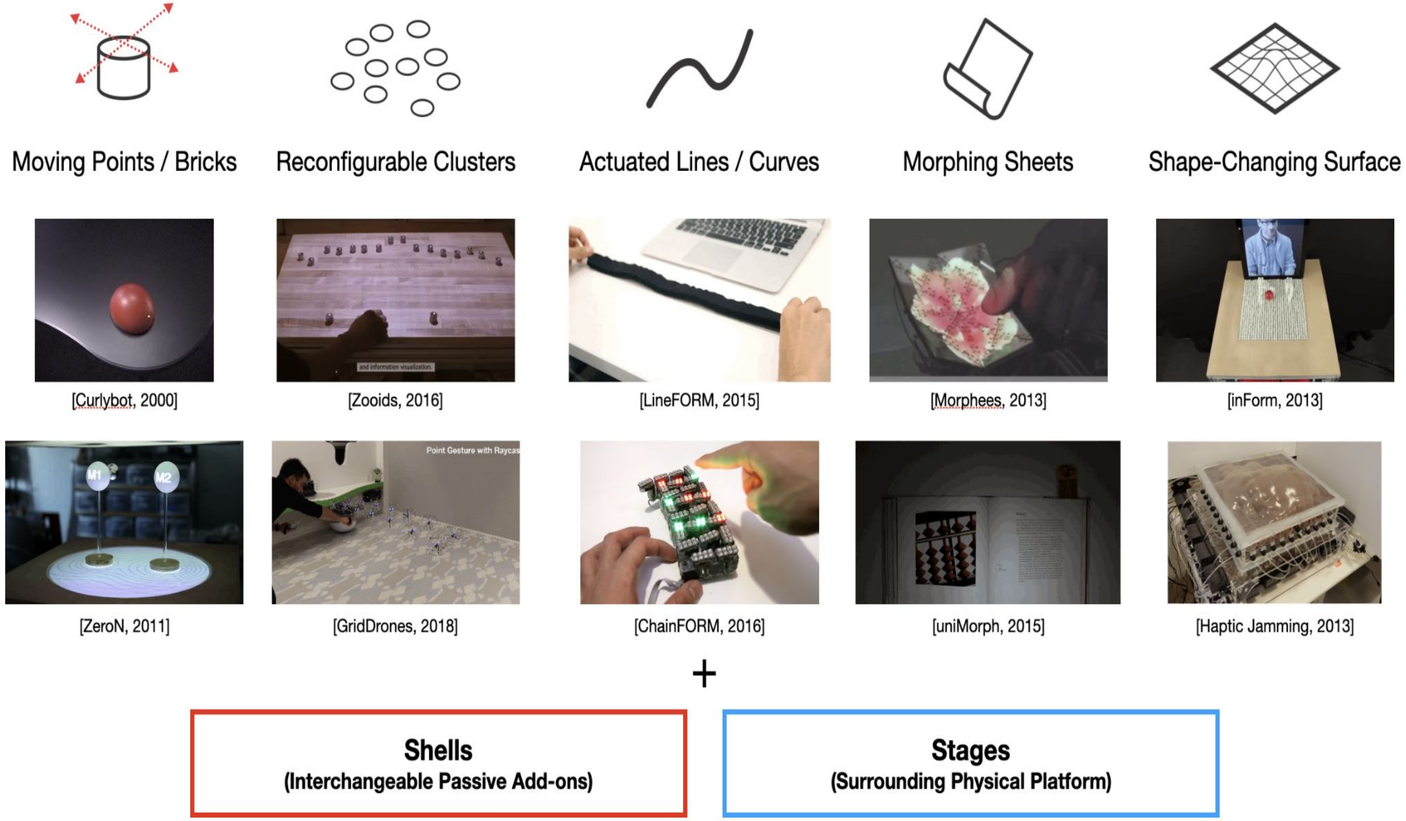
1. Introduction

貢獻 Contribution

1. 從下面的10個過去的研究，以及5種不同的TUI的互動介面，創造出Shells 與Stages 兩大核心成果

2. 提出四個不同的實際貢獻

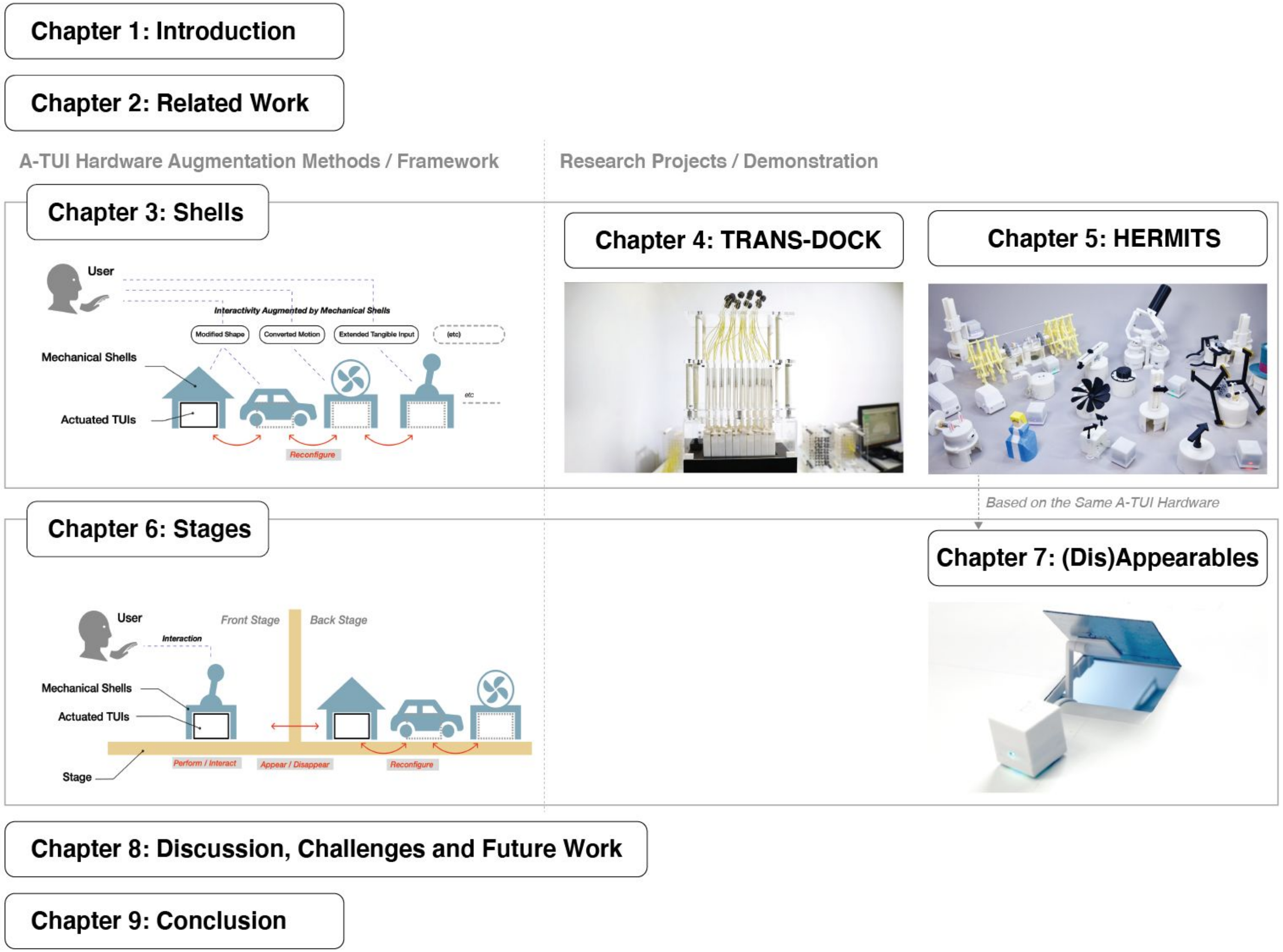
   a. 介紹什麼是Actuated TUI（A-TUI)硬體並可以轉化成Mechanical Shells與Stages
   b. 利用Shell與Stage的硬體實際做出三個應用案例:TRANS-DOCK、HERMITS、Dis/Appearables
   c. 討論並實際提出未來可供給研究者如何運用Shell與Stage進行設計與實作
   d. 為HCI與Actuated TUI研究領域奠定新的典範，可重新配置主動式機器人與被動式機械結構之間的相互作用



1. Introduction

論文架構 Outline

- Chapter 2 介紹 Actuated 與 Modular Tangible User Interface (例如Robotics)
- Chapter 3 說明 Mechanical Shell的增強硬體功能，對於A-TUI的被動機構相互作用
- Chapter 4 與 5 說明2個實作案例TRANS-DOCK、HERMITS
- Chapter 6介紹Stages的概念
- Chapter 7介紹(Dis)Apperables用於Stages的概念
- Chapter 8 討論Shell在於硬體增強相關的階段、挑戰、侷限性與未來性
- Chapter 9 結論



2. Background

Ubiquitous Computing, TUI, and Radical Atoms

- “Ubiquitous Computing”無所不在的計算，最早由Mark Weiser於1988年所提出，當電腦還很笨重的時候，他就認為計算機應被融合在環境之中。
- "Tangible User Interfaces (TUIs)"最早由Hiroshi Ishii與Brygg Ullmer於1997年所提出，他們認為數位資訊與物理物件融合再一起可被抓取、觸碰甚至操控，因此也創造了TUI研究領域。
- 世界上第一個研究Actuated TUI的是Gian Pangaro et al.在2002年所提出，當時他們運用電磁控制讓可觸控的突出物被制動成不同曲面。
- 在後來的Hiroshi Ishii教授於2012年提出了 “ Radical Atoms”的概念，使TUI介面往新的研究方向前進。
- 本篇論文也是基於Radical Atoms的概念進行延伸

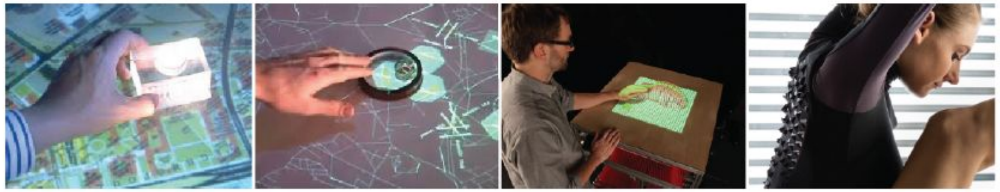
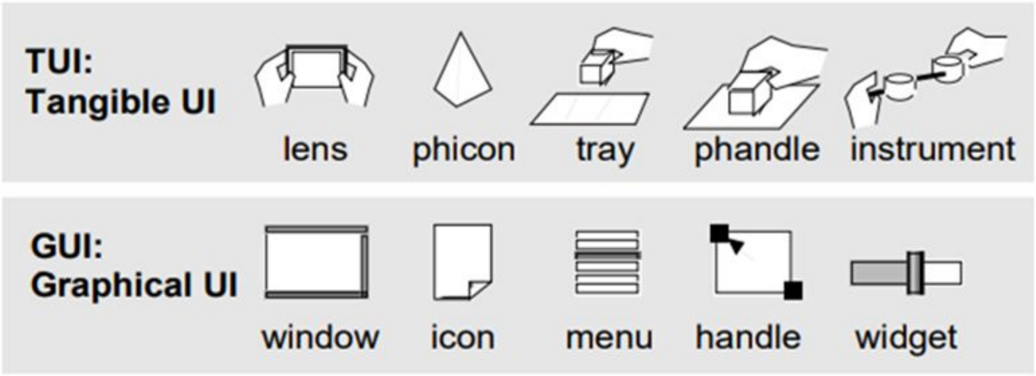


Figure 2-1: Research Related to TUI and Radical Atoms (metaDesk [160], PICO [111], inForm [33], and bioLogic [175])



2. Background

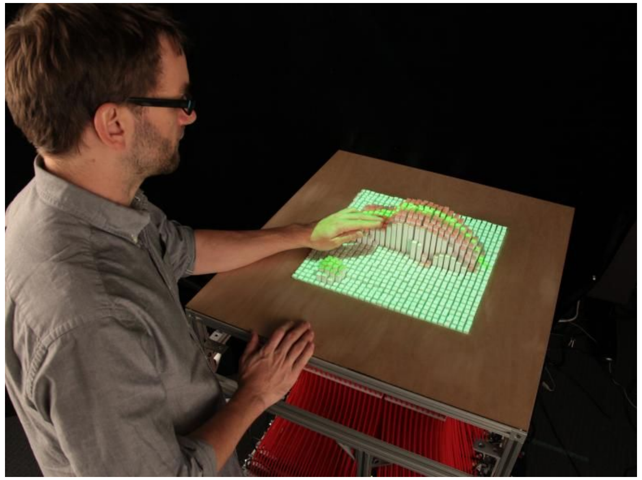
Two Major Approaches in Radical Atoms informing Shells

- "Active Machines"

  which employ self-powered and computationally controlled electromagnetic motors

  動作中的機械, 可自供電與可計算的控制電磁馬達

  → 作品 inFORM https://vimeo.com/145211058

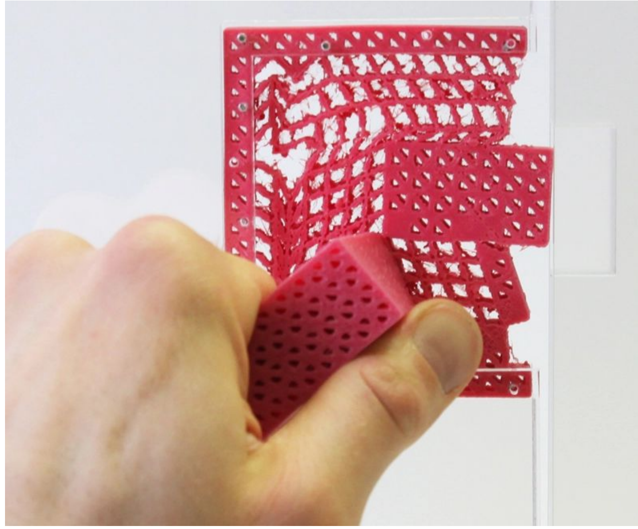


- "Passive Mechanical Structures"

  which make use of the inherent material structure and physical mechanisms that are set in motion by external forces, such as by user manipulation.

  由外力所驅動的材料結構與物理機構

  → 論文 Metamaterial Mechanism https://dl.acm.org/doi/10.1145/2984511.2984540
  https://www.youtube.com/watch?v=uHXqqO5Jj0A&t=1s



2. Background

Ambient Media and Spatial User Interfaces in-forming Stages

- “Ambient Media" (源自於 Tangible Bit 之中的重要概念之一)

  Ambient Media combines foreground tangible objects with an environment-based background or atmosphere that provides small bits of information as enriching context.

  ** A-TUI 也提供了foreground (interactive) 與 background (ambient) 讓使用者進行注意 **

  → 作品

  1. Topobo https://www.youtube.com/watch?v=50JdK_K2NWk&t=4s
  2. Printed Optics https://www.youtube.com/watch?v=eTeXTbXA6-Y
  3. Acoustruments https://www.youtube.com/watch?v=llOKDcr1gsY
  4. Kinetic Blocks https://www.youtube.com/watch?v=2PeCBrHgwo4

Figure 2-2: Interactive Devices Extended with Passive Tangible Objects (Topobo [115], Printed Optics [169], Acoustruments [73], Kinetic Blocks [125])

2. Background

Ambient Media and Spatial User Interfaces in-forming Stages

- "Robotics Modularity"

  Robotics, as a eld itself, is an interdisciplinary domain that develops physical systems that can locomote through actual environments and manipulate real objects.

  機器人學本身就是一個跨領域的學科，並且透過物理系統可以操控真實物體。

  ** A-TUI 也提以Robotics為基礎 **

  → 作品

  1. Programmable Matter https://makezine.com/article/science/claytronics-nanoscale-rob/
  2. m-Blocks https://www.youtube.com/watch?v=hI5UDKaWJOo
  3. Zooids https://www.youtube.com/watch?v=S36AusIvzrk
  4. omniSkins https://www.youtube.com/watch?v=I7ebM-Gcs-M

Figure 2-3: Modular, Reconfigurable and Swarm Robotics (Programmable Matter / Claytronics [39, 40], m-blocks [121], Zooids [74], omniSkins [13])

2. Background

My Research at the MIT Media Lab and Positioning of My Approach

- 作者本身進行過去7年來的比較，在MIT Media Lab所做的Actuated Tangible User Interface
- 最早的LineFORM與ChainFORM，如圖A, B
- 後來延伸出inFROM的多個不同應用，如圖C~F，作者本身透過創意玩出不一樣的內容
- 後來TRANSFORM的專案提供了動態、可適應的家具版本
  https://www.youtube.com/watch?v=lCARHatJQJA
- 激發作者提出AnimaStage的想像，並使用pin-base shape displays型式

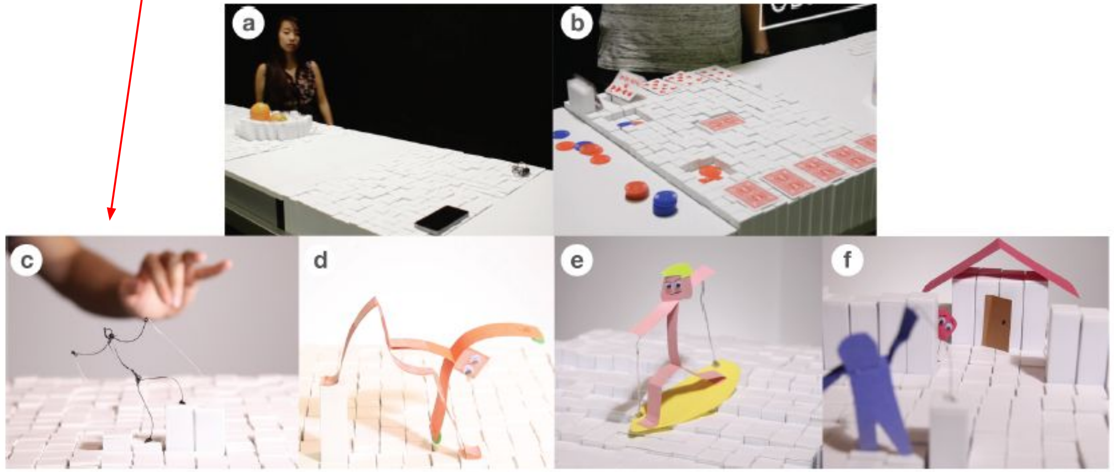


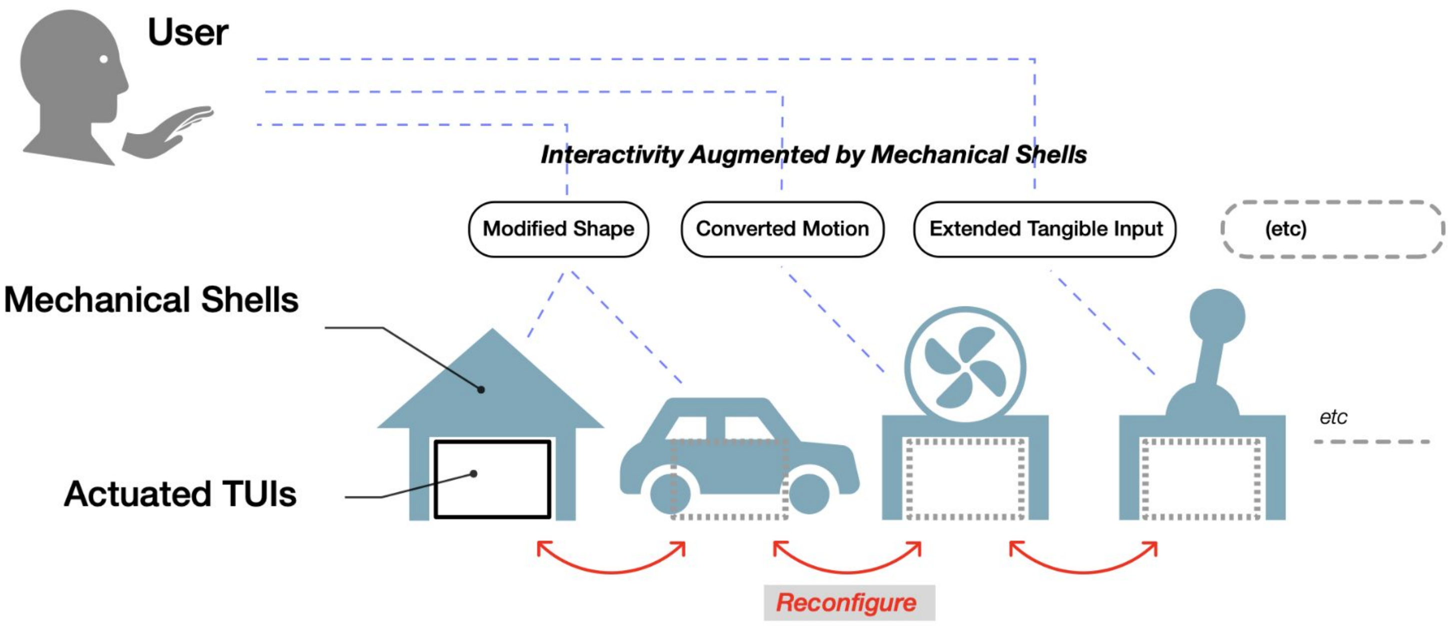
Figure 2-5: My prior research in inter-material interaction with A-TUIs that informs the concepts and methods proposed in this thesis (a, b: TRANSFORM as Adaptive and Dynamic Furniture [164], c-f: AnimaStage [99])

3. Mechanical Shell : Passive Mechanical Add-ons

Basic Concept :

I define the Mechanical Shell as “an external passive attachment to an existing actuated tangible interface that can be manually or automatically attached and detached, that can adaptively extend, convert and configure the hardware interactivity for versatile tangible applications."

