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- **Education**
  - City University of Hong Kong (2017-2022)
    - PhD in Creative Media, Supervisor: Prof. Hongbo Fu
  - University of Science of Technology of China (2012-2016)
    - BA in Communication

- **Research interests:** intersection between CG and HCI
  - 3D Prototyping in Mobile AR

- **Publications**
  - ARAnimator: In-situ Character Animation in Mobile AR with User-defined Motion Gestures (ACM TOG, Special Issue of SIGGRAPH 2020). H. Ye*, K.C. Kwan* (joint first author), W. Su, and H. Fu. 2020.
  - 3D Curve Creation on and around Physical Objects with Mobile AR (IEEE TVCG, Accepted for publication). H. Ye, K.C. Kwan, and H. Fu. 2021.

SIGGRAPH 2020 S2020.SIGGRAPH.ORG THINK BEYOND

ARAnimator: In-situ Character Animation in Mobile AR with User-defined Motion Gestures

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School of Creative Media, City University of Hong Kong

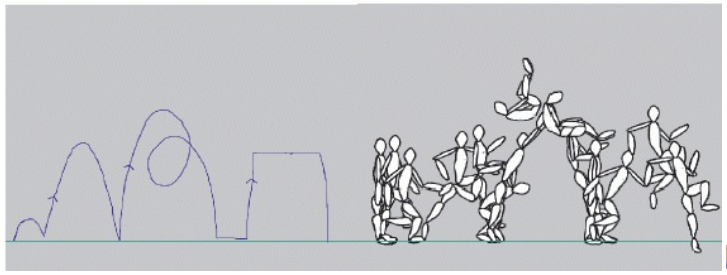
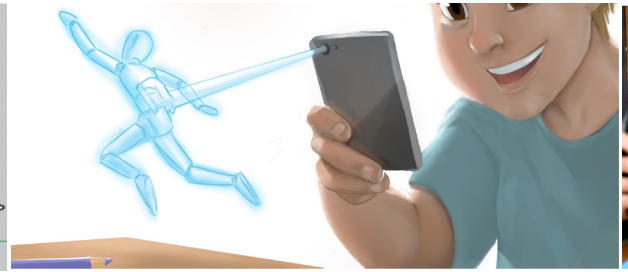
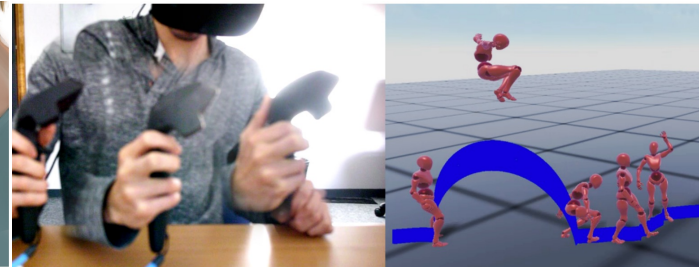
*Authors contributed equally, †Corresponding author

Augmented Reality (AR)