作者直接定義，Mechanical Shell是一個外部的被動式 Actuated Tangible Interface外掛，它可以手動或自動被依附或解除並且自適應地可延伸、轉換、設定硬體的互動性與多樣化可觸應用。



Mechanical Shell
可被改變外型、增加動態、延伸
TUI的輸入方式…等

3. Mechanical Shell : Passive Mechanical Add-ons

Inspiration from Computer Architecture :

1. Shell名稱來自於電腦的計算機結構的核心架構 “Shell”，一個Unix作業系統最早由1960年代Louis Pouzin所提出的shell所使用至今，現代的作業系統仍然有shell指令模式加上”interface”的GUI介面，因此Mechanical Shell是一個如同機械shell的概念。

2. 除了shell，Mechanical Shell還融合了google chrome extension的擴充概念，在現有的瀏覽器功能上增加 add-ons

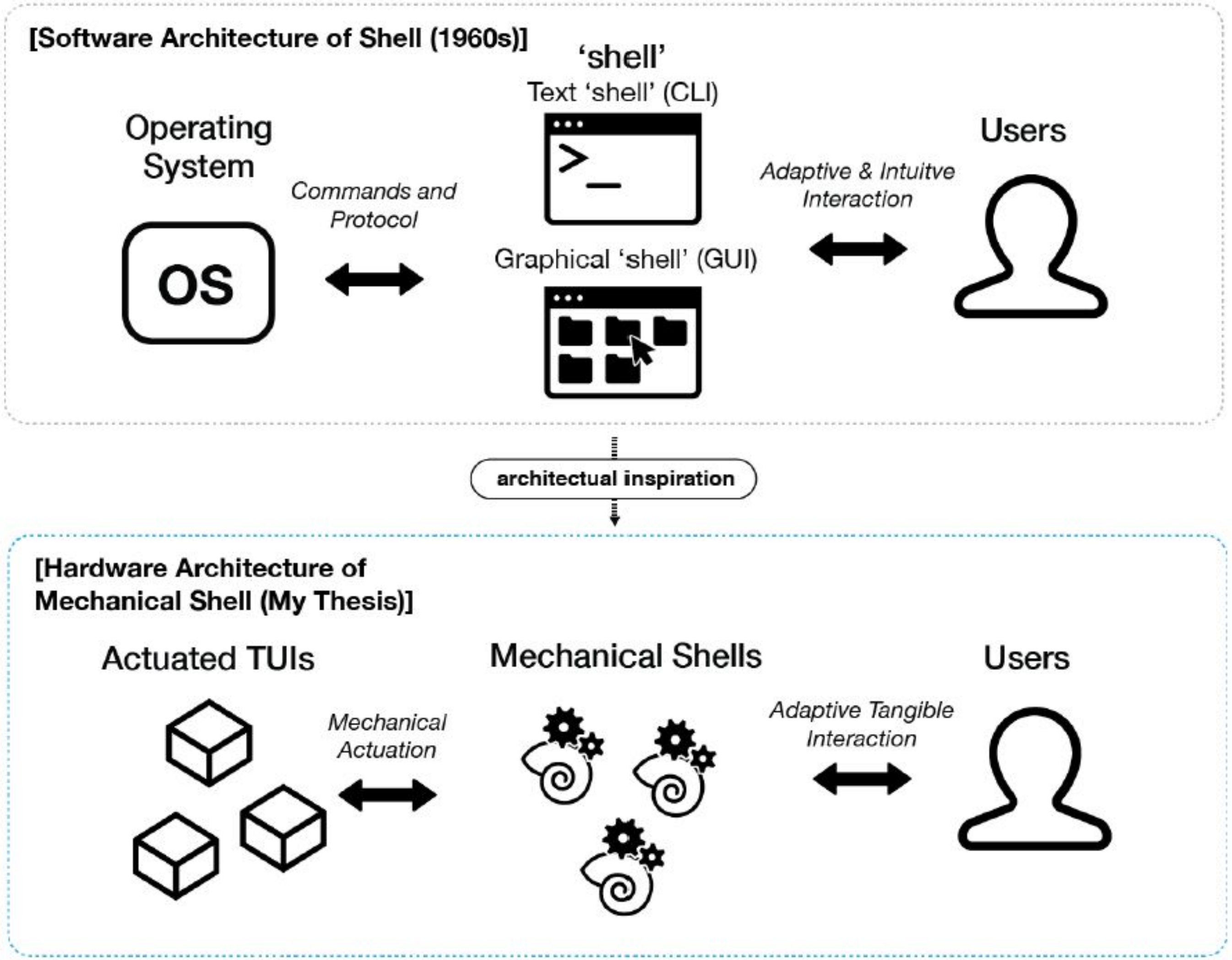
3. 此外，shell概念也借鏡了iOS或Andorid系統的 APP概念，每一個shell與A-TUI都可以是一個APP

Mechanical Shell融合了以下要素

1. OS的Shell
2. Chrome的add-ons
3. 手機的APP

3. Mechanical Shell : Passive Mechanical Add-ons

Inspiration from Computer Architecture :

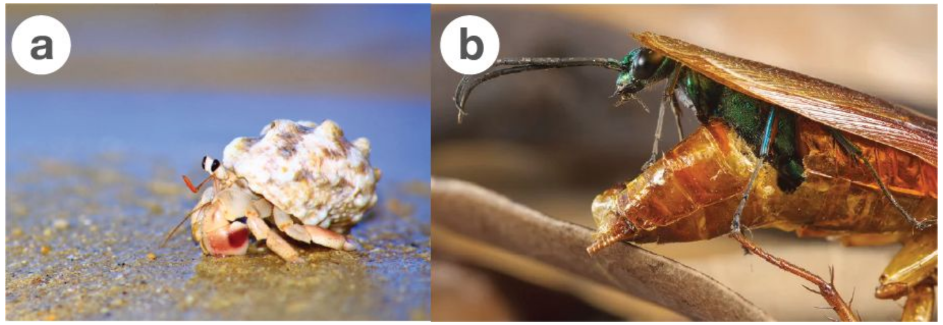


Mechanical Shell融合了以下要素

- 人與電腦透過shell + GUI進行互動
- A-TUI透過Mechanical Shells與人進行互動

3. Mechanical Shell : Passive Mechanical Add-ons

Inspiration from Biology :



a. **Hermit Crab 寄居蟹**
b. **cockroach**

Inspiration from Mechanical System :

a. **多頭鑽刀**
b. **動力機械裝置**
c. **動力裝置**
d. **土耳其機器人**
e. **特洛伊木馬**

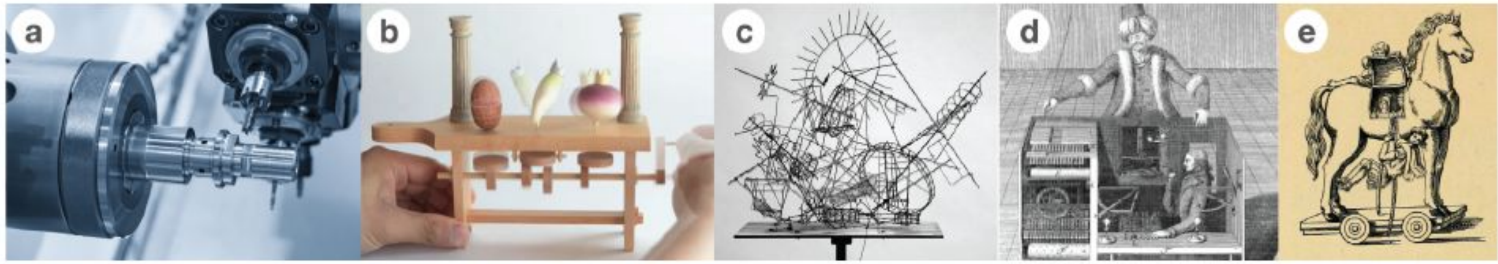


Figure 3-5: Inspiration for *Mechanical Shells* from Mechanical System (a. multi-tool machining center, b. mechanical automata by kazuaki harada [66], c. kinetic art by Arthur Ganson [38], d. mechanical turk, e. Trojan Horse)

3. Mechanical Shell : Passive Mechanical Add-ons

Inspiration from Everyday tools:

a. 電鑽組
b. SLR 單眼相機
c. 手工具
d. [Skeltonics Exoskeleton]

Figure 3-6: The inspiration for *Mechanical Shells* from everyday tools and human augmentation (a. electric drill and drill bits, b. camera and lenses, c. hand tools, d. Skeltonics Exoskeleton [23]).

Inspiration from Human Augmentation :

a. 機動戰士鋼彈
b. 新世紀福音戰士
c. 進擊的巨人
d. 攻殼機動隊

Figure 3-7: The inspiration for *Mechanical Shells* from Sci-Fi (a. Mobile Suit Gundam, b. Neon Genesis Evangelion, c. Attack on Titan, d. Ghost in the Shell).

3. Mechanical Shell : Passive Mechanical Add-ons

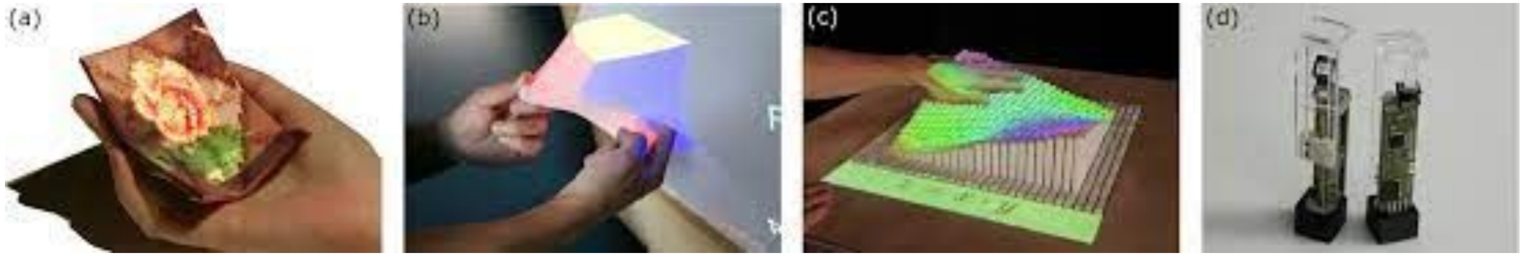
Roles and Benefits of Mechanical Shells

角色以及優點

1. Adaptation for Human Interaction (Display / Affordance ） 可作為展示或可用性
2. The Versatility of Functionalities (Task and Locomotion ） 多任務與多功能性（任務與動作）
3. Other Logistical Utilities 邏輯性工具

以下四個案例為Mechanical Shell的過去相關研究

[Grand Challenges in Shape-Changing Interface Research]



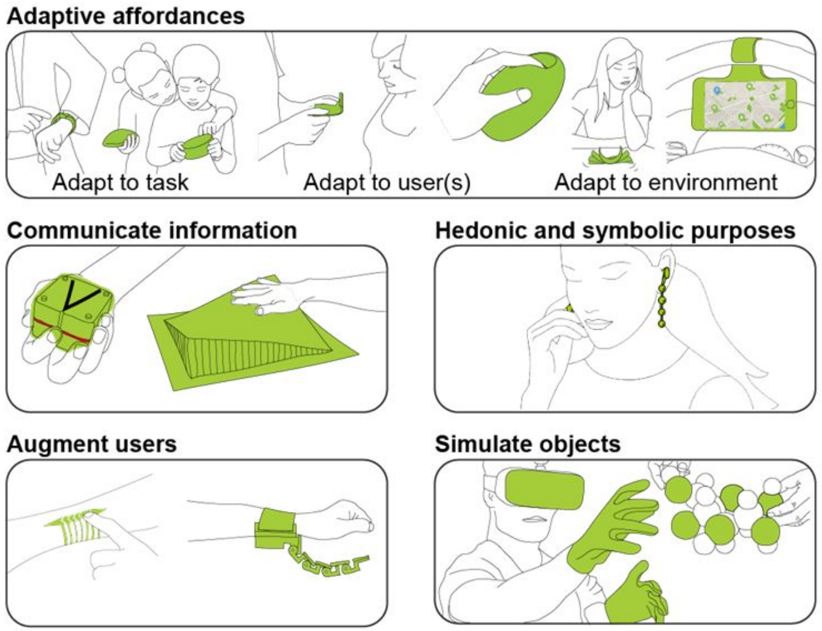
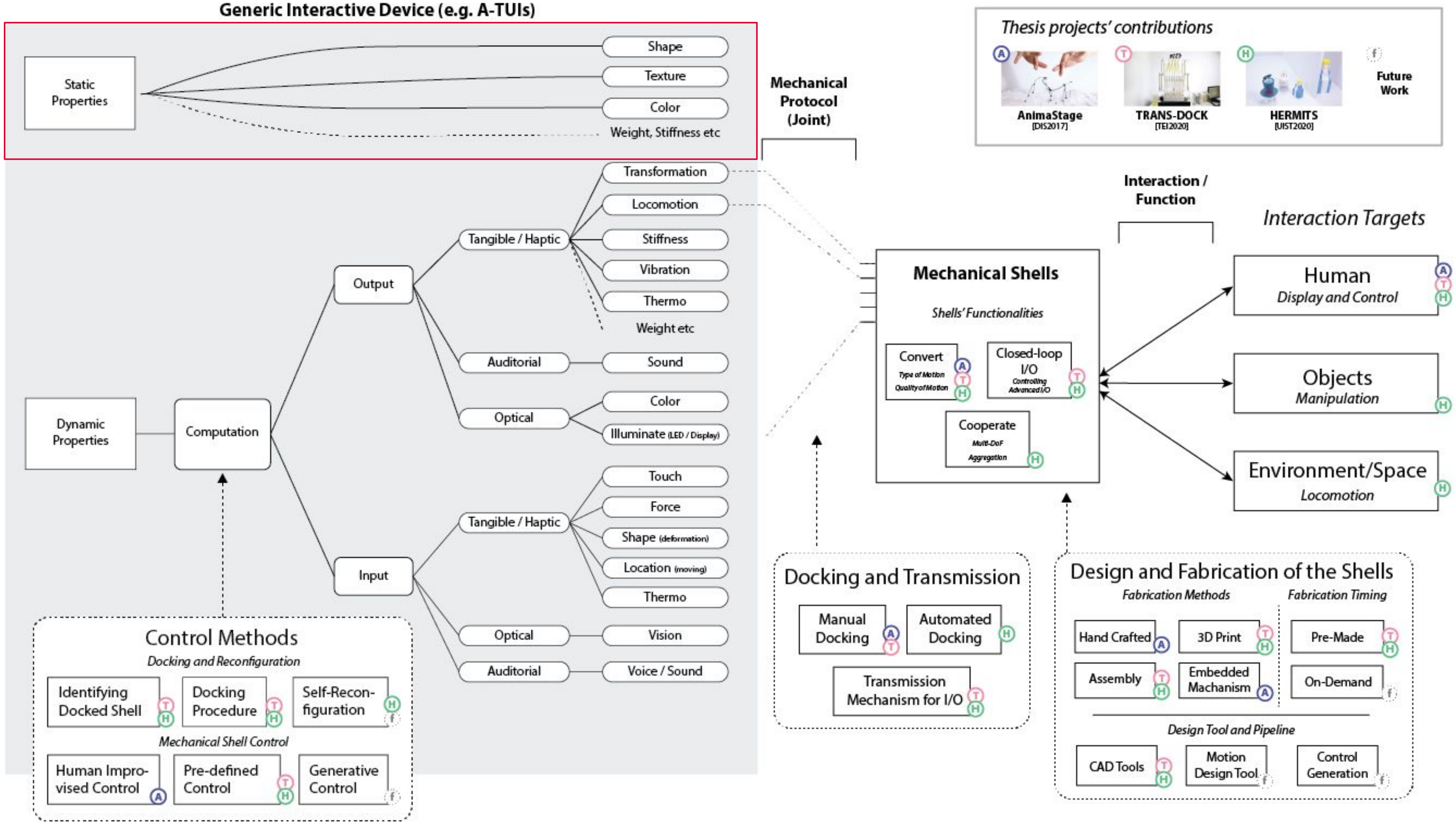


Figure 2. Five purposes of shape changes in end-user interactive devices.

3. Mechanical Shell : Passive Mechanical Add-ons

Design Framework and Implementation Strategy

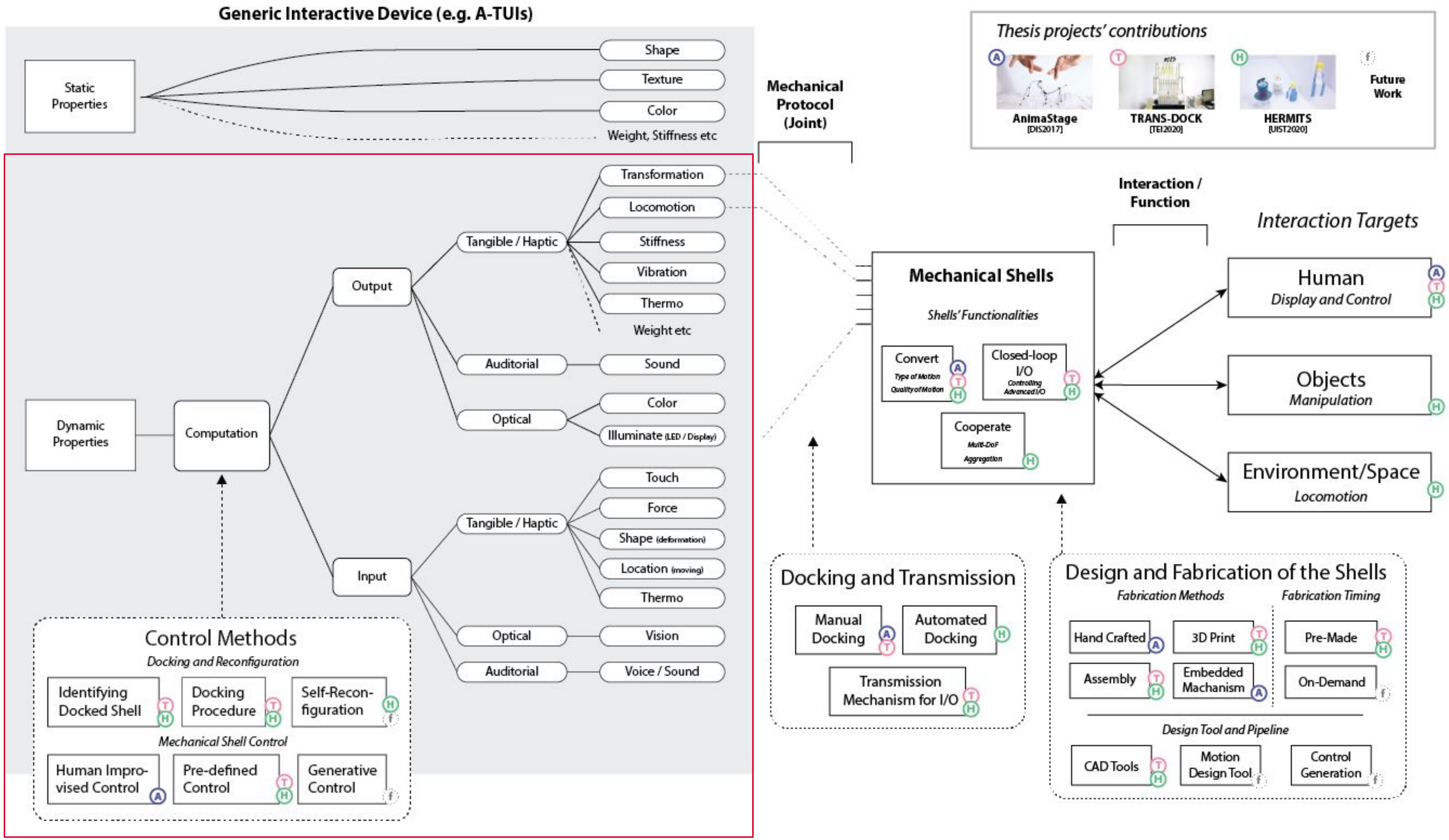


分成靜態、動態兩種

- 靜態：外型、材質、顏色、重量...等
- 動態：輸入與輸出兩大內容
  - 輸入：觸覺、光學、聲音的、觸碰、運動
  - 輸出：震動、聲音、光學、變形
- Mechanical Shell可結合不同A-TUI跟外型進行動態或靜態的結合作展示

3. Mechanical Shell : Passive Mechanical Add-ons

Design Framework and Implementation Strategy



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3. Mechanical Shell : Passive Mechanical Add-ons

Mechanical Shell Functionalities

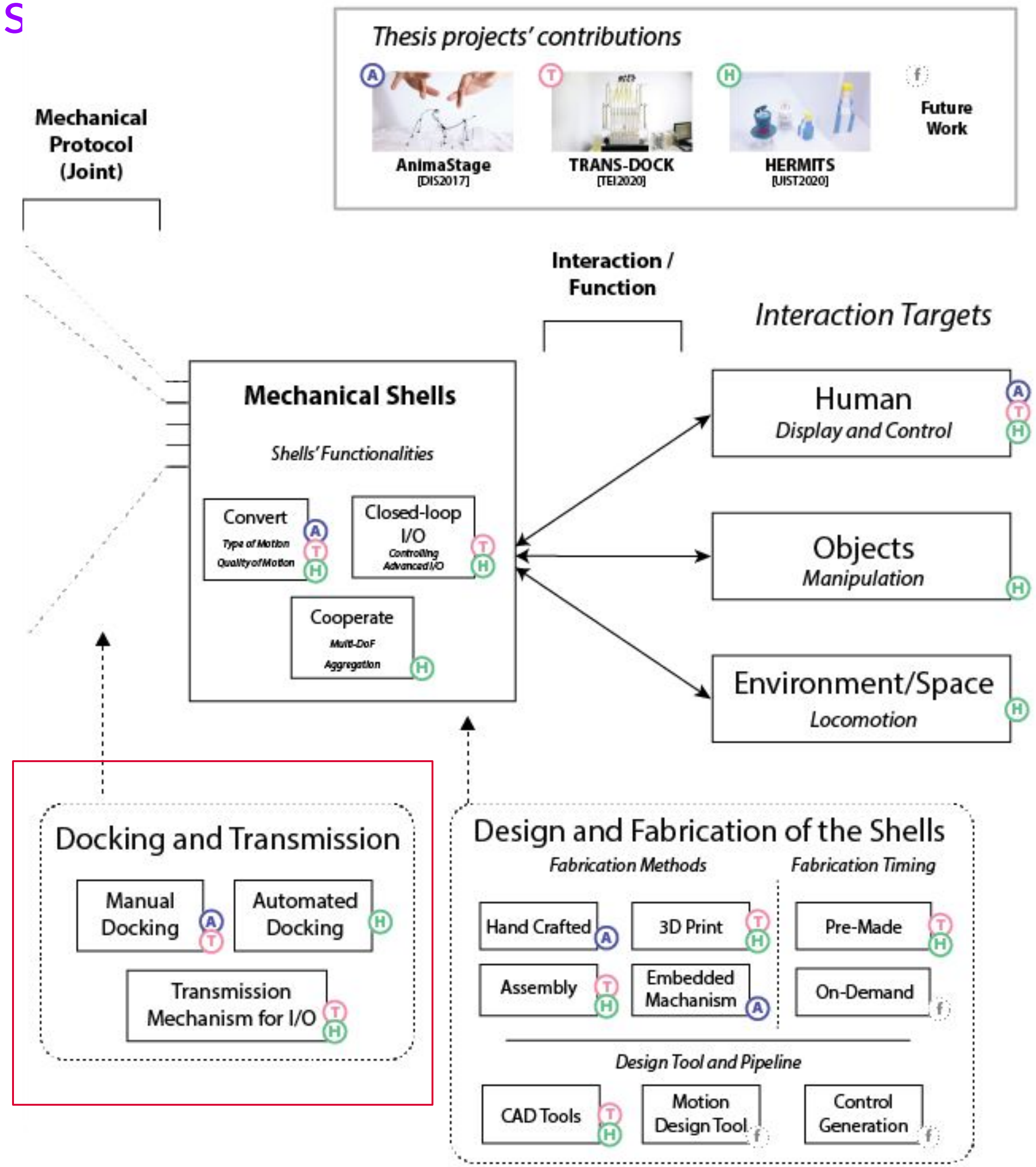
1. Docking and Transmission
2. Design and Fabrication of Shells
3. Interaction Target
4. Control Methods

** 功能基本具備駐足與傳輸、可設計與數位自造的shells、互動目標以及控制功能 **

數位自造包含了手工藝、3D列印、CAD 工具...等

Mechanical Shell包含了三個案例產出 :

a. AnimaStage
b. TRANS-DOCK
c. HERMITS



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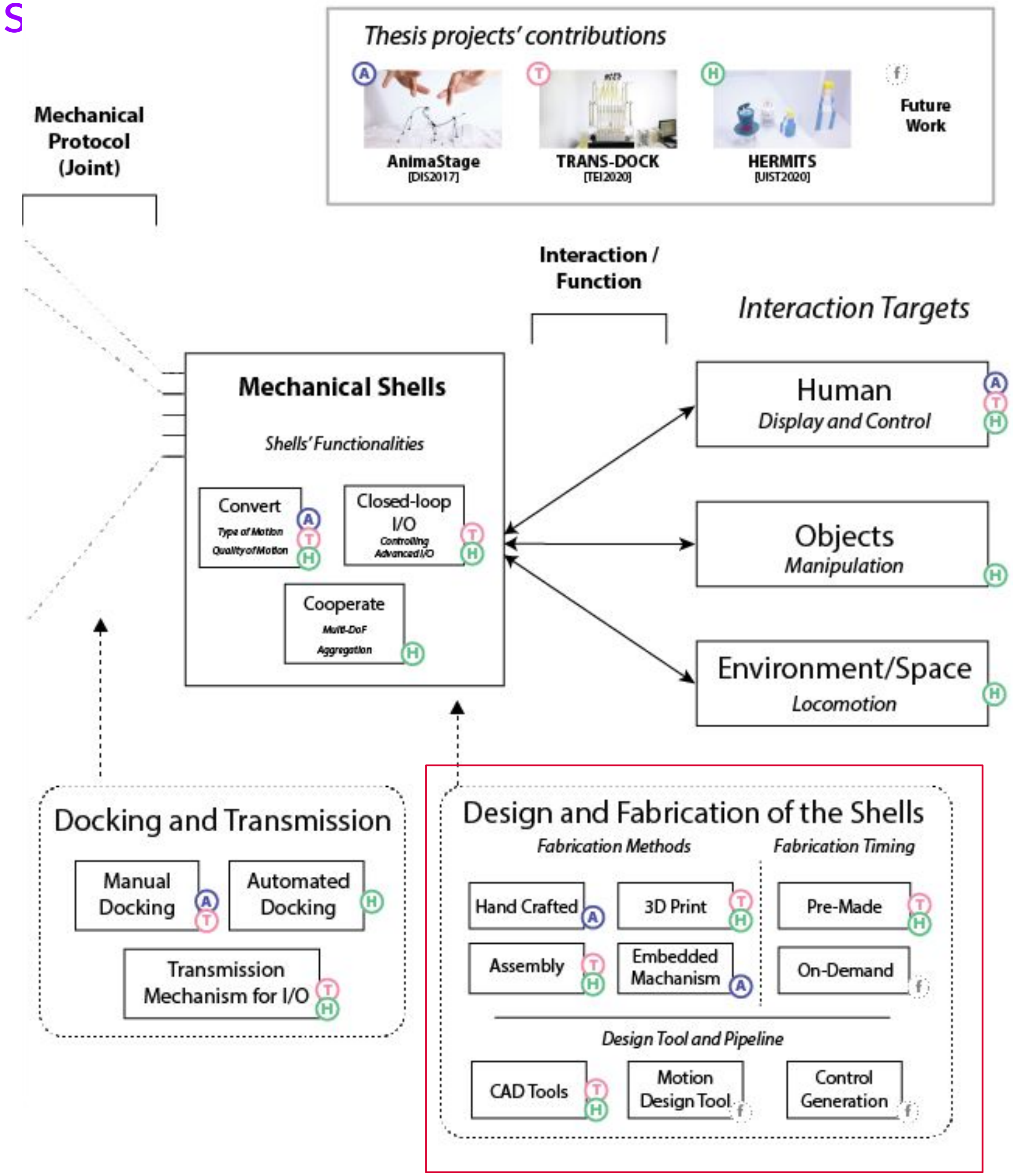

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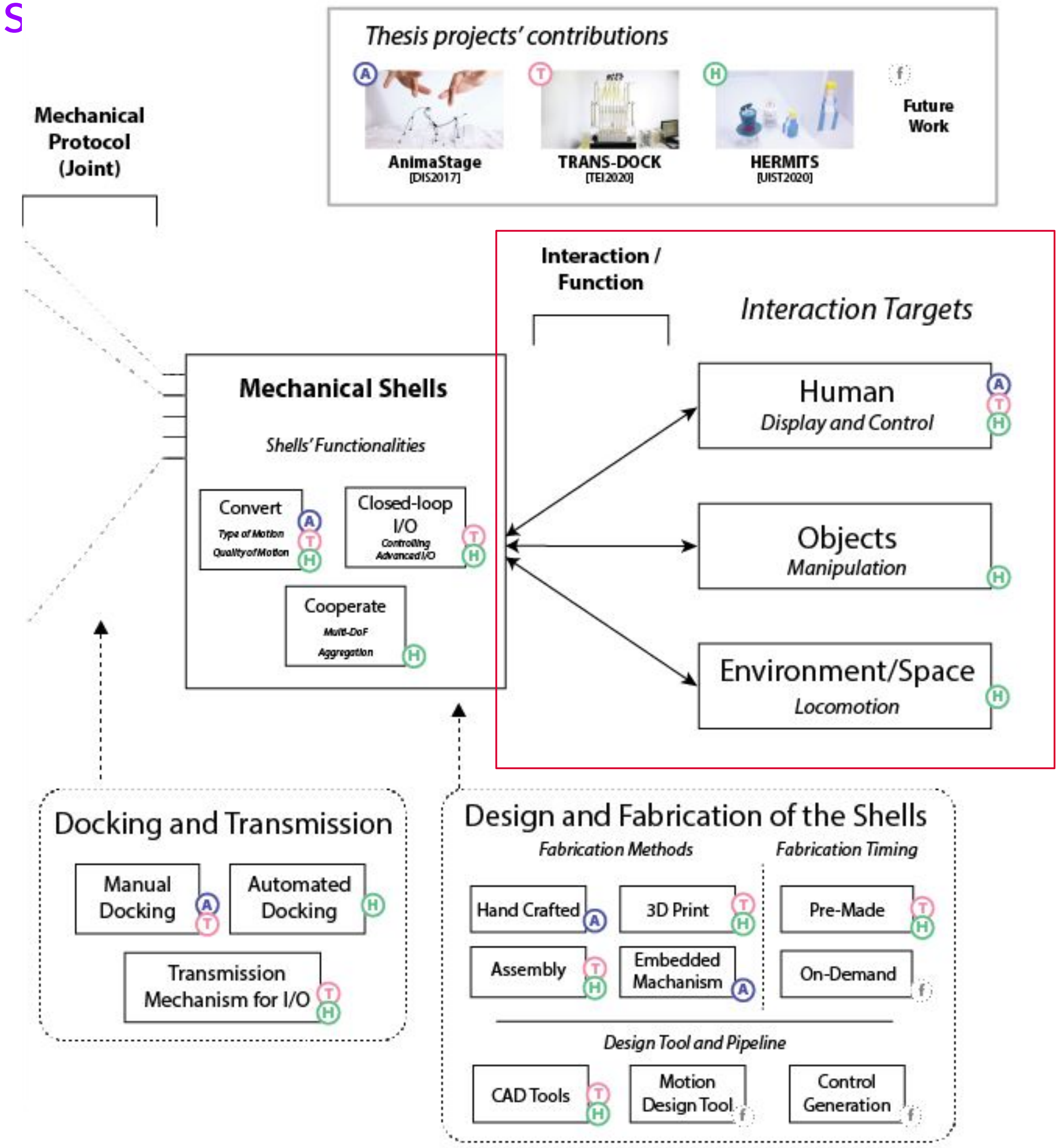

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Mechanical Shell Functionalities

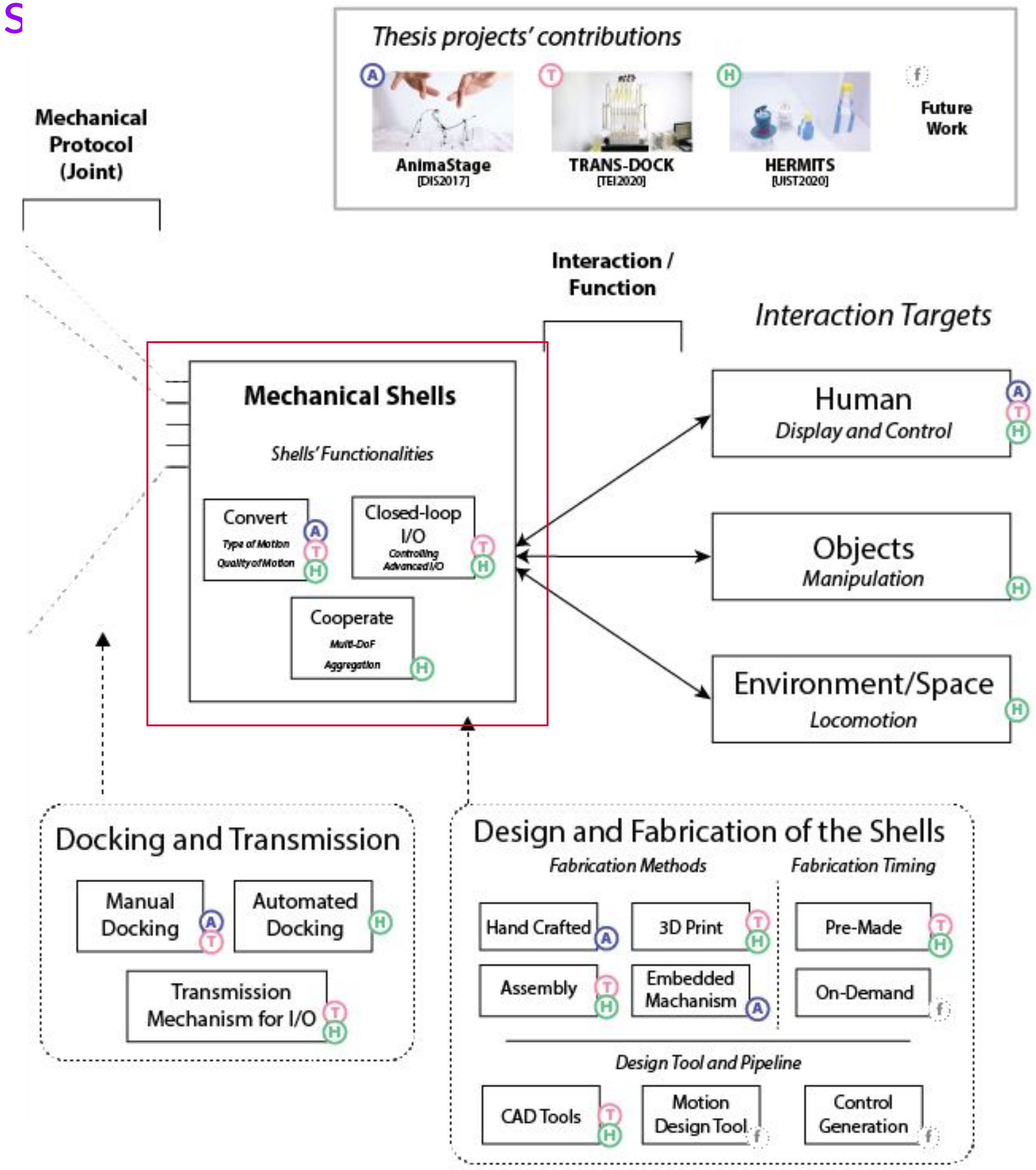
1. Docking and Transmission
2. Design and Fabrication of Shells
3. Interaction Target
4. Control Methods

** 功能基本具備駐足與傳輸、可設計與數位自造的shells、互動目標以及控制功能 **

數位自造包含了手工藝、3D列印、CAD 工具...等

Mechanical Shell包含了三個案例產出：

a. AnimaStage
b. TRANS-DOCK
c. HERMITS



3. Mechanical Shell : Passive Mechanical Add-ons

Mechanical Shell Functionalities

1. Docking and Transmission
2. Design and Fabrication of Shells
3. Interaction Target
4. Control Methods

** 功能基本具備駐足與傳輸、可設計與數位自造的shells、互動目標以及控制功能 **

數位自造包含了手工藝、3D列印、CAD 工具...等

Mechanical Shell包含了三個案例產出：

a. AnimaStage
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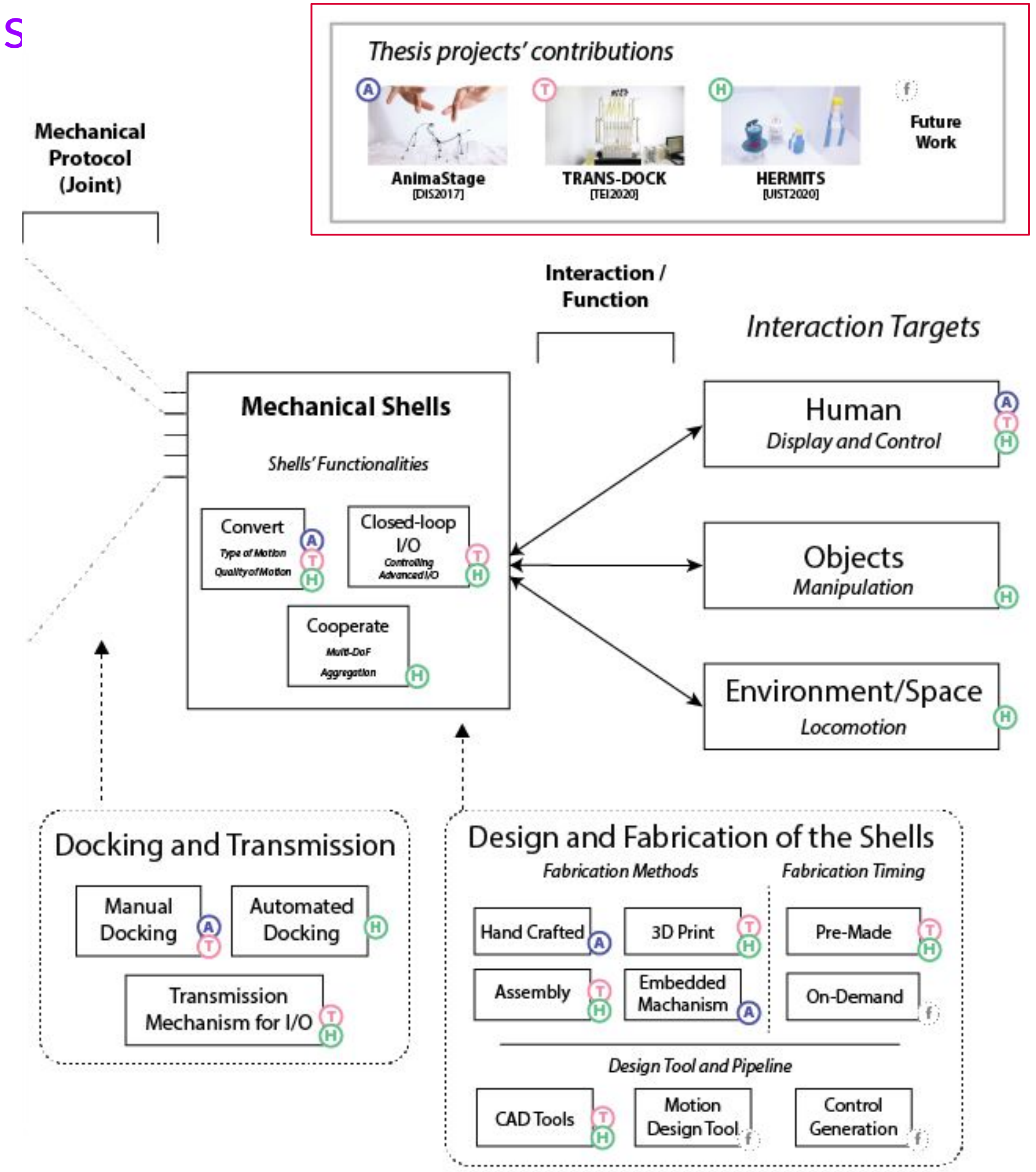


4. TRANS-DOCK

- **TRANS-DOCK a docking system for pin-based shape**
- **Shape Changing Interfaces → 在TUI的領域常因外型與物理特性進行變化**
- **目標有三個功能:**
  - expressibility 表現功能
  - adaptability 適應性
  - customizability 客製化

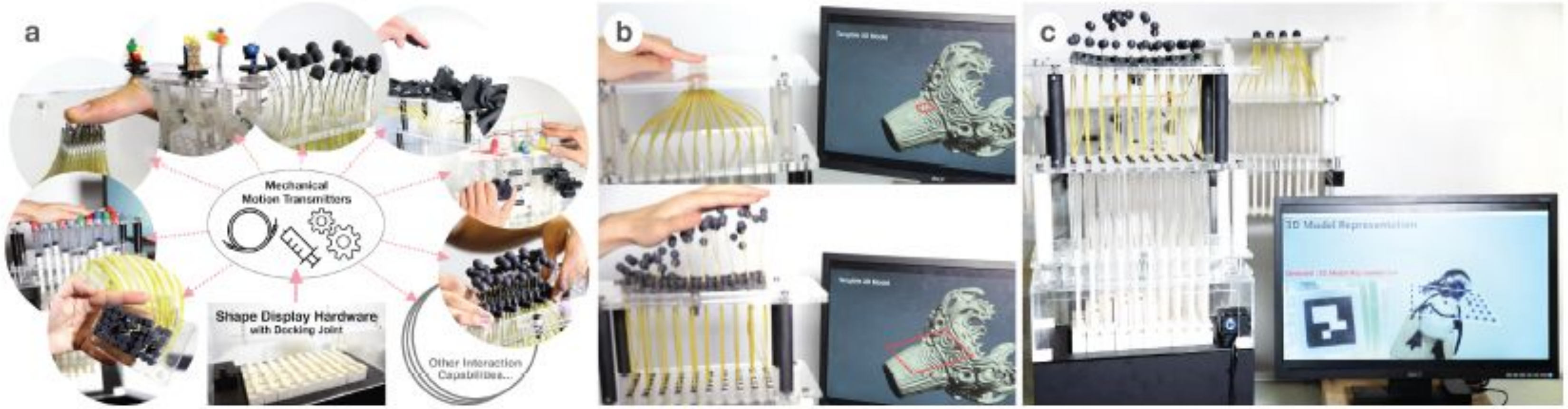


Figure 4-1: TRANS-DOCK: *Mechanical Shells* for Pin-based Shape Display.

4. TRANS-DOCK

- **TRANS-DOCK, I refer to the Mechanical Shell as “transducers" or “mechanical transducers" in the writings and gures, as it was originally defined in our published paper . While transducers are used to be intended for motion transmission system, the dened concept largely overlaps with Mechanical Shells.**

TRANS-DOCK的概念如同一個"轉換器"或是稱之為"機械轉換器"，用於輔助Mechanical Shell的整個轉換系統

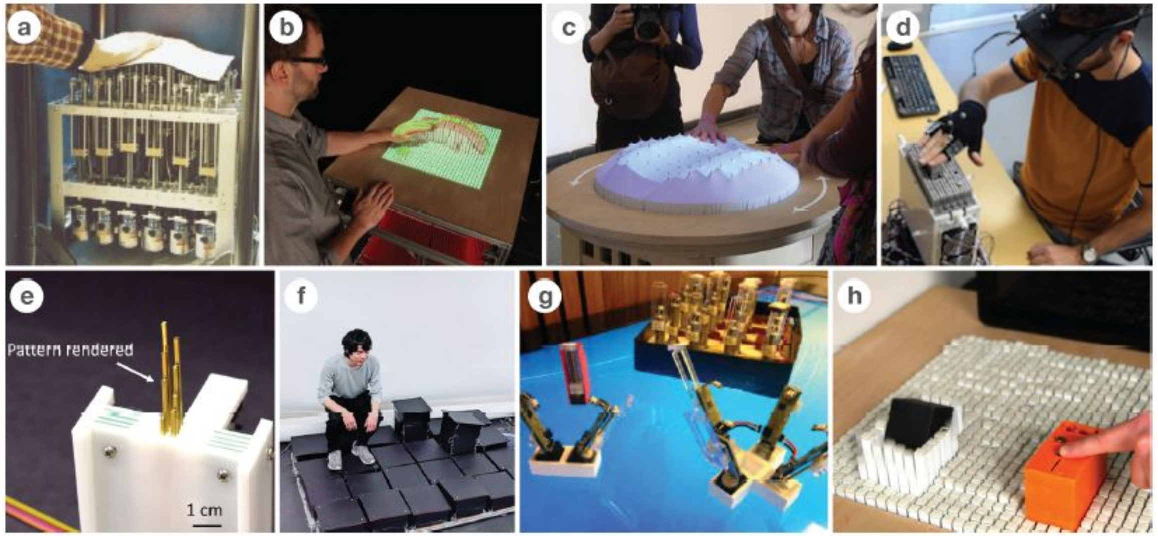


Figure 4-2: Related Work of TRANS-DOCK (a. FEELEX [55], b. inForm [33], c. Relief [79]), d. ShapeShift [131], e. High Resolution Shape Displays [178], f. LiftTiles [142], g. ShapeClip [47], h. KineticBlocks [125])

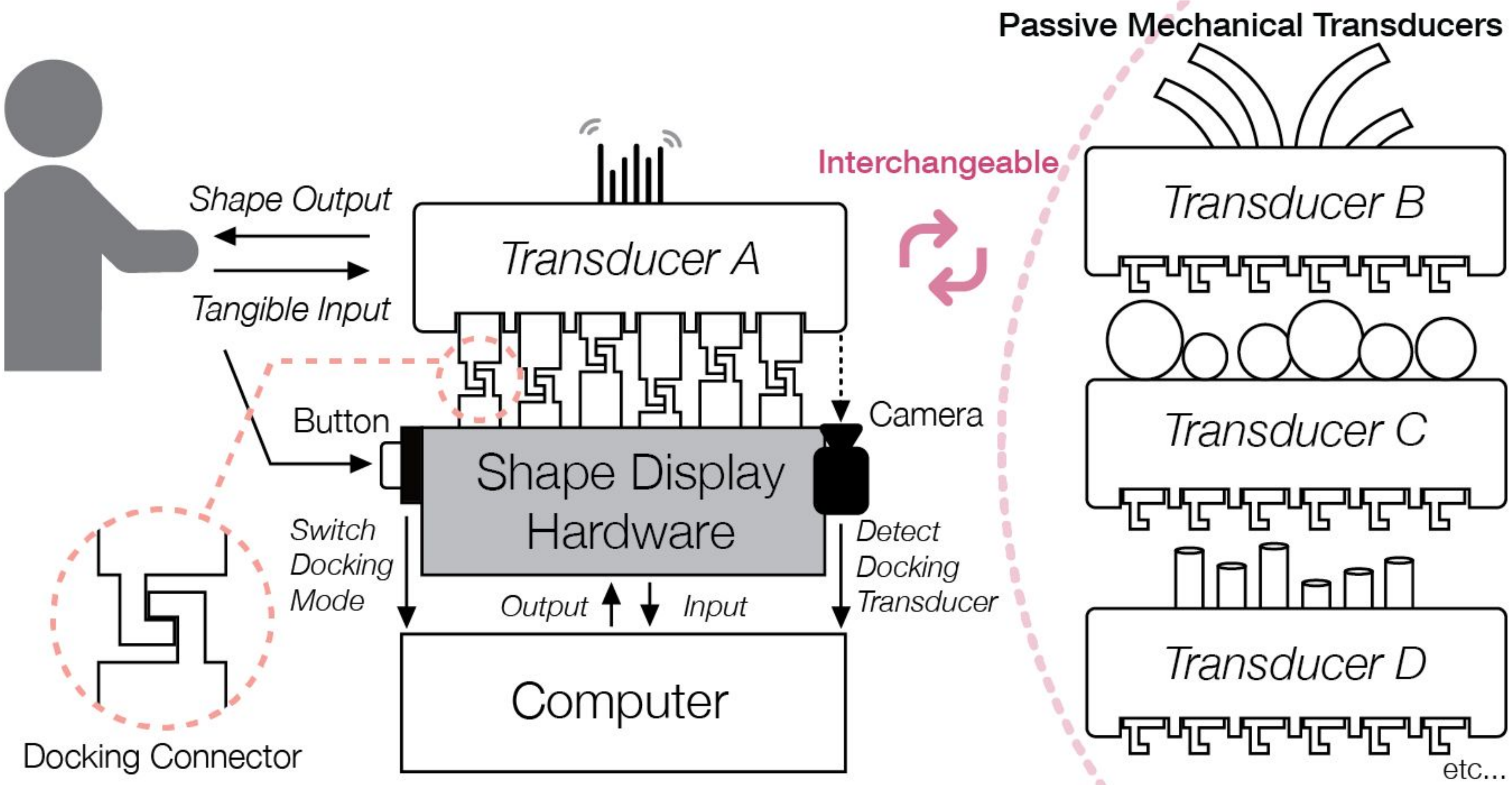
ShapeShift : https://www.youtube.com/watch?v=1fV-B0E9rP4&t=1s