Character Animation in AR

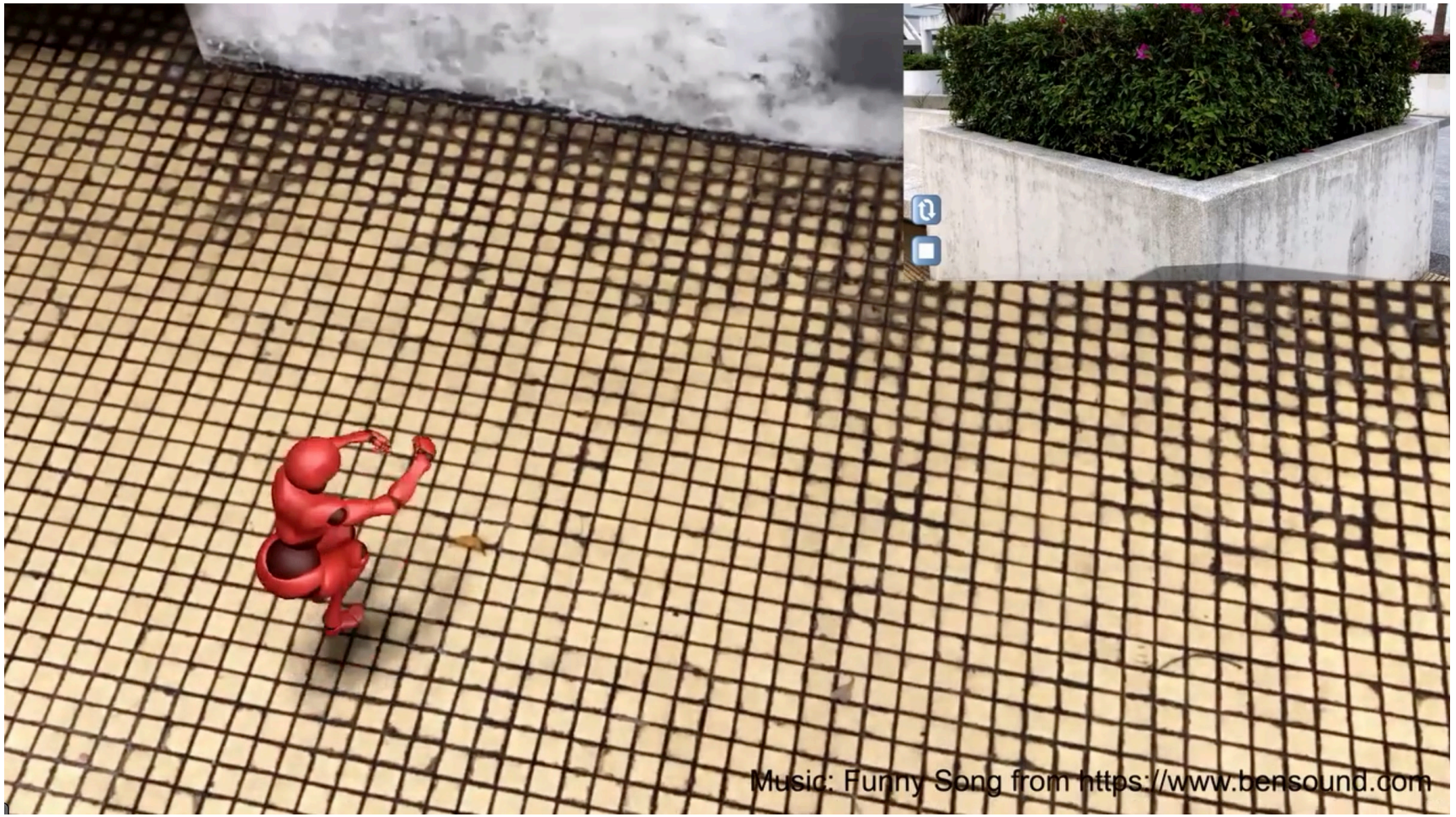
Source: https://www.youtube.com/watch?v=7T4ddYd4tO0

Character Animation Creation

	Motion Doodles [Thorne et al. 2004]	PuppetPhone [Anderegg et al. 2018]	Spatial Motion Doodles [Garcia et al. 2019]
			
Designed for VR/AR	VR	AR	VR
Work without planes	No	No	Yes
Devices	PC	Mobile	HTC Vive
Gestures	2-DoF	3-DoF	3-DoF

Not applicable for creating in-situ character animation closely interacting with the complex real scenes