4. TRANS-DOCK

- **TRANS-DOCK Overall Design**

Transducer, shape display, computer, camera and button

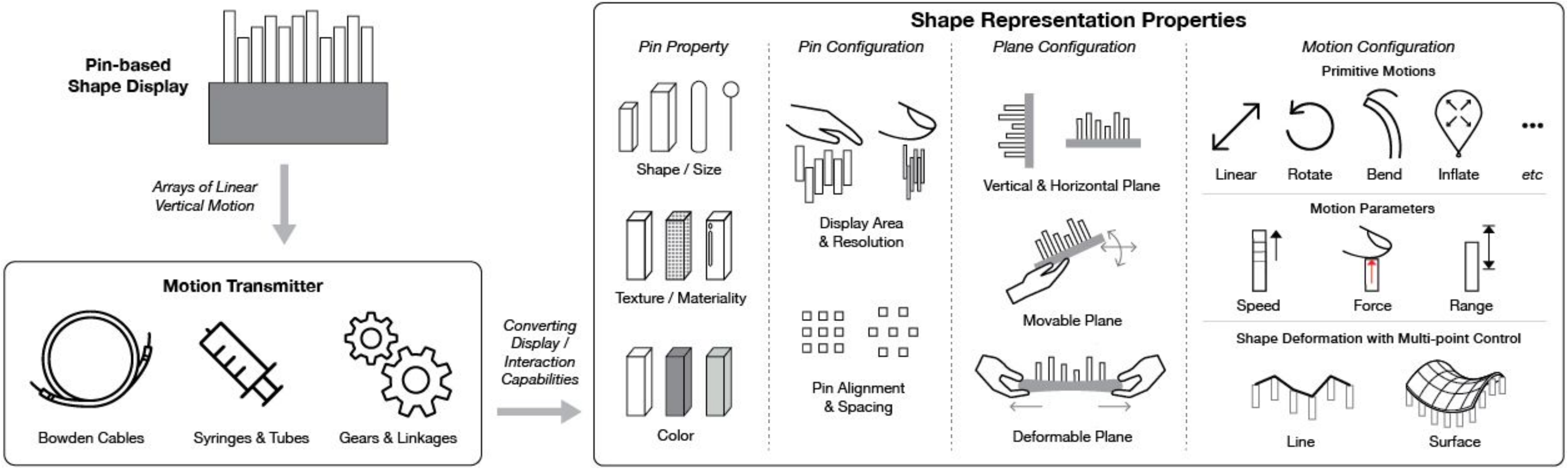
轉換器包括了外型顯示器、攝影機、電腦、按鈕...等組成



4. TRANS-DOCK

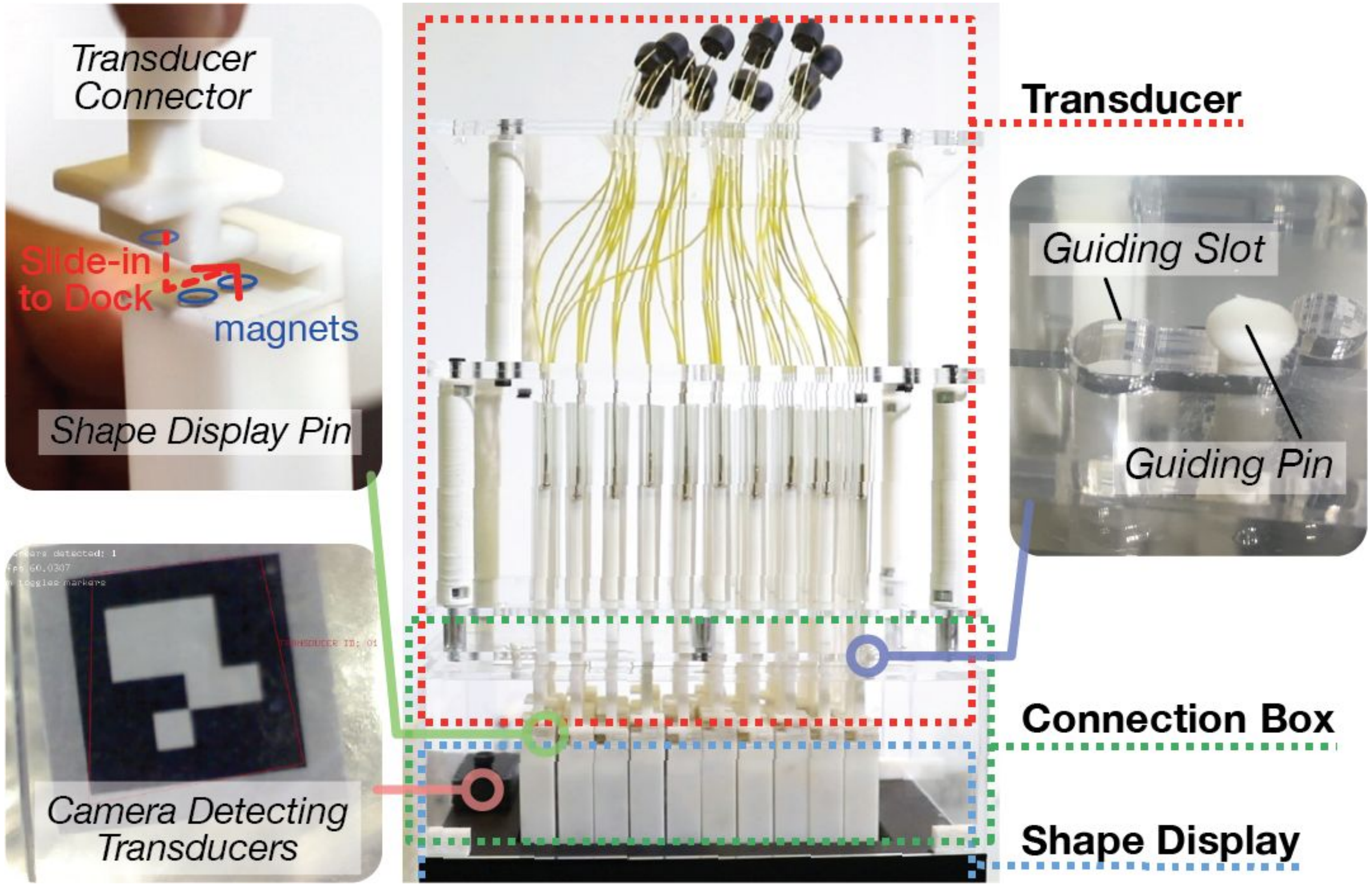
- **TRANS-DOCK Overall Design**

Transducer 轉換器裡面的Pin-based Shape Display 的組成透過氣管、注射系統、尺輪組等所構成，可以透過 pin property 進行不同的大小、材質、顏色等進行感應，pin本身也可以"被設置 Configuration"，甚至有垂直、水平的設置，移動的或形變得設置。這些不同的形變運用都影響這著 TRANS-DOCK的設計



4. TRANS-DOCK

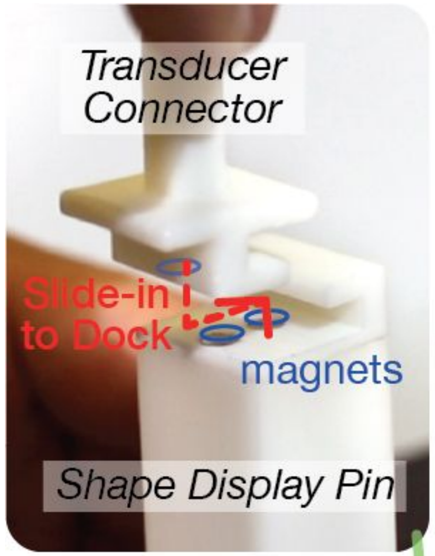
- **TRANS-DOCK Shape Representation Properties**
  - **Pin Properties**
    - **shape**
    - **size, texture**
    - **materiality**
    - **color**
  - **Pin Configuration**
    - **Display area**
    - **resolution**
  - **Plane Configuration**
    - **horizontal**
    - **vertical**
    - **movable**
    - **deformable**
  - **Motion Configuration**
    - **horizontal**
    - **diagonal**
    - **rotary motion**
    - **bending motion**
    - **inflation**
    - **surfaces**

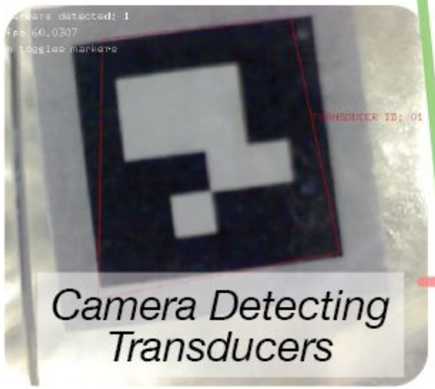


4. TRANS-DOCK

- **TRANS-DOCK Implementation**
  - **Pre-developed Shape Display Hardware**
    - **基於inFORCE的硬體, 10 x 5pins 的數量進行實驗**
    - **每一個pins尺寸為19.2的方柱體, 並且每一個方柱體間格0.8mm**
    - **總共可顯示200 x 100 mm 顯示區域**
  - **Joint Docking System**
    - **dock採用一種連結器進行銜接, 可快速用磁力進行扣緊**
    - **連結器的單元保險範圍在50組的pins進行, 多組的系統要進行拆分**
  - **Force Transmission Efficiency**
    - **在每一個pin都可以承受一定的按壓壓力, 壓力的最大連續壓力與最小壓力公式如下:**

$$F_{SD} > F_s^{max} + F_{ex} + (F_{touch})$$





FSD 為顯示區域的制動力之最大連續壓力, 應大於 Fmax + Fex + Ftouch(最大值、額外顯示、壓力 值)

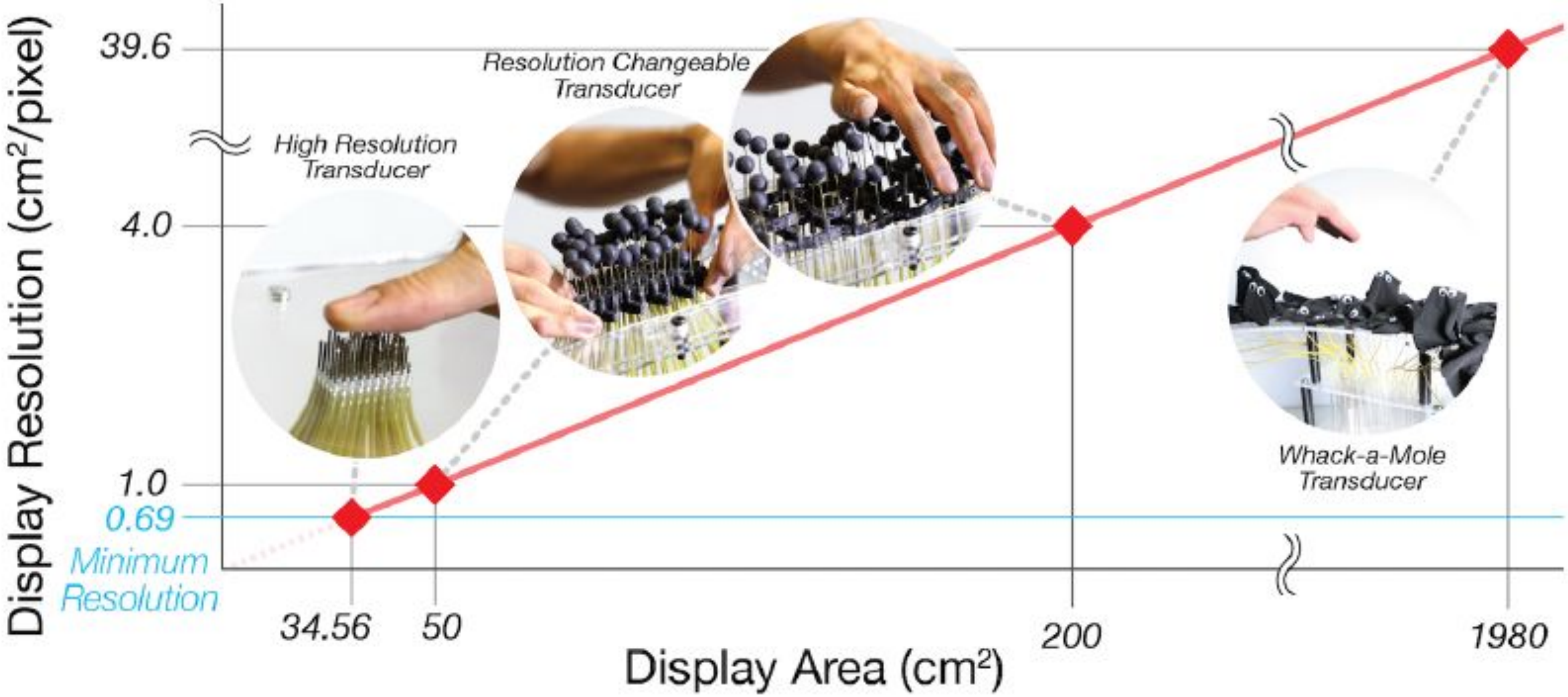
4. TRANS-DOCK

- **TRANS-DOCK Display Area vs Resolution**

Motion Transmitters	*Types of Enabling Motion*	**Transmission Efficiency** For Force I/O	**Compactness** For Resolution and Bulkiness	**Flexibility** For Arrangibility and Movability	**Durability** For Robustness
Bowden Cables	Bend	*[Push]* Poor *[Pull]* Good	Good	Good	Fair
Gears & Linkages	Linear (*Direction can be Changed*) Rotate	Good	Poor	Poor	Fair
Syringes & Tubes	Inflate	Fair	Fair	Good	Poor

4. TRANS-DOCK

- **TRANS-DOCK Display Area vs Resolution**
  - **顯示區最小區域34.56平方公分**
  - **最佳區域為200平方公分**
  - **最大顯示區域為1980平方公分**



4. TRANS-DOCK

- **TRANS-DOCK 的Transducers with General Functionalities**
  - **a~c. 高解析度傳動模式**
  - **d~e. 球體或可移動平面**
  - **f~h. 可敘事用或資料實體化的模式**

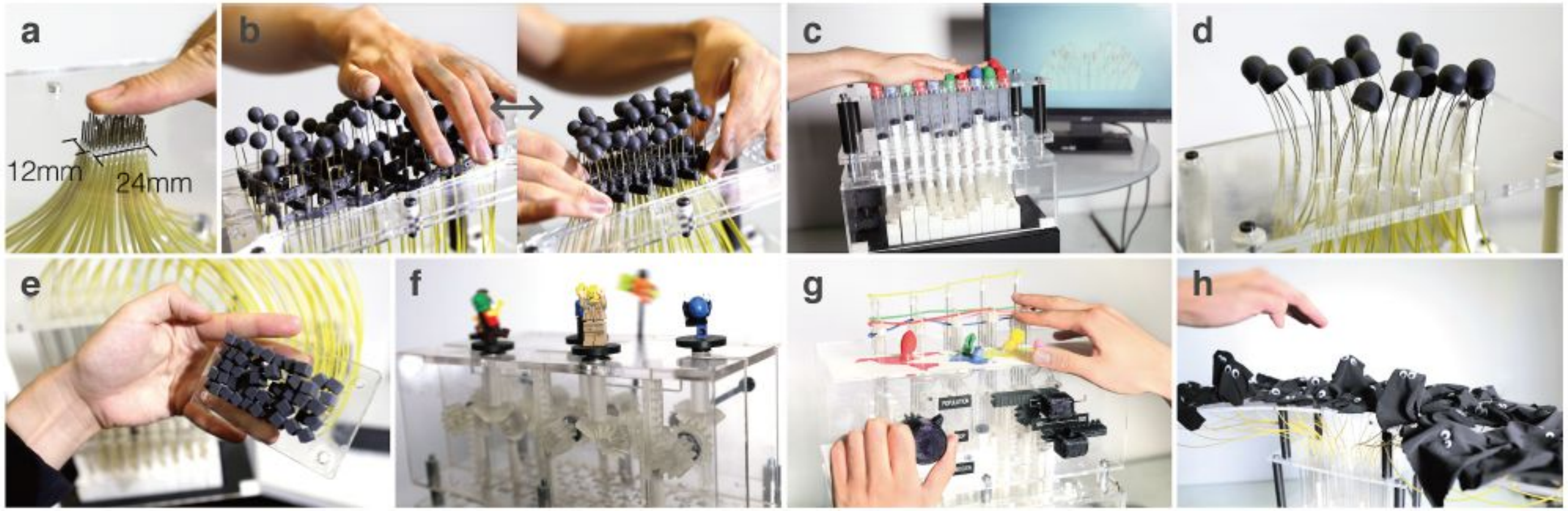
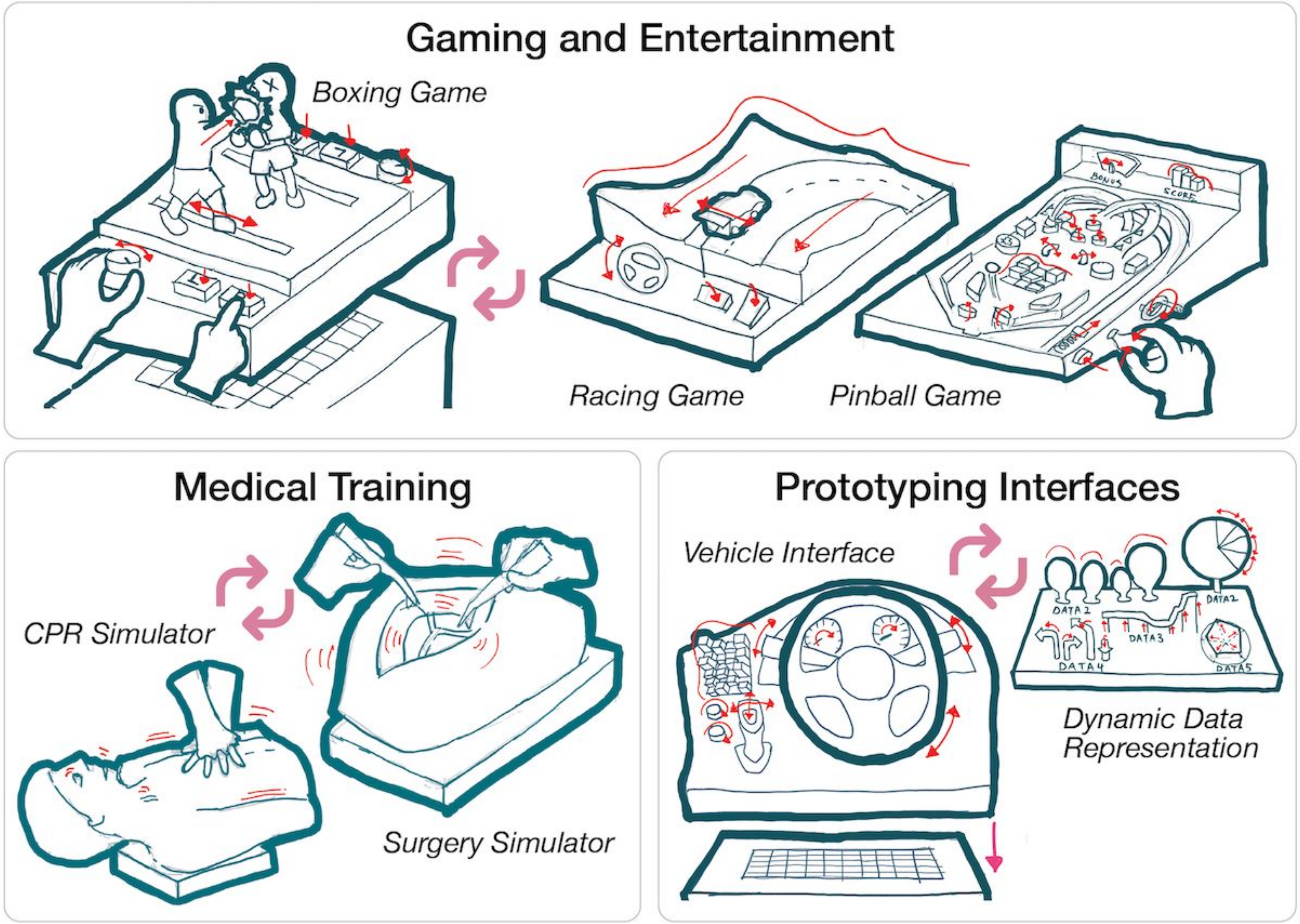


Figure 4-9: *TRANS-DOCK* Transducers for General Functionalities (a: High Resolution Transducer, b: Resolution Changeable Transducer, c: Balloon Array Transducer, d: Bending Pin Transducer, e: Movable Plane Transducer) and for Specific Applications (f: Story-telling and Animation, Data Physicalization, g: Whack-a-Mole)

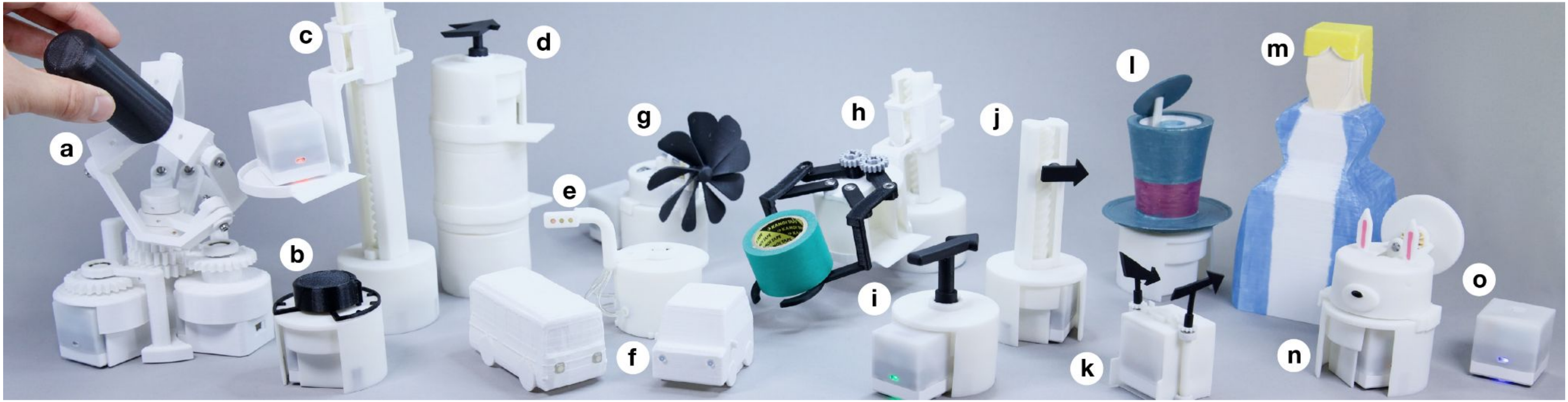
4. TRANS-DOCK

- **TRANS-DOCK Discussion of Potential Use Cases**



5. HERMITS

- **HERMITS(隱士) : Mechanical Shells for Self-propelled TUIs**
  - a modular interaction architecture for self-propelled TUI 模組化的互動結構，可自替換與可觸握
  - 運用Mechanical Shell的概念，將Mini Robot進行結合，可透過Robot進行位移、閃光與人進行互動
  - HERMITS 同時具有互動性、自適應性以及驅動Shape外型改變的能力



5. HERMITS

- **HERMITS(隱士) : Self-Propelled TUI and Swarm UI**
    - **Self-Propelled TUI 自走式TUI**
    - **Swarm User Interface (SUI) 群體使用者介面**
        - **ShapeBots、RoomShift**

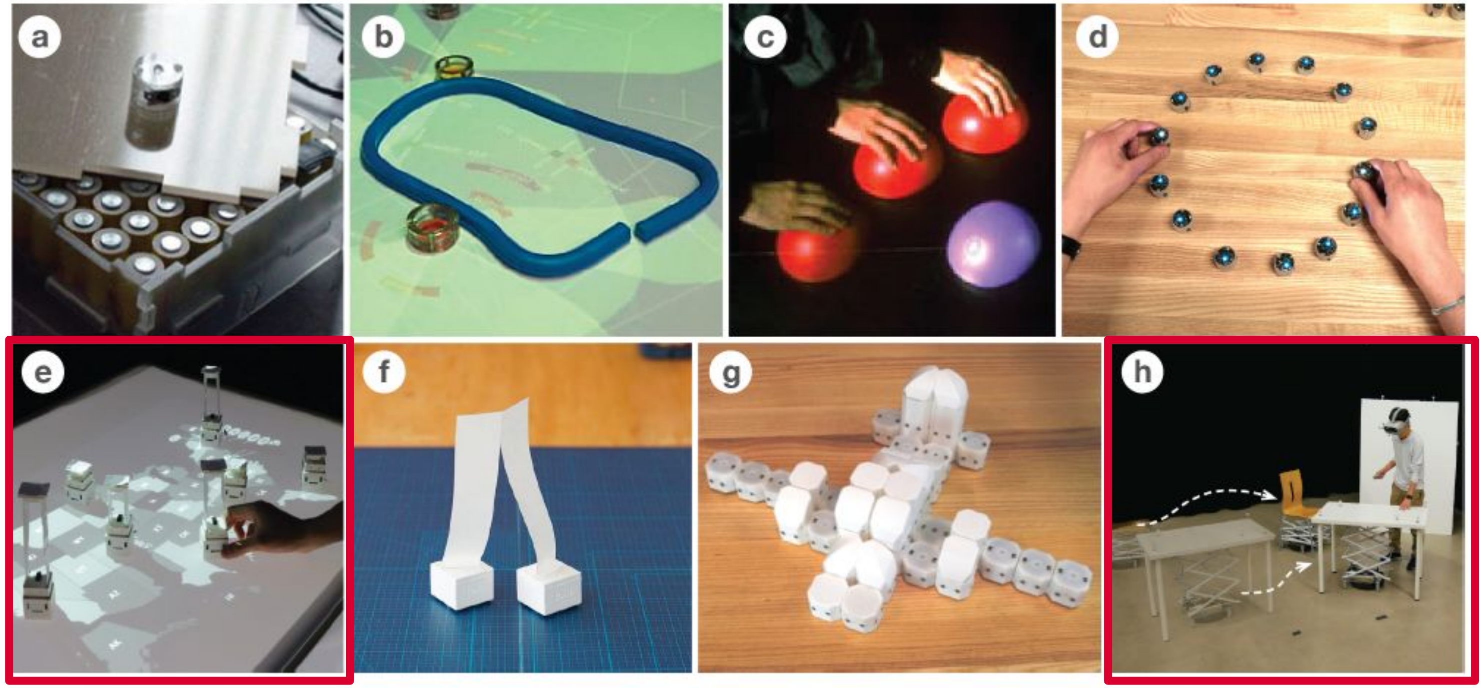
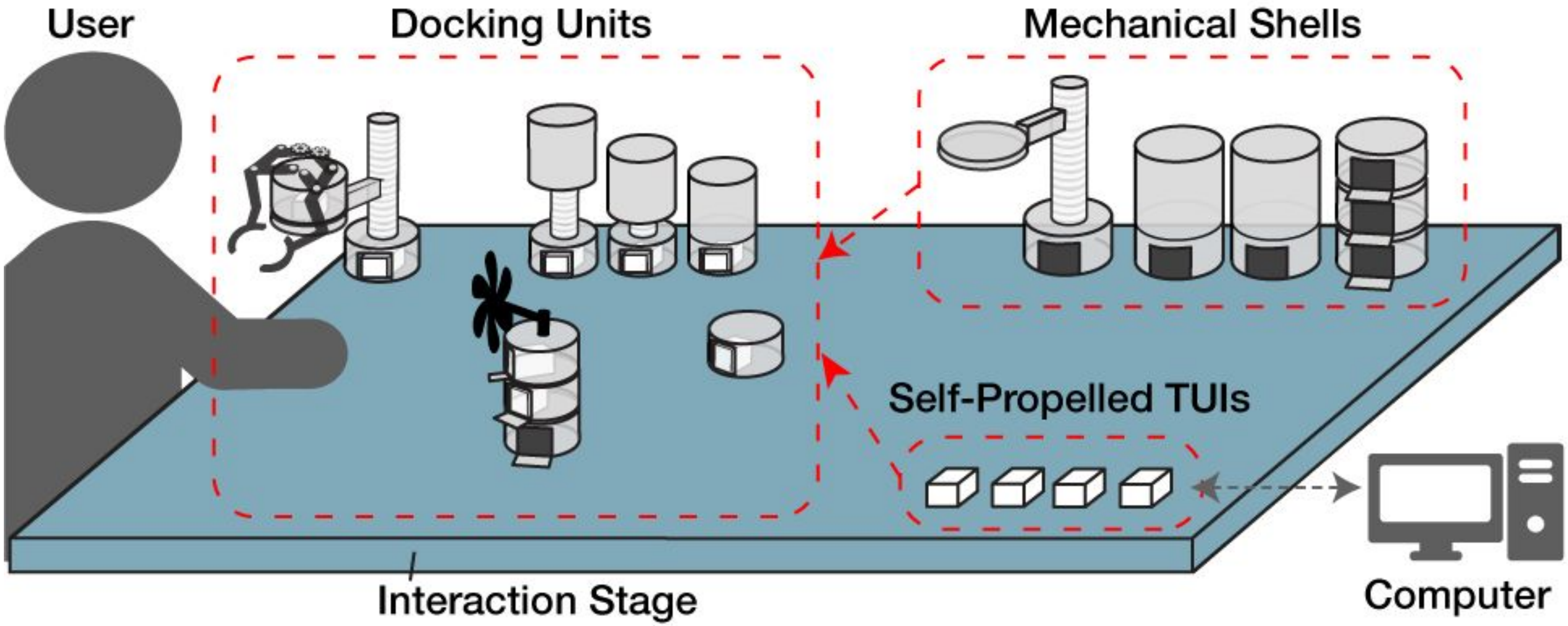


Figure 5-2: Related Work of *HERMITS* (a. Actuated Workbench [110], b. PICO [111], c. Curlybot [35], d. Zooids [74], e. ShapeBots [145], f. toio's Gezunroid [28], g. Robotic Assembly of Haptic Proxy [180], h. RoomShift [140]).

5. HERMITS

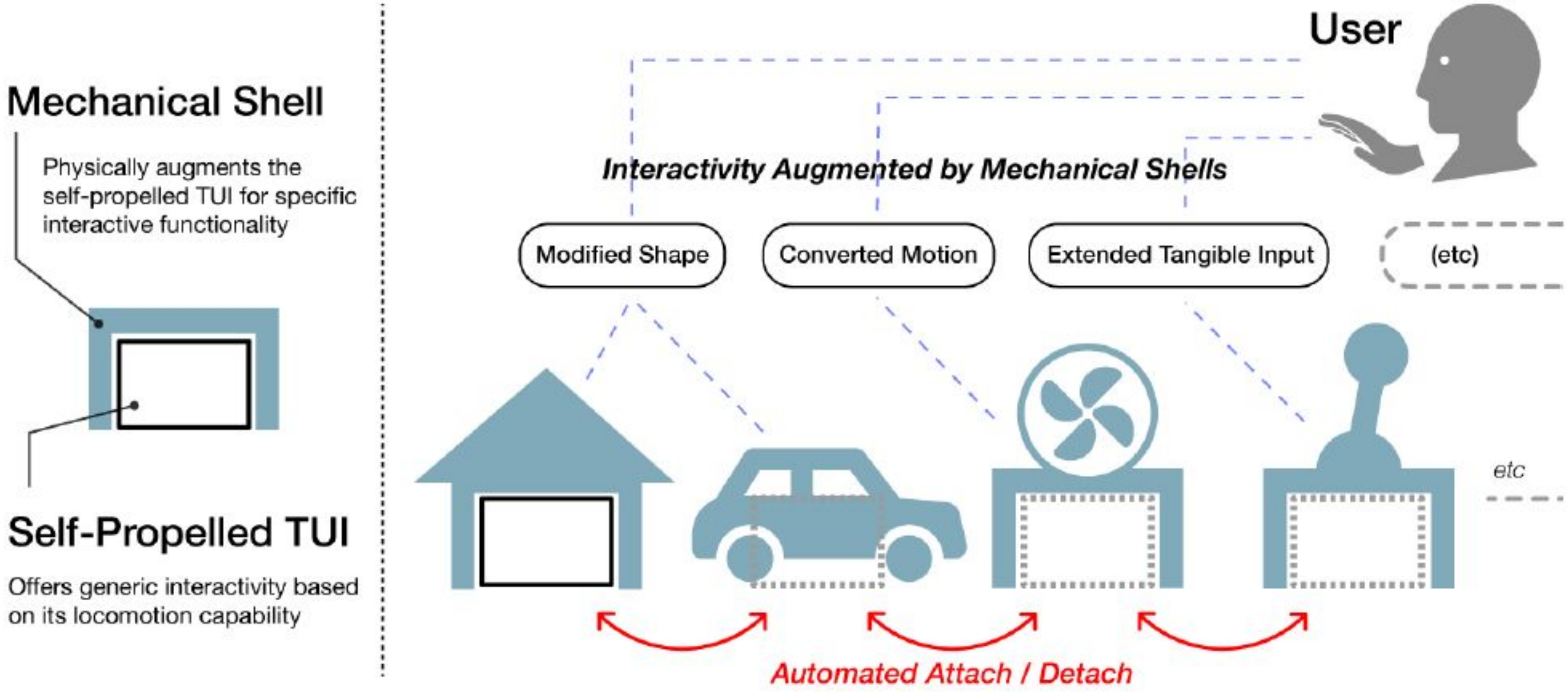
- **HERMITS(隱士) : Overall Design**



Mechanical Shells 是各種外殼
Self Propelled TUI 會根據電腦指令進行載入不同的Shell進行互動

5. HERMITS

- **HERMITS(隱士) : Concept of mechanical shell**



互動過程不同的Actuated TUI可透過Mini Robots進行附掛與解附掛，再跟使用者進行互動

5. HERMITS

- **HERMITS(隱士) : Concept of mechanical shell**

'igure 5-5: Overview of interaction design purposes and benefits of *Mechanical Shells* :om instances of *HERMITS* (a. Tangible and Haptic Controllers, b. Data Phys- :alization / Tangible Representation, c. Storytelling with Expressive Shapes and Iotion, and d. Extended Robotic Manipulator and Locomotion)

各種不同的TUI 搭配Mini Robots進行各種延伸應用
例如電阻、旋鈕、齒輪機構、角色人物、或風力發電
工具。

5. HERMITS

- **HERMITS(隱士) : Design space for primitive properties**

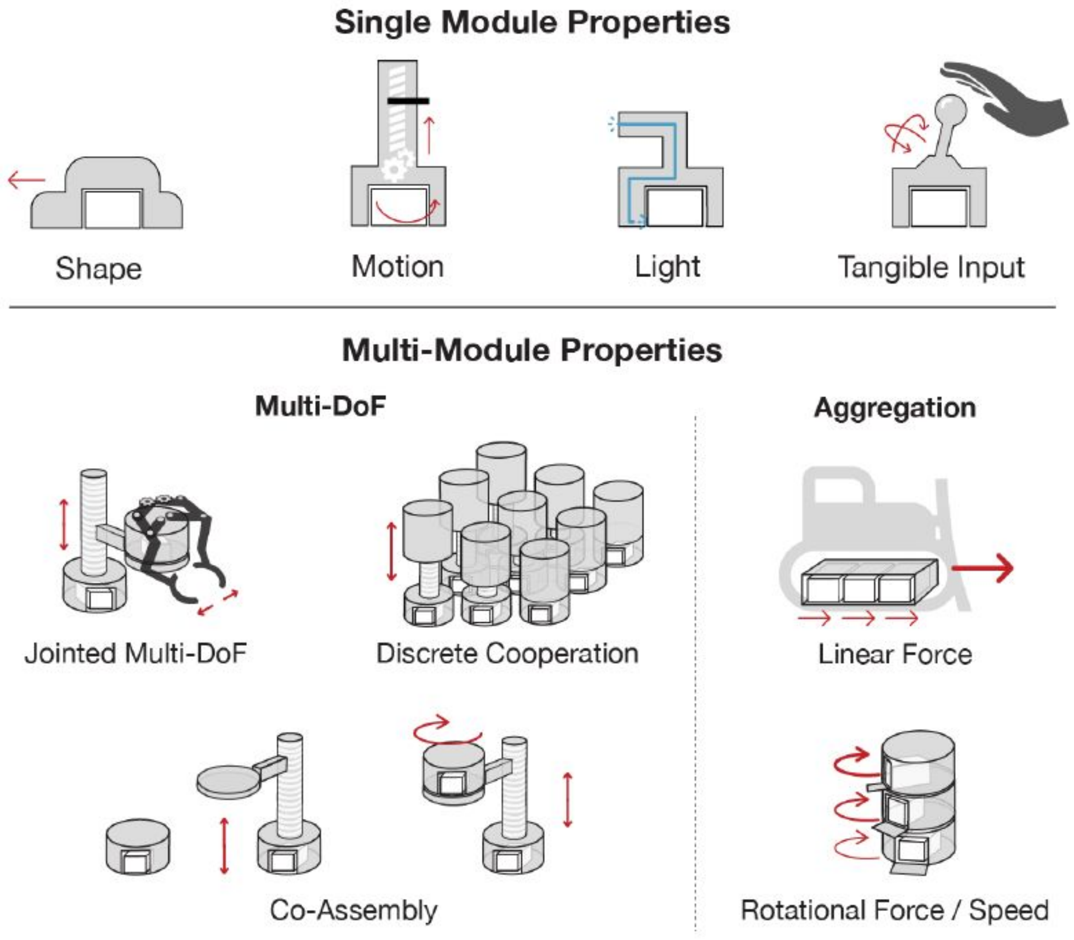


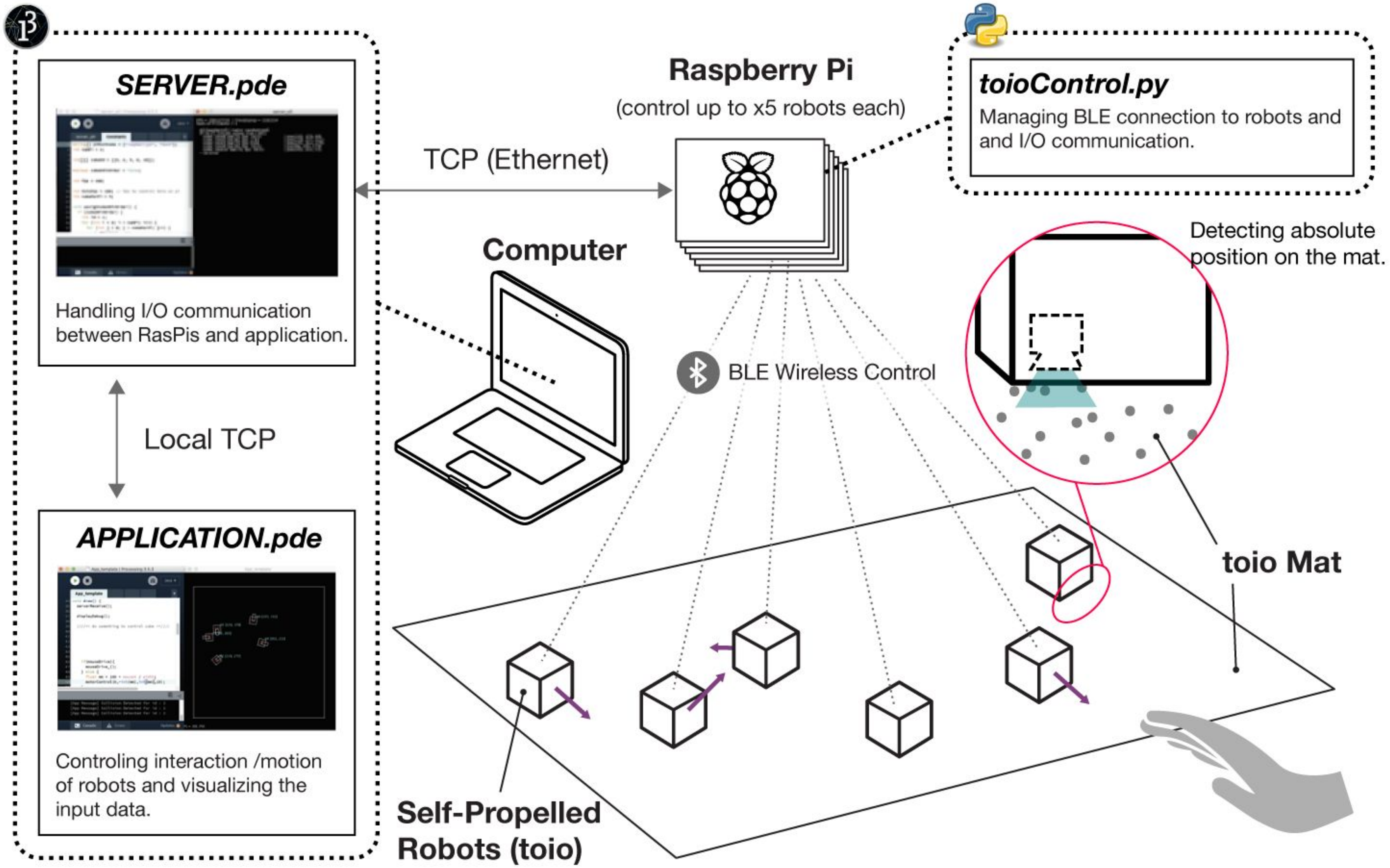
Figure 5-6: Design space for primitive properties of *Mechanical Shells*.

單模式的屬性
- 外型替換
- 運動(單軸)
- 光線折射
- 搖桿輸入

多模式的屬性
- 加入多軸感測器
- 分散式群控
- 線性驅動
- 共同組裝
- 旋轉壓力與速度

5. HERMITS

- **HERMITS(隱士) : Overall System Design based on toio (Sony公司研發)**



Server架設

- Raspberry Pi
- toioControl.py
- BLE Wireless Control

應用性架設

- 桌面上嘿有多個
- toio (mini robots)
- toio mat (定位)

5. HERMITS

- **HERMITS(隱士) : Overall System Design based on toio (Sony公司研發)**

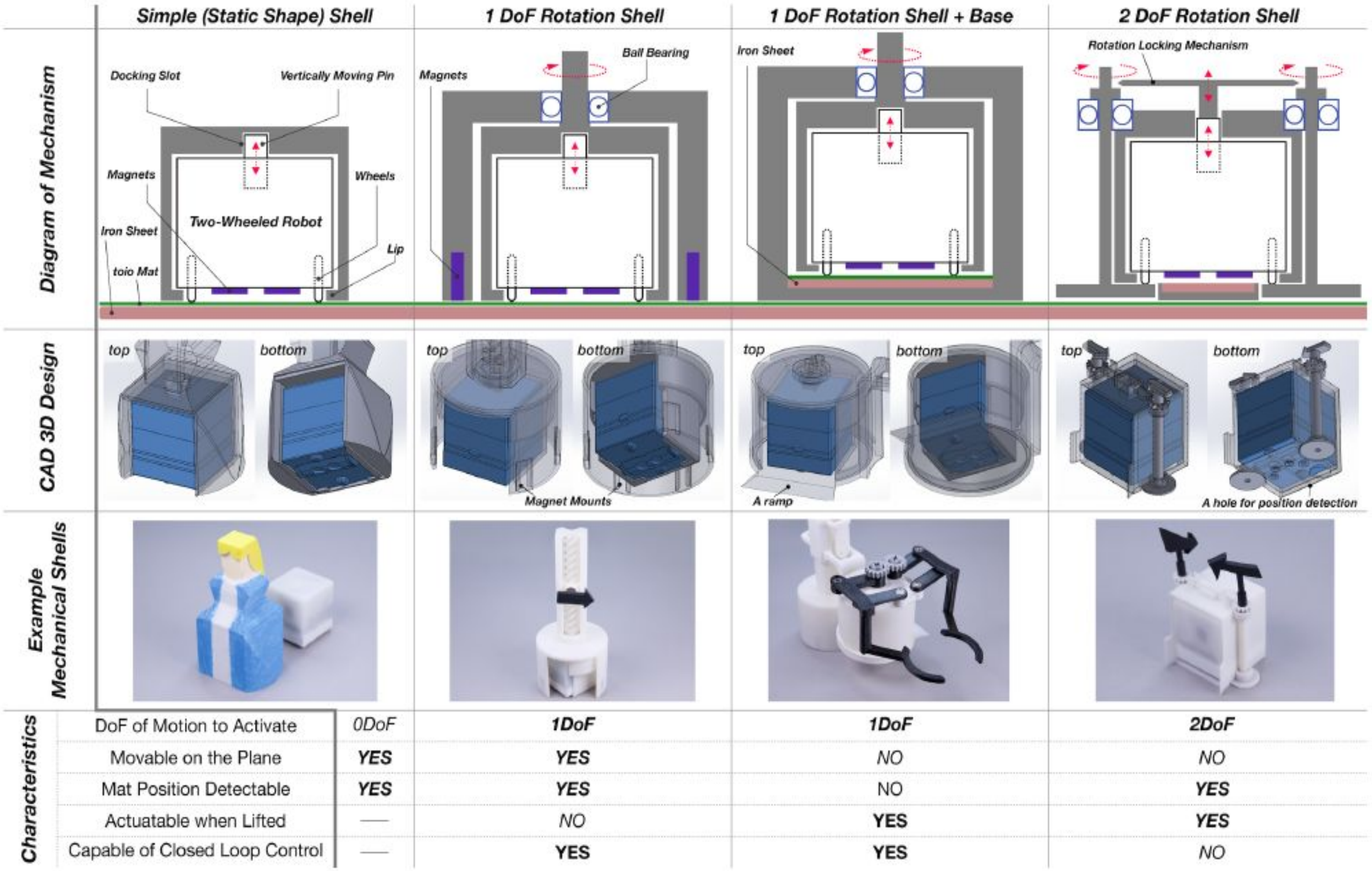
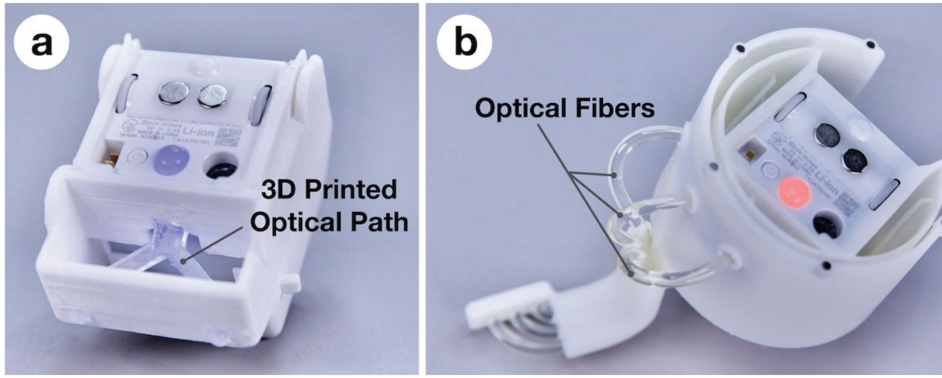


Figure 5-10: Design and mechanism of four basic types of *Mechanical Shells* implemented for *HERMITS*, and their characteristics.