Desired Character Animation in AR



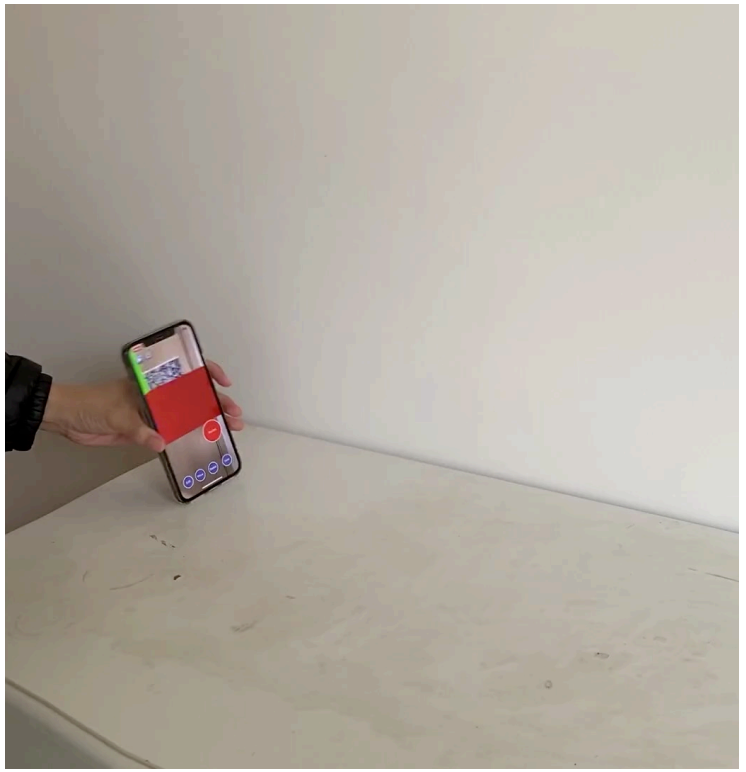
- **In-situ:** specific animations can be created easily at specific locations.
- **Close interaction:** interact closely with complex real environments.
- **Expressive:** diversified character motions.

Our Goal

- Design a tool to allow users to create such in-situ AR character animation
  - Intuitive, easy to use, and low cost

Key Idea

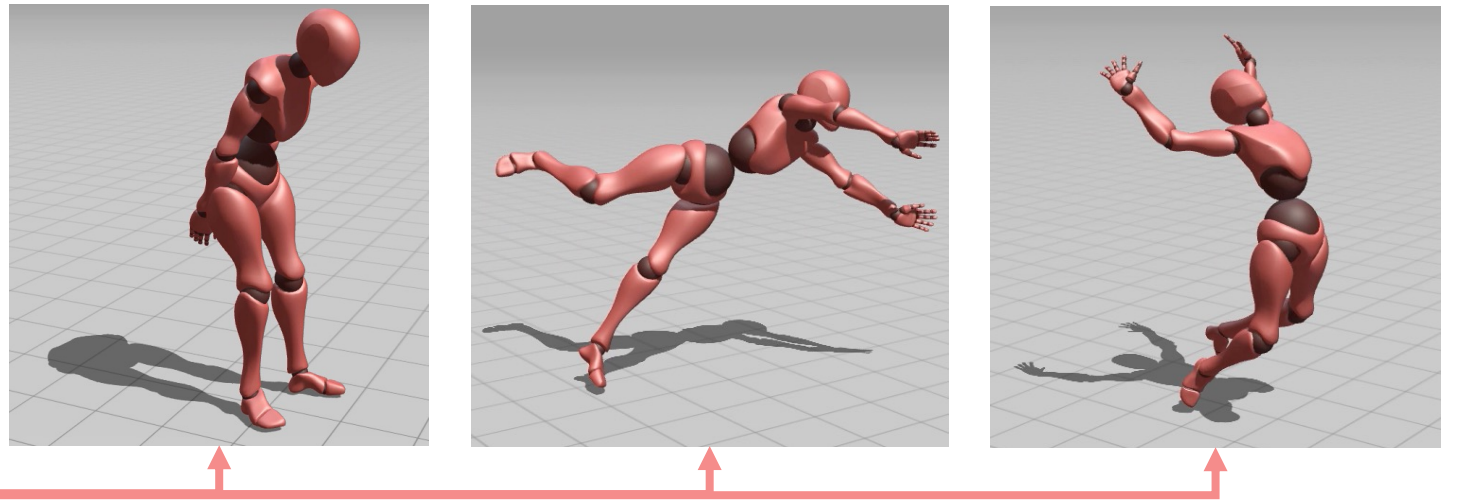
- Doll play: well-known, natural
- Our idea: move and control the mobile device to perform 6-DoF motion gestures to **mimic** the doll plays



Challenge

Mobile device: Low DoF

Virtual character: High DoF

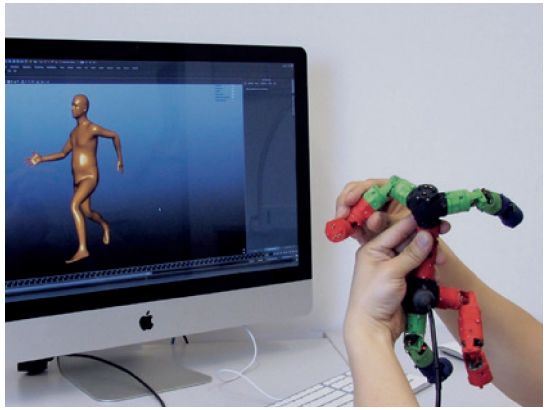


Which one?

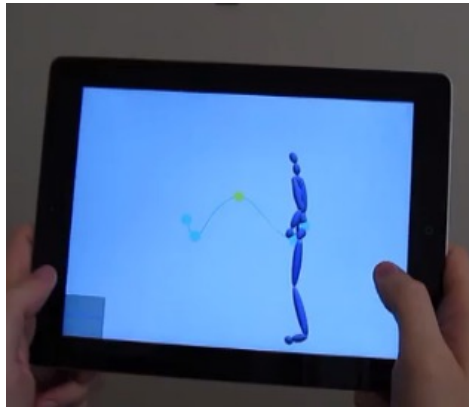
- Our solution: user-defined motions & motion gestures

Related Works

- **Computer puppetry:**
  authors-defined mappings

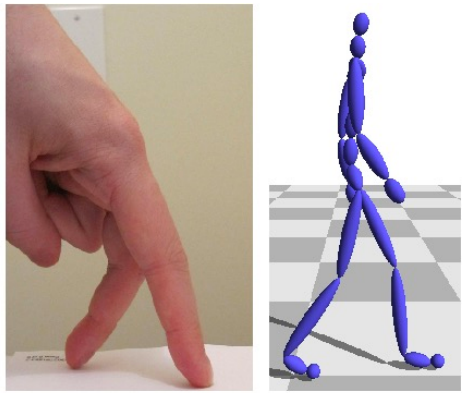


[Glauser et al. 2016]



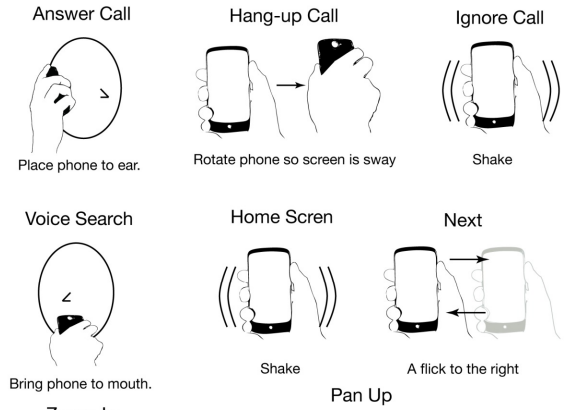
[Lockwood and Singh. 2016]

[Hiroki et al. 2012]

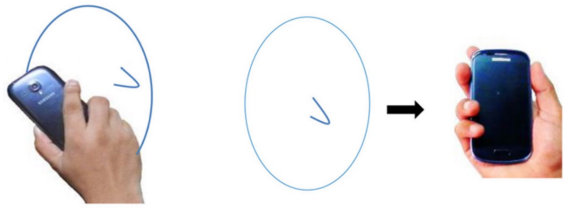


[Lockwood and Singh. 2012]