初步各種 shell與A-TUI 進行。創意發現並進一步思考

拆開後，會老大份等工具的遺留物品再還給同學



5. HERMITS

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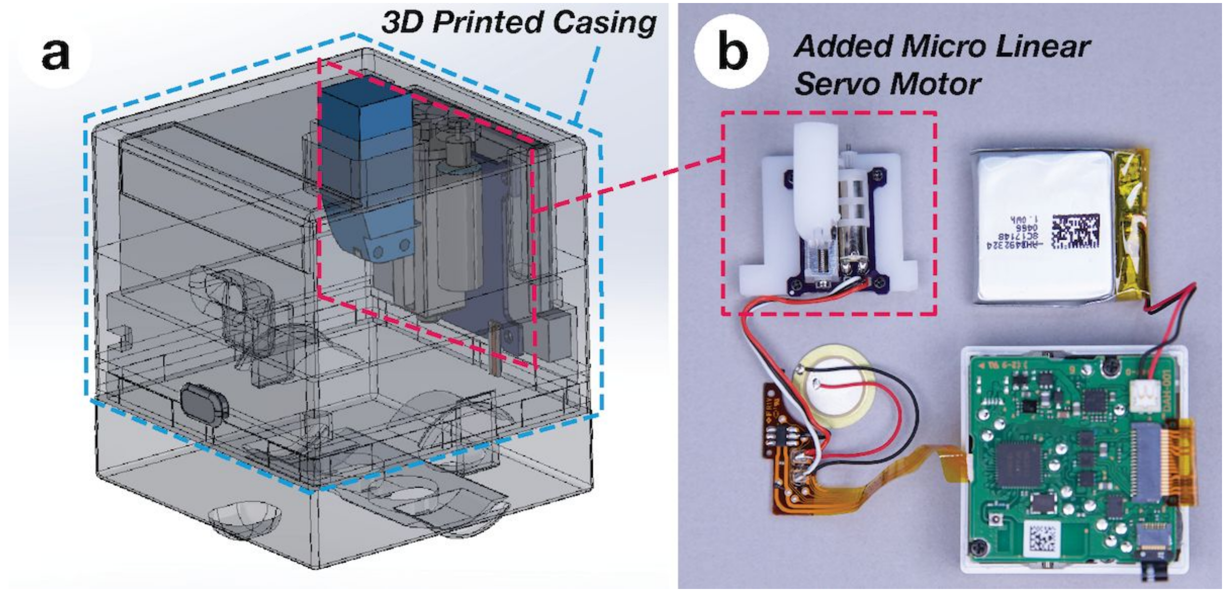
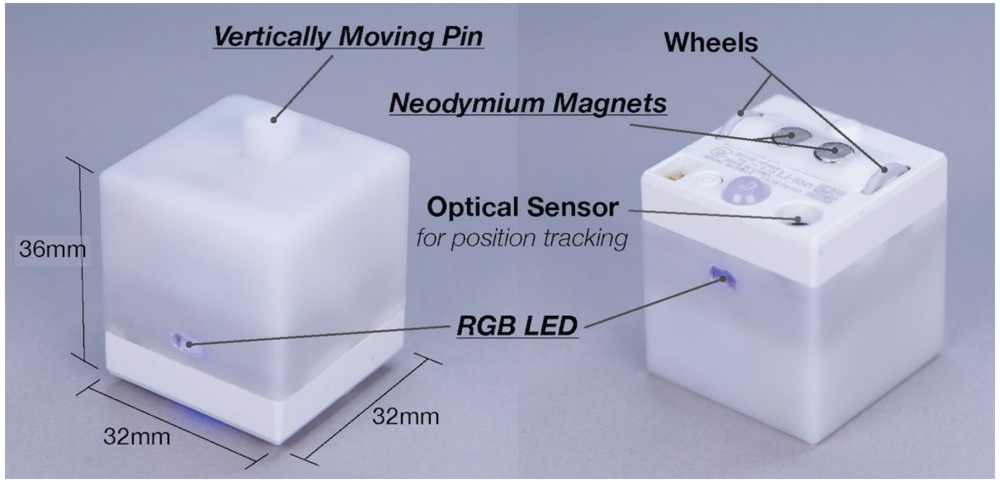


左圖上:
3D列印的外殼
線性微機電馬達
控制電路
電池



左圖下:
輪組
磁力感測
垂直狀態時用的pin
LED顯示、光學感測

5. HERMITS

- **HERMITS(隱士) : Demonstration of Storytelling and Alise 在生態情境下進行設計**
- **故事腳本**
- **自適應與人物交織**

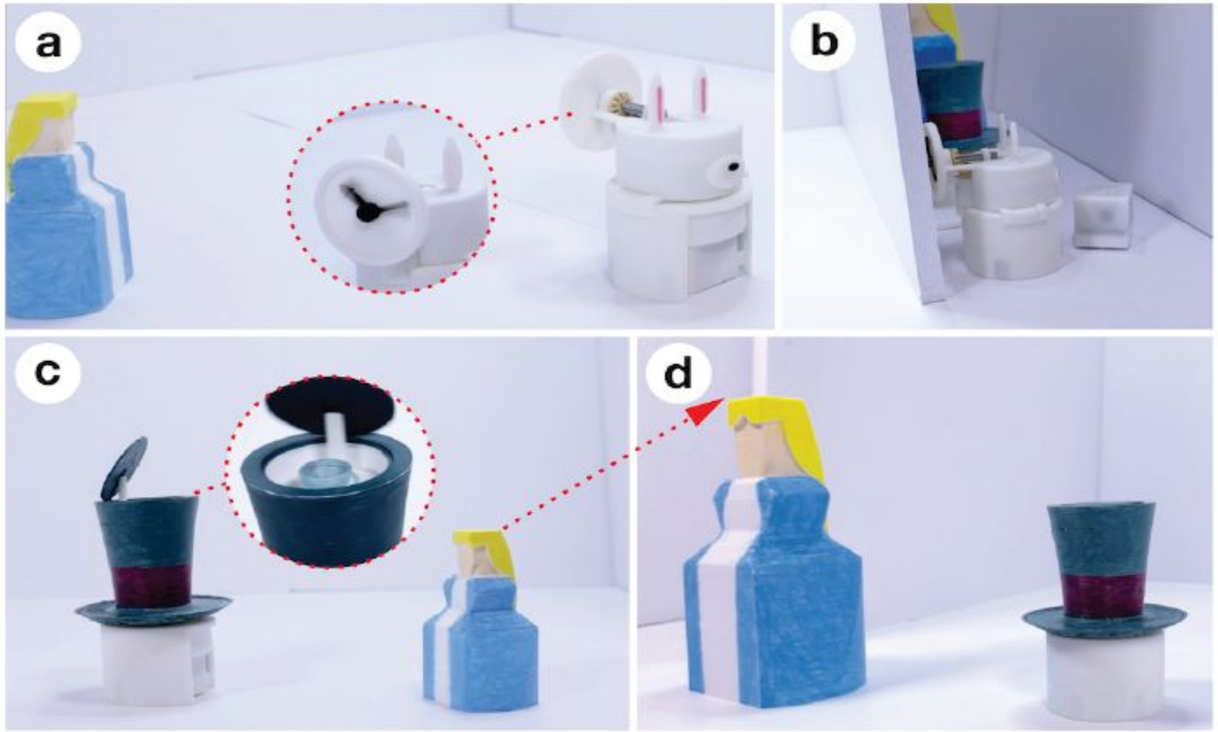
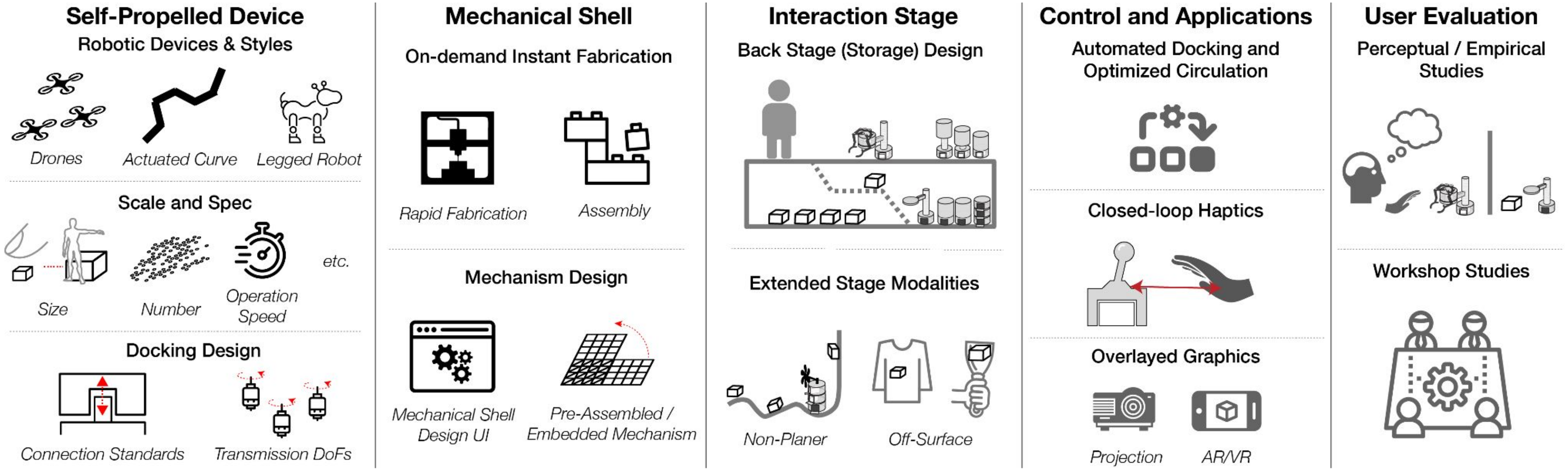


Figure 5-16: Demonstration of storytelling with *Alice in Wonderland* scenario (a. Alice chasing bunny holding spinning watch, b. robots changing the shell in the back-stage, c. Mad Hatter dancing in front of Alice, d. Alice with grown body by switching the shell.)

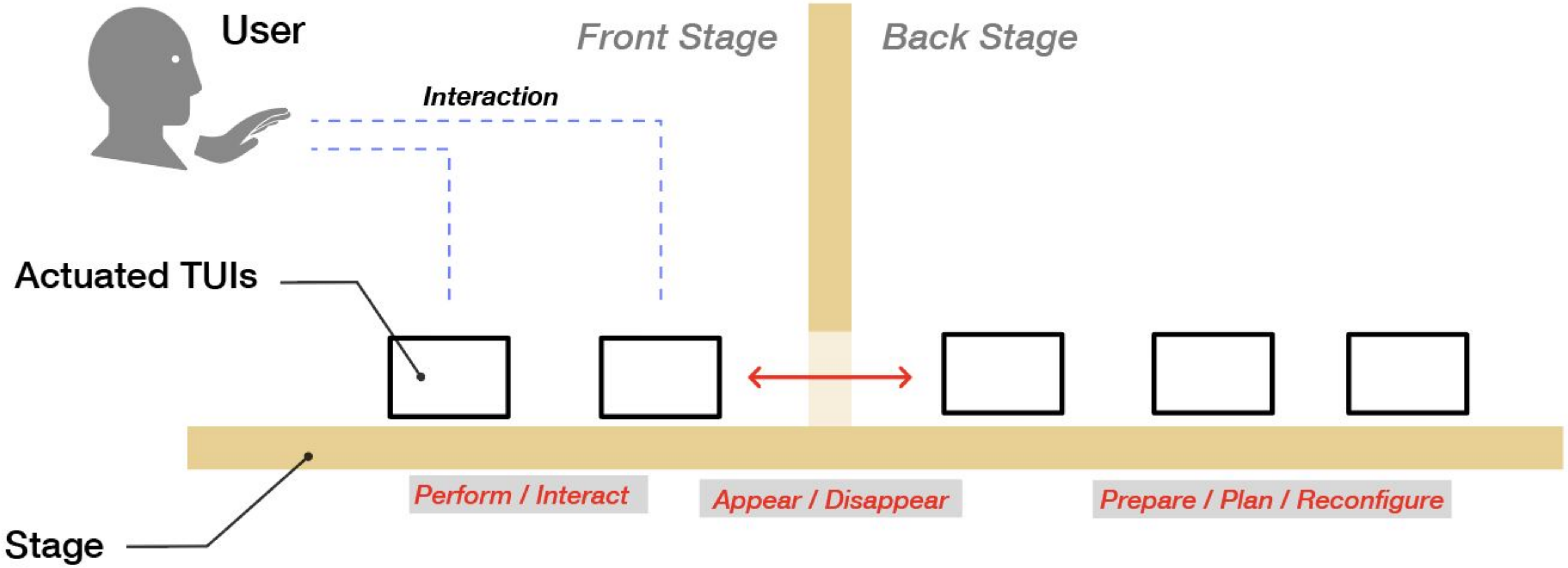
5. HERMITS

- **HERMITS(隱士)：未來應用**
  - **自走式裝置、快速成形的數位自造、互動舞台(戲劇)、IoT 控制與應用面、XR(AR/VR)、使用者評估**



6. Stages: Physical Platforms

- **Stages basic conecpt**
  - **I define Stages as “physical platforms” on which the Actuated TUI**
  - **Front Stage / Back Stage**
  - **Appear / Disappear**



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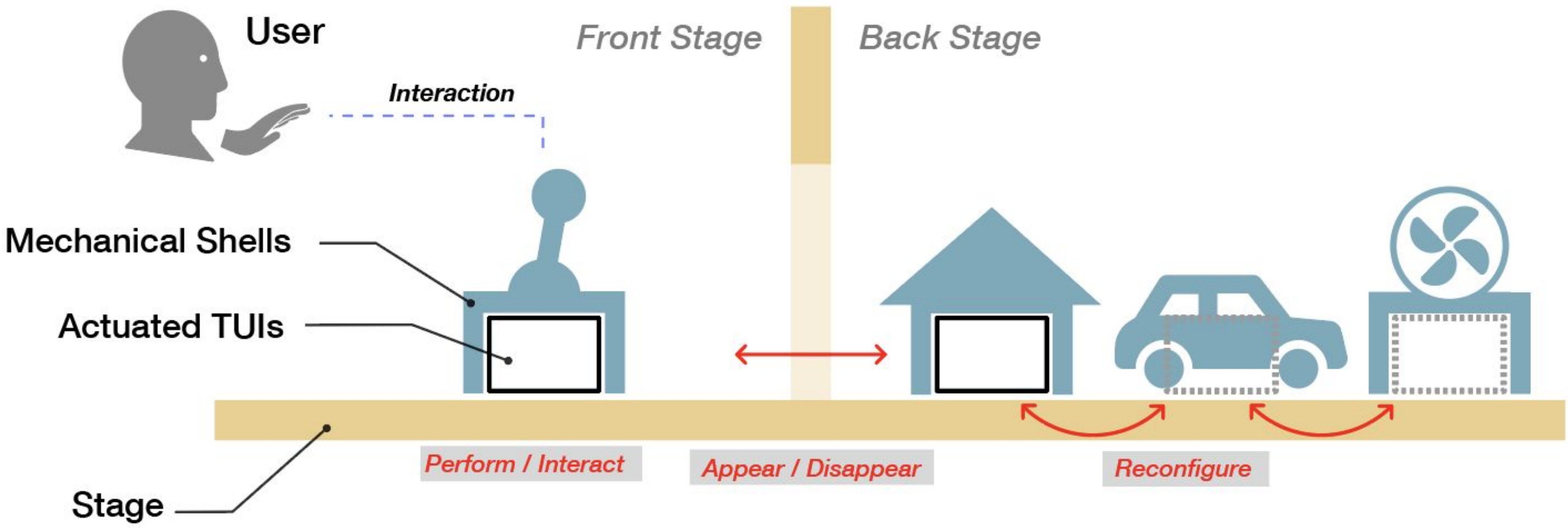
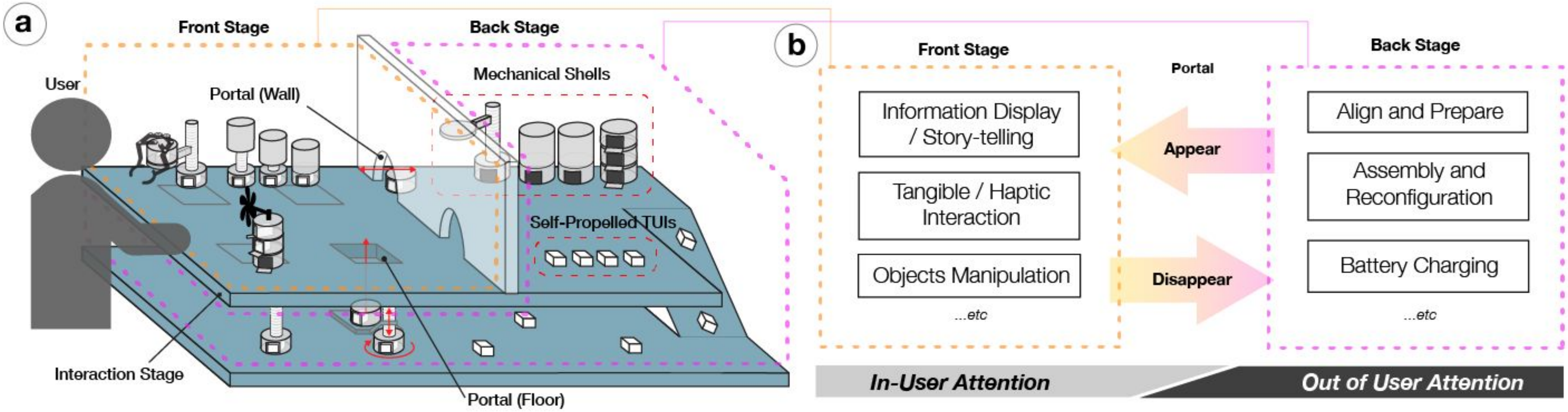


6. Stages: Physical Platforms

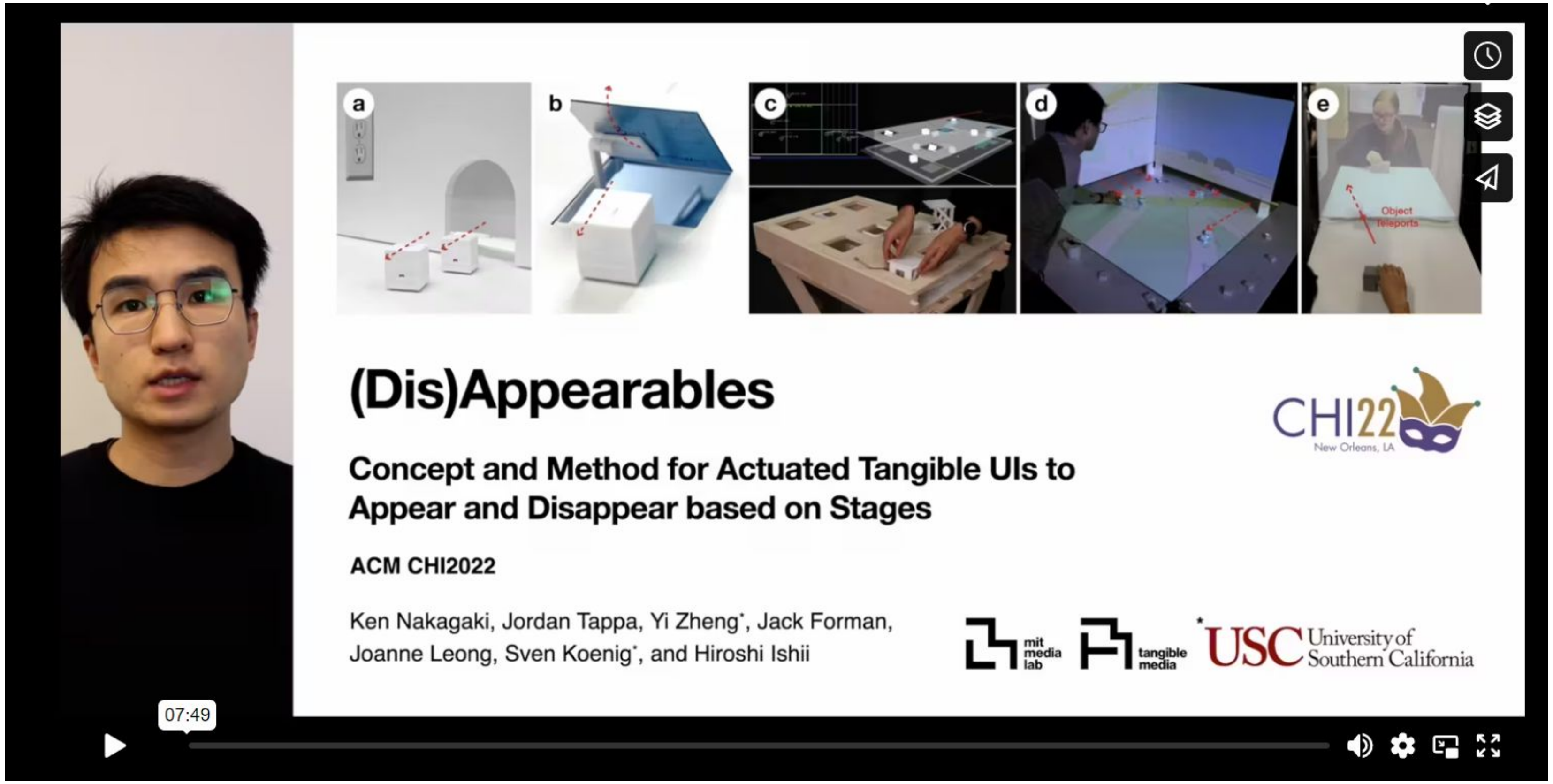
- **Compositions of Stage and Design Space**
  - **Front Stage / Back Stage (in-user Attention 或 Out of user attention)**
  - **Boundaries (Wall / Floor)**
  - **Transition Portals (Actuated TUI to move in-between)**
  - **整體架構如下**



7. Dis(Appearables)

(Dis)Appearables is an approach for Actuated Tangible User Interfaces to appear and disappear from user experience perspective which is supported by a physical platform, Stage.

- **致力於A-TUI的消失與出現的使用者經驗**
- **運用Stage的概念將物理性的平台進行實作**



https://vimeo.com/689454384?embedded=true&source=video_title&owner=11720996

7. Dis(Appearables)

(Dis)Appearables contribution incluses:

- **A research exploration of (Dis)Appearables**
- **Design Space of (Dis)Appearables for creating Appearing and Disappearing**
- **A proof-of-concept prototype base on an off-the shelf two-wheeled robotic**
- **Applications to demonstrate the design space fo Stages**

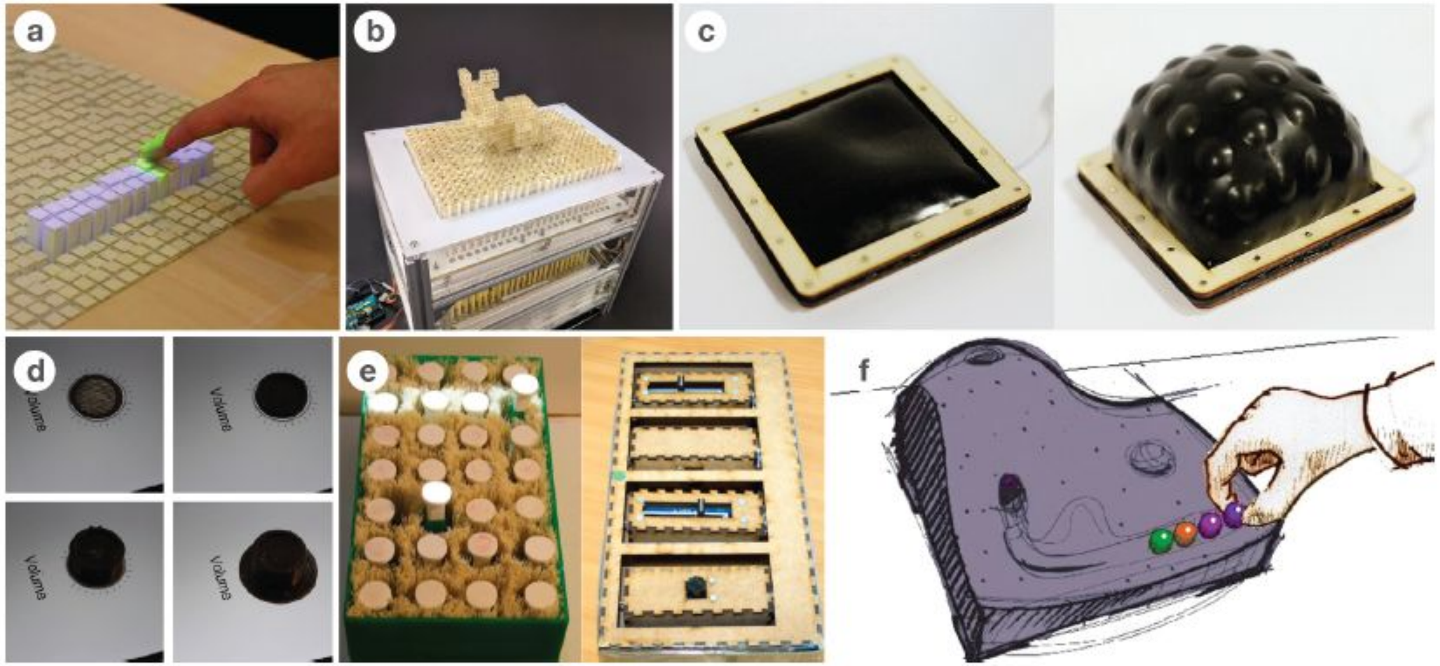


Figure 7-1: Related Work of *(Dis)Appearables* (a. inForm [33], b. DynaBlock [144], c. PneUI [174], d and e. Emergeables [119], f. Marble Answering Machine [21])

7. Dis(Appearables)

(Dis)Appearables Concept and Overall Design

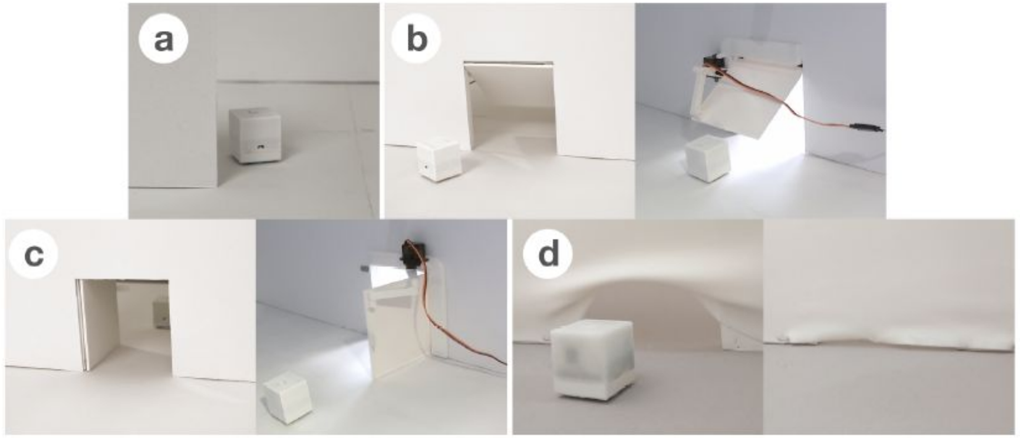


Figure 7-3: Transition Portals on Wall (a. Wall, b and c. Actuated Door, d. Fabric Door).

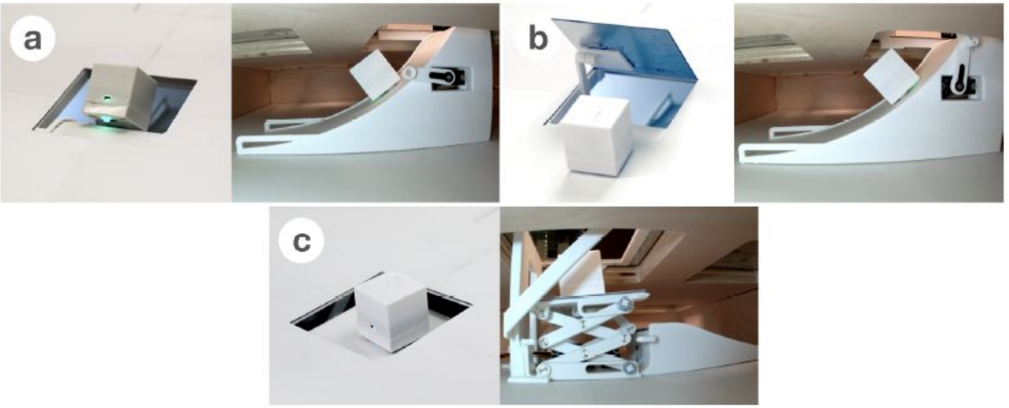
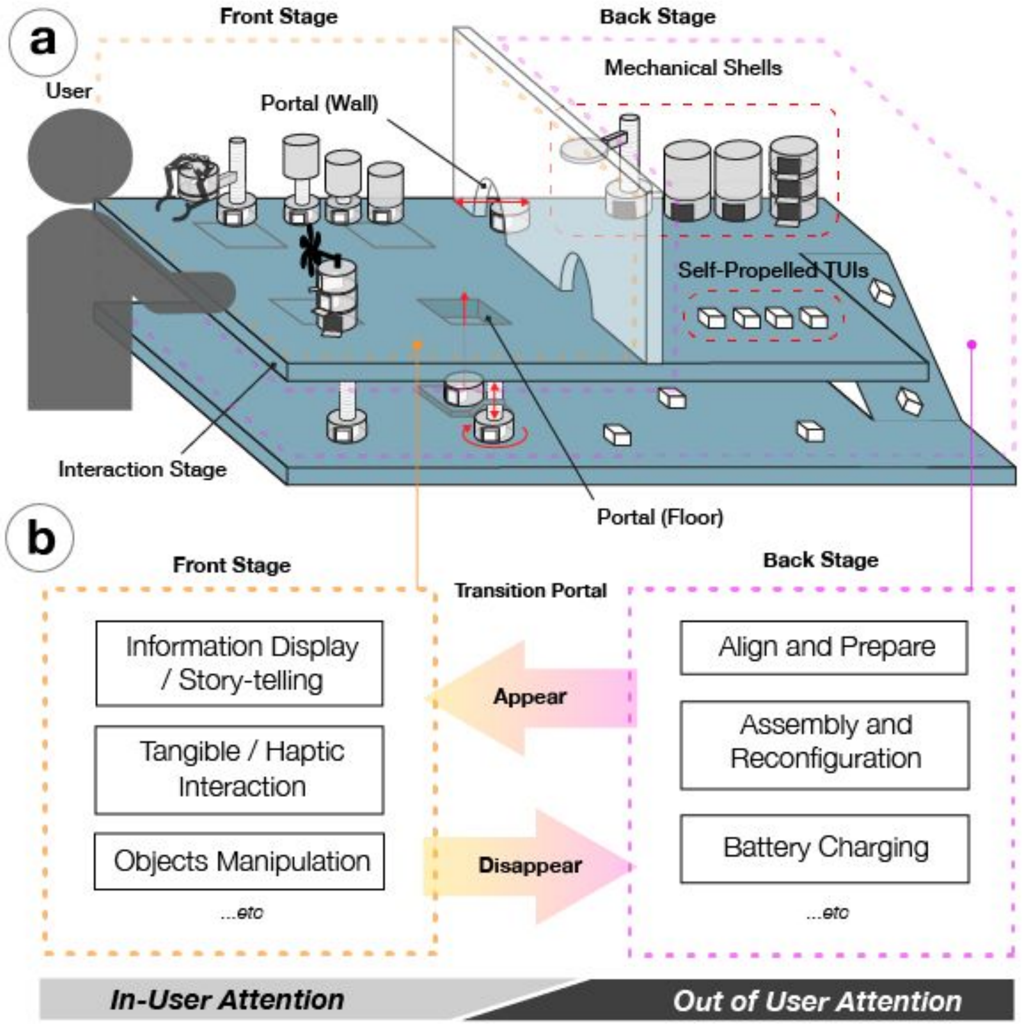


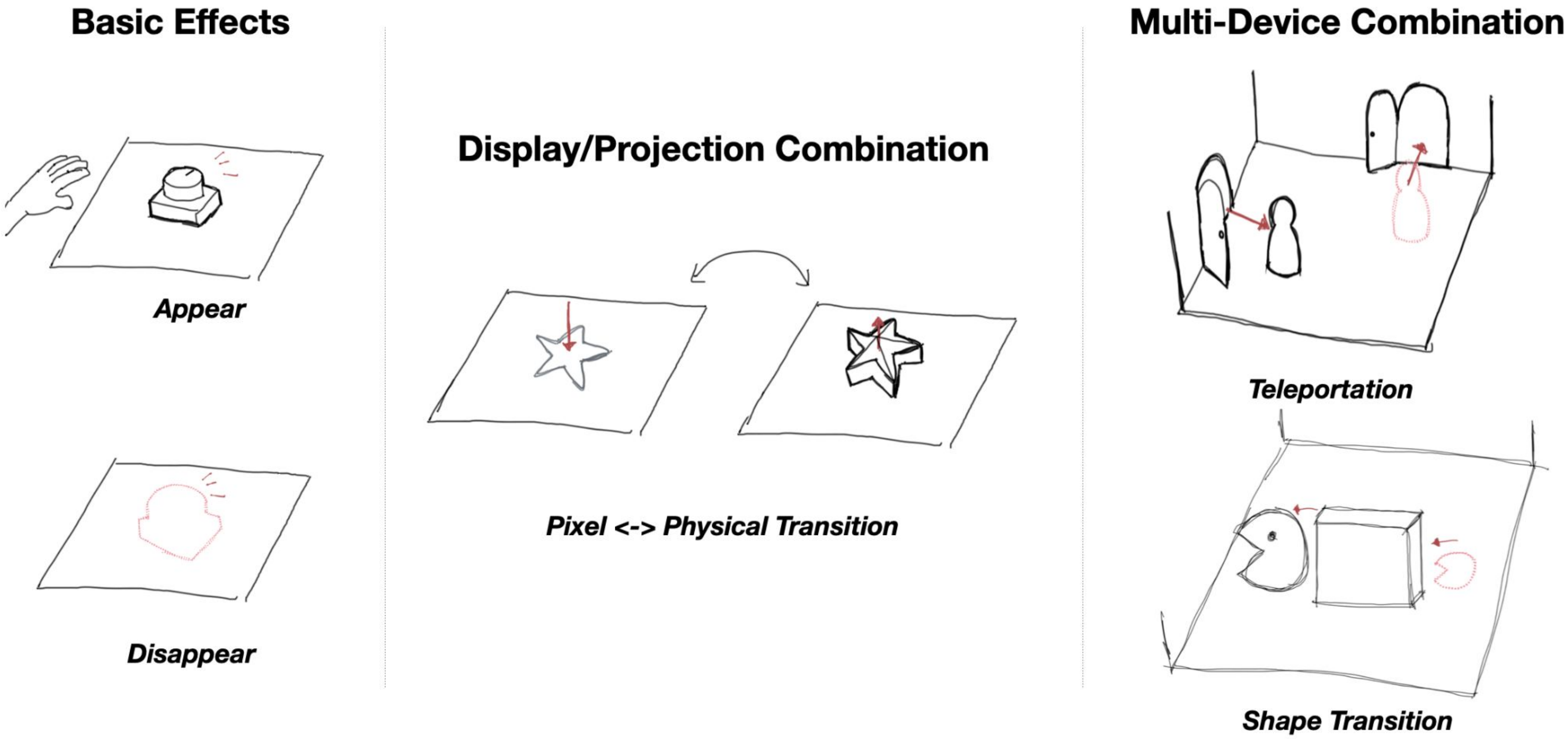
Figure 7-4: Transition Portals on Floor (a. Slope, b. Slope with Trap Door, c. Lift).



7. Dis(Appearables)

(Dis)Appearables Concept and Overall Design

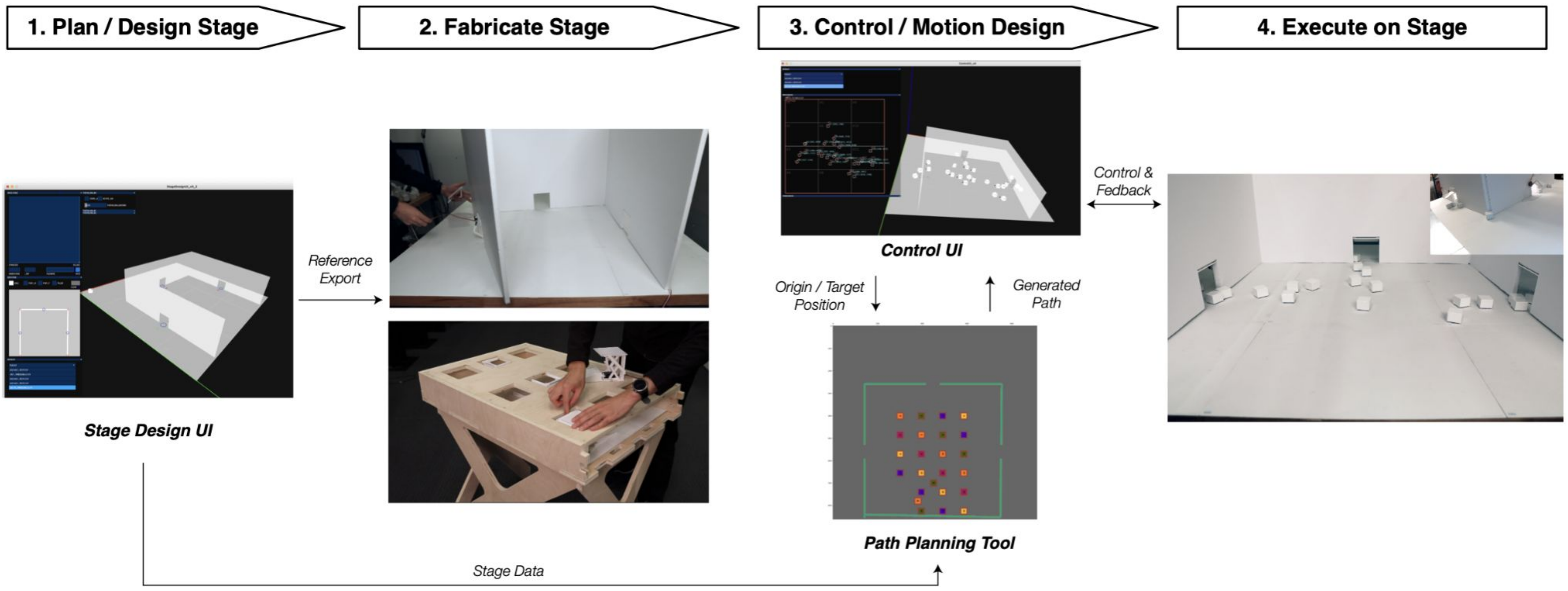
- **Pixel - Physical Transition**
- **Teleportation**
- **Shape Transition**



7. Dis(Appearables)

(Dis)Appearables Implementation

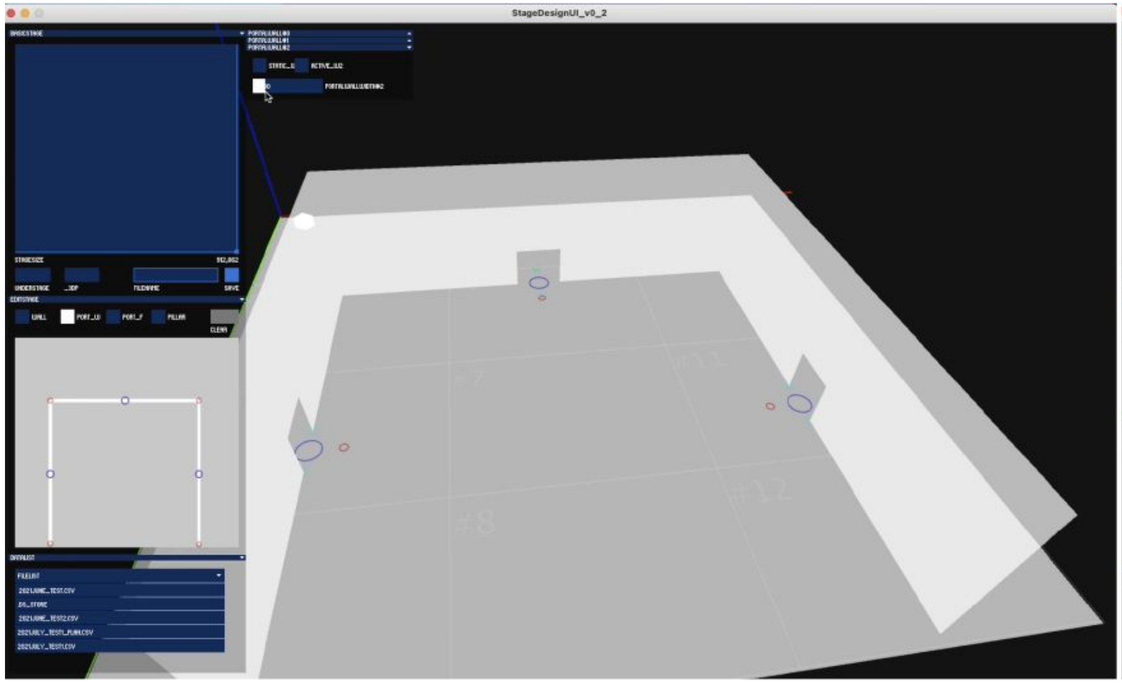
- 規劃
- 數位自造Stage
- 控制與群控
- 執行Stage

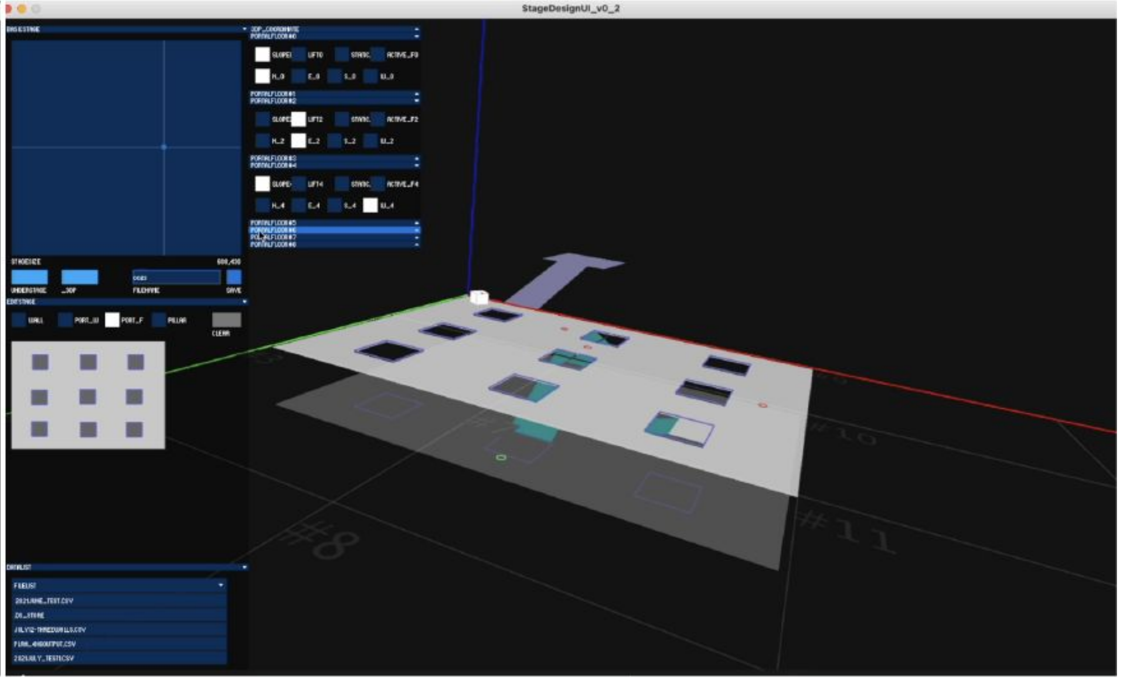


7. Dis(Appearables)

(Dis)Appearables Implementation

- **3D visualization model in the tool**
- **Stage for control UI for the robotic hardware**
- **software tool for Stage using processing 3.x**

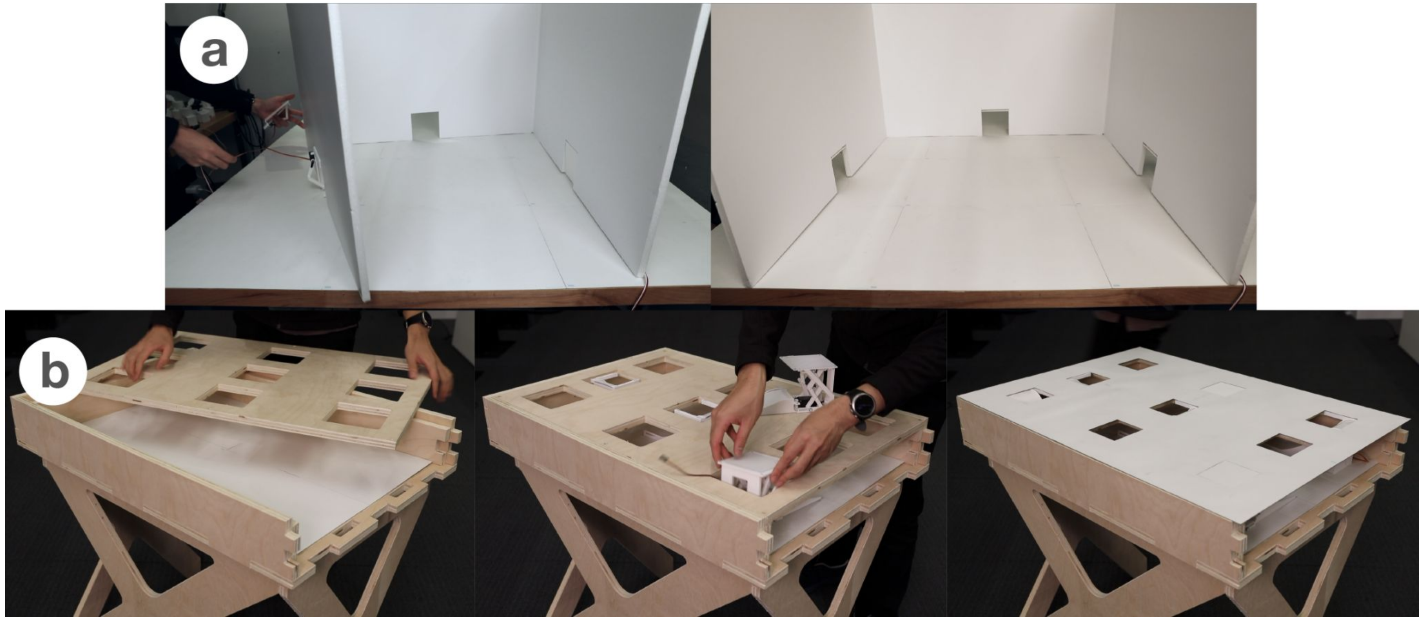


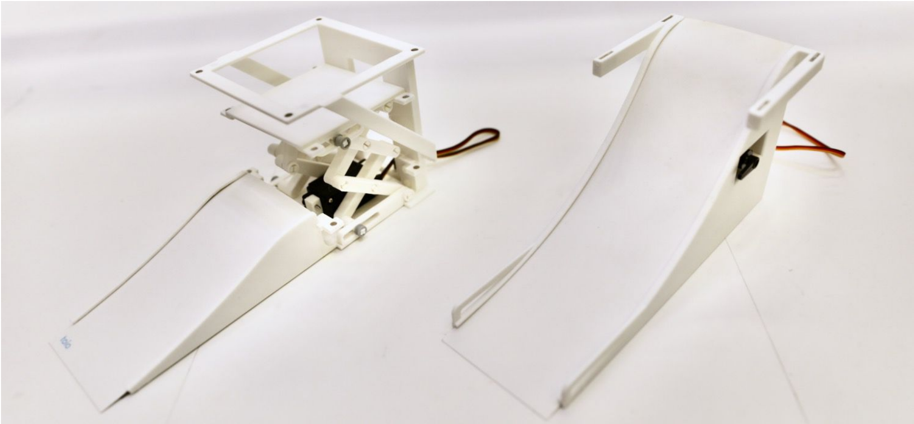


7. Dis(Appearables)

(Dis)Appearables Implementation

- **數位自造運用木材搭建舞台、並用toio的迷你機器人進行控制**

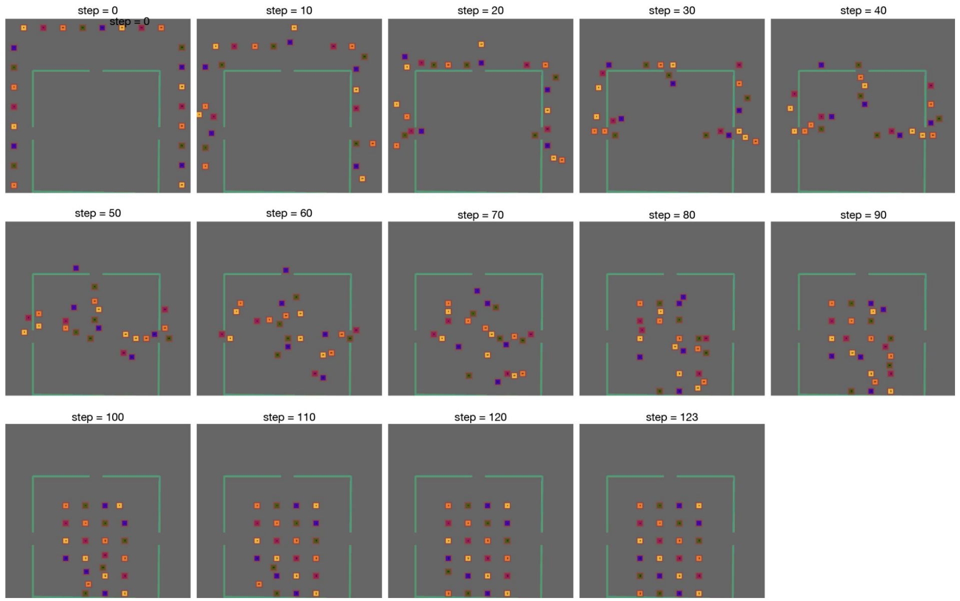


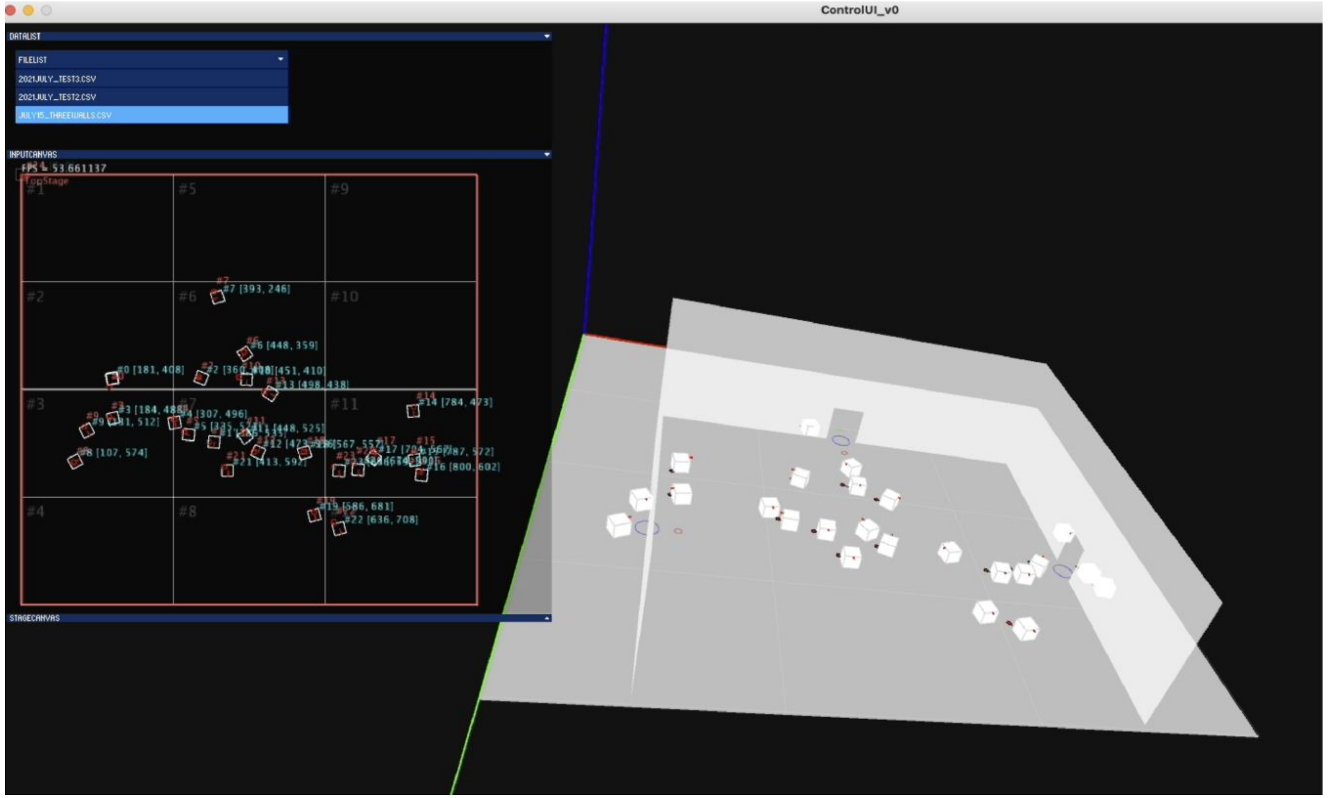


7. Dis(Appearables)

(Dis)Appearables Implementation

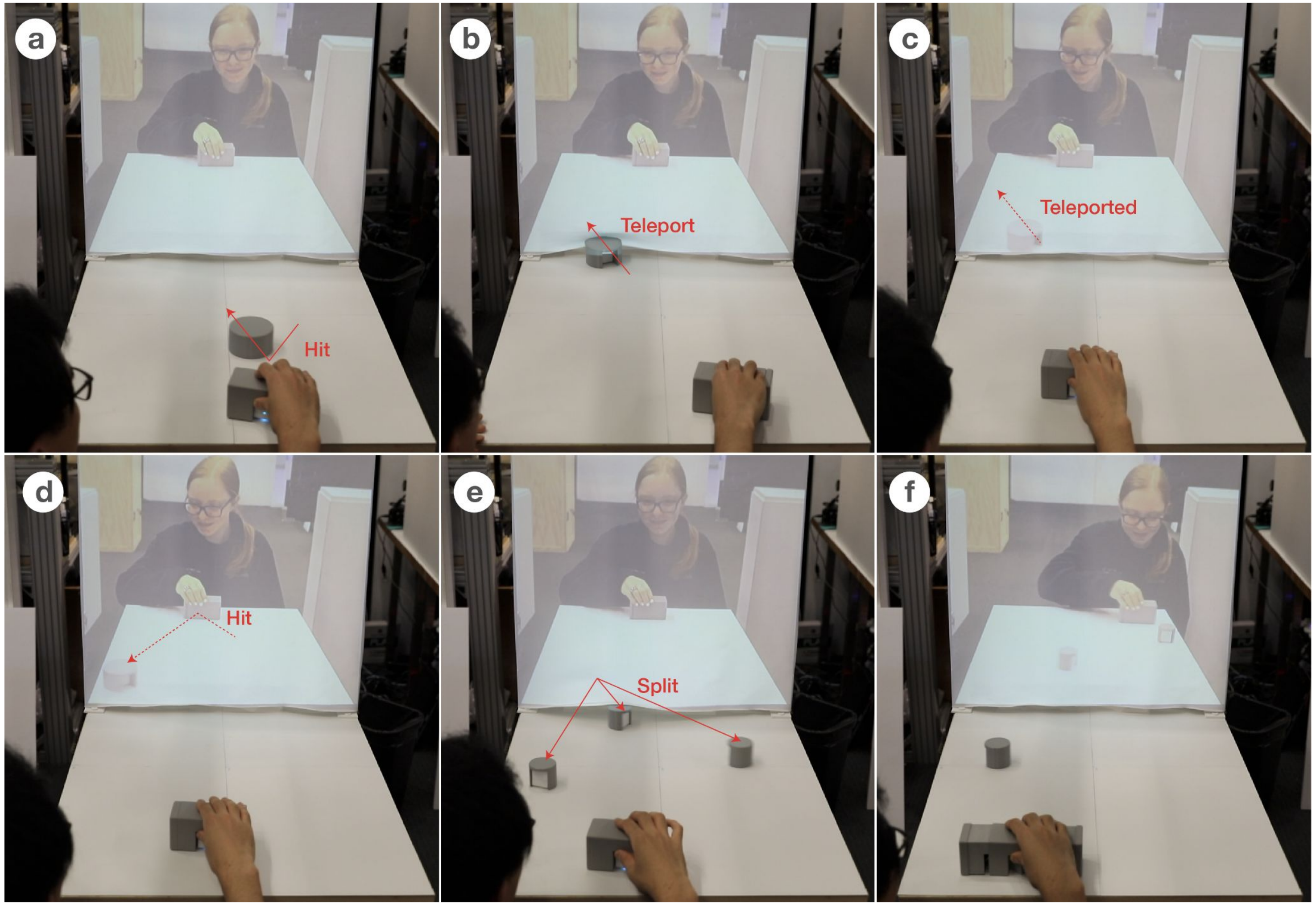
- **群控方式採用Multi-Agent Path Planning Tool**
- **基於CBS搜尋法 [Conflict-Based Search](#) 多機器人路徑規劃演算法**
- **在用MAPF最佳化算法 Multi-agent Pathfinding 智能多路徑規劃算法**

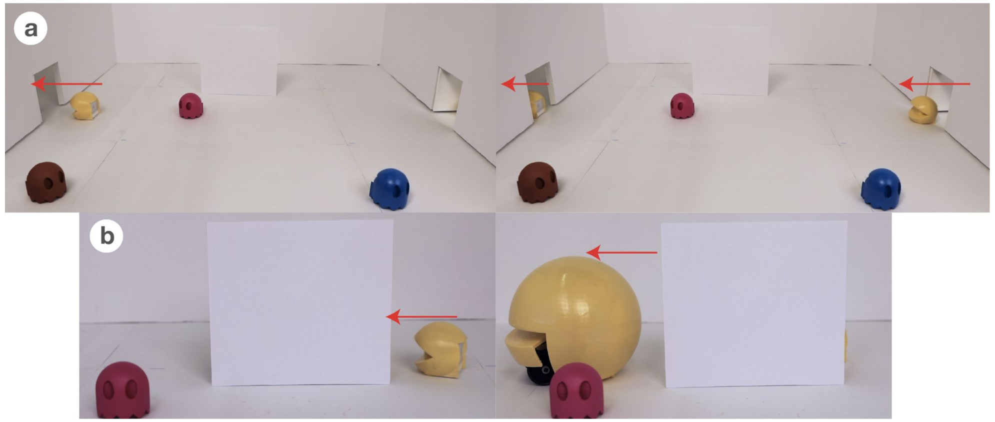


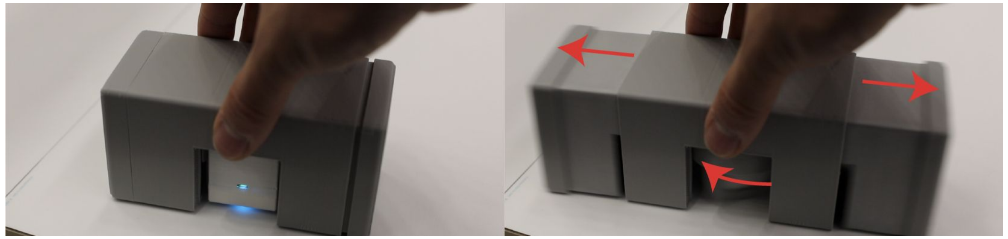


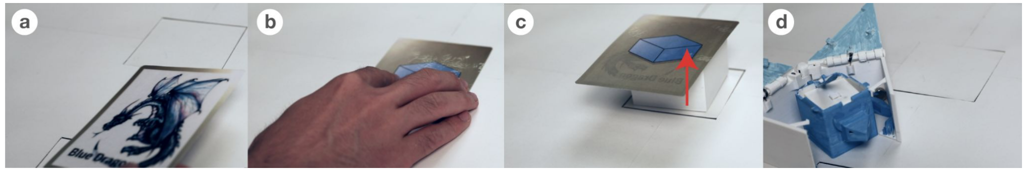
7. Dis(Appearables)

(Dis)Appearables Gaming and Interactive



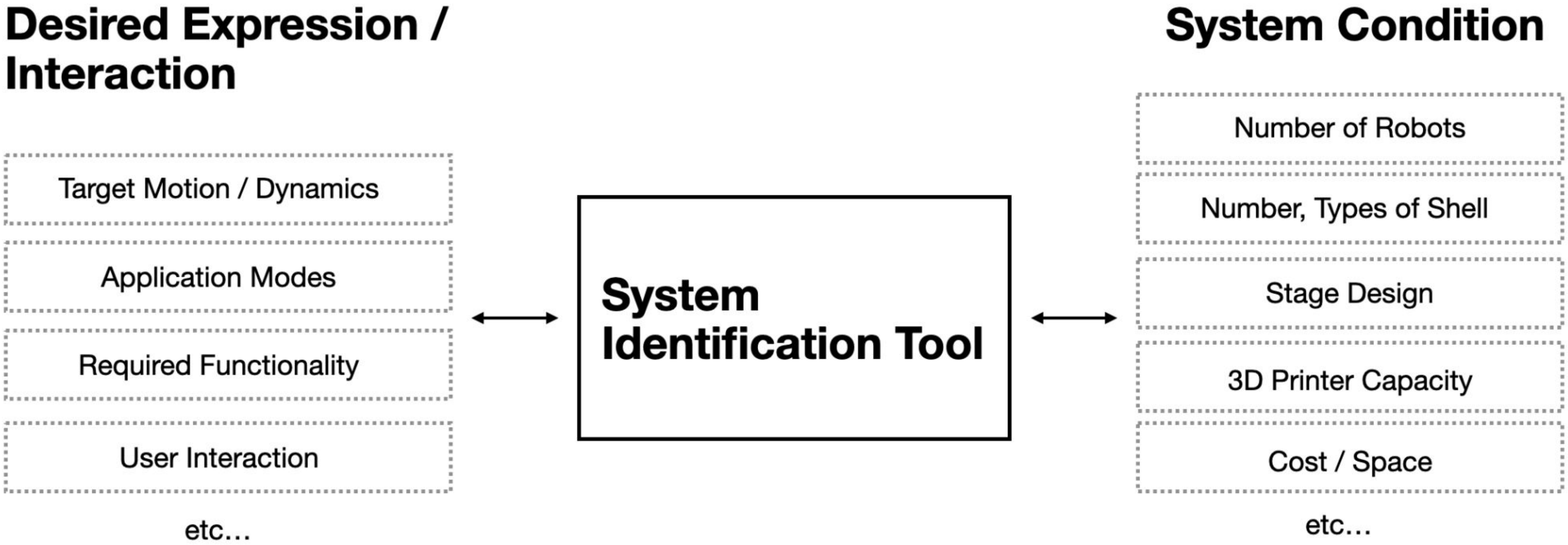






8. Discussion, Challenge and Future Work

- **Shell Design and Generative Tools**
  - **TRANS-DOCK → LEGO-like**
  - **HERMITS → 如同Build-Blocks方式進行客製化設計**
  - **如何最佳化?**



想要表達的互動型態有這麼多　　系統要設計一個辨識工具　　造成系統的條件越來越複雜

8. Discussion, Challenge and Future Work

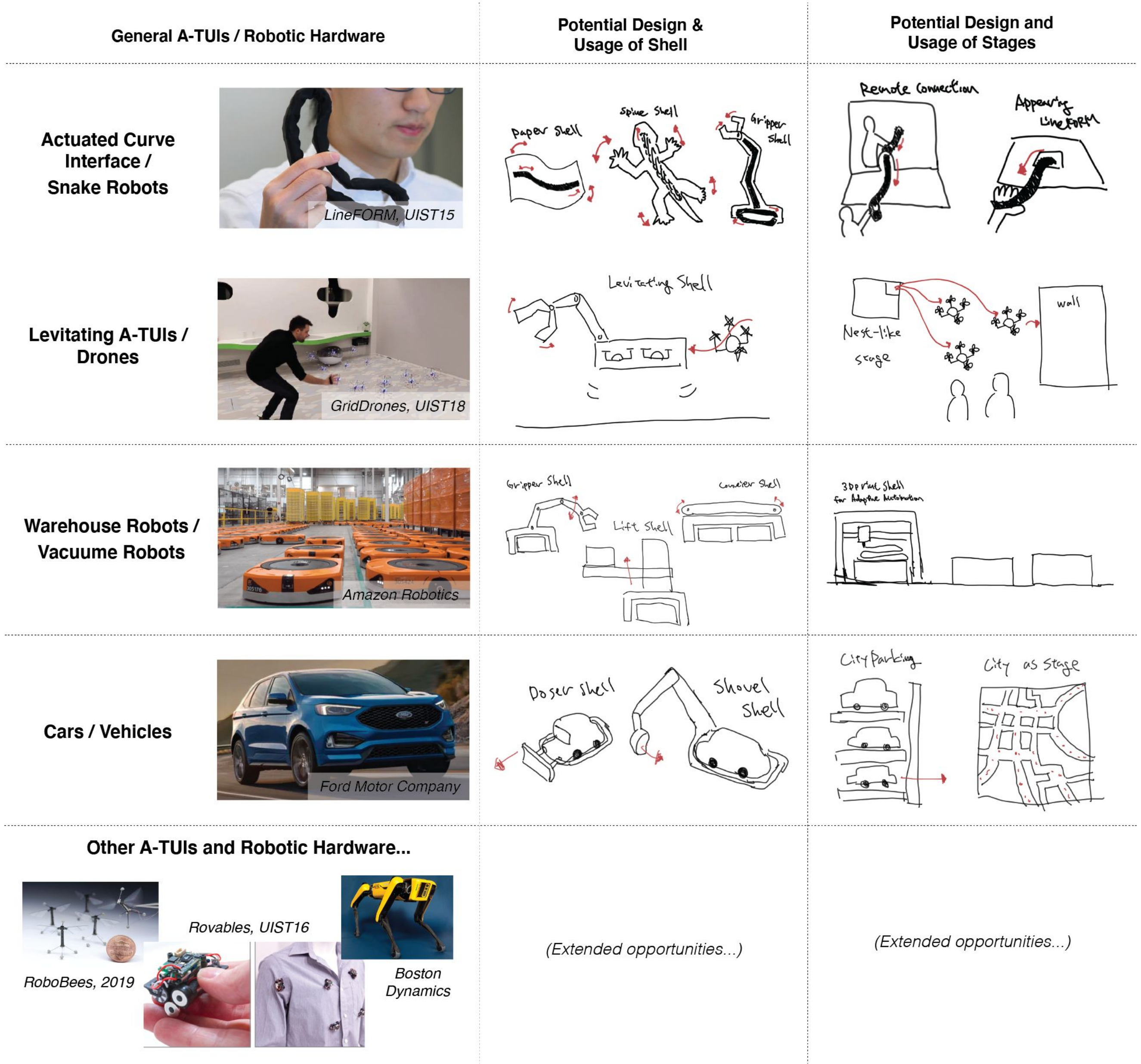
- **User Evaluation and Study for Shells and Stages**

While the COVID-19 situation made it dicult to conduct user studies with the implemented systems in this thesis, there are a variety of evaluation opportunities to be conducted to assess the effects and value of Shells and Stages.

本篇論文因COVID-19影響，沒辦法找使用者進行驗證，但提供些可能的機會進行討論

未來也許可運用在醫學、博物館、導覽人員、舞台導演等...

A-TUI 未來的使用範疇，透過這些領域進行使用者評估與增加廣闊度與使用性



9. Conclusion

- 完成Shell與Stage兩個概念的實例製作，基於A-TUI
- A-TUI的硬體包括了TRANS-DOCK、HERMITS、Dis(Appearables) 三個案例
- 未來可把A-TUI的概念拆解成生活環境用途
- A Desktop and A Room 的場域轉換
- 希望本論文可創造出一個生態系，讓多樣化的互動方式進行延伸
- 將電腦的計算概念從螢幕變成實體空間中
- 動態的Machine-material-environment信號可成為下一個HCI的研究選項