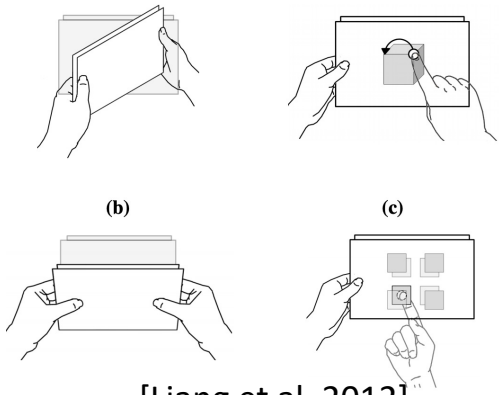
- **User-defined gestures:**
  not for character animation



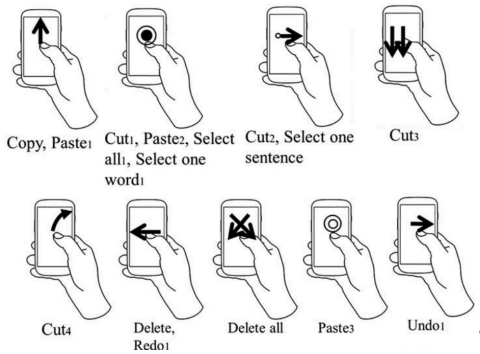
[Ruiz et al. 2011]



[Dim and Ren. 2014]



[Liang et al. 2012]



[Zhu et al. 2017]

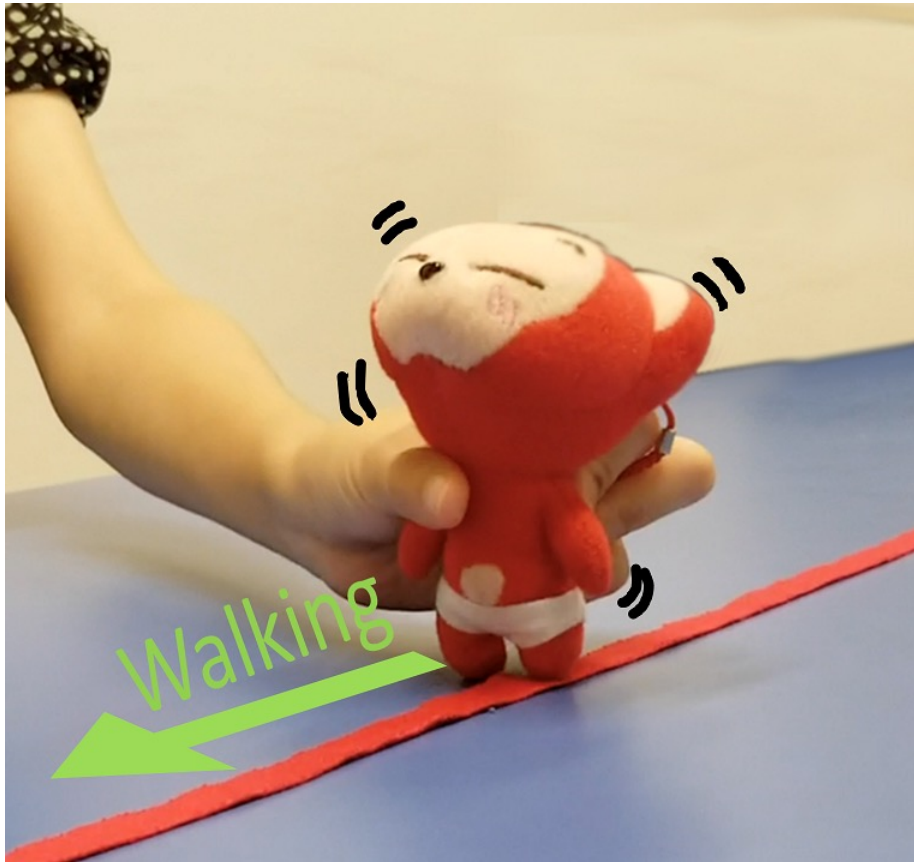
Elicitation Studies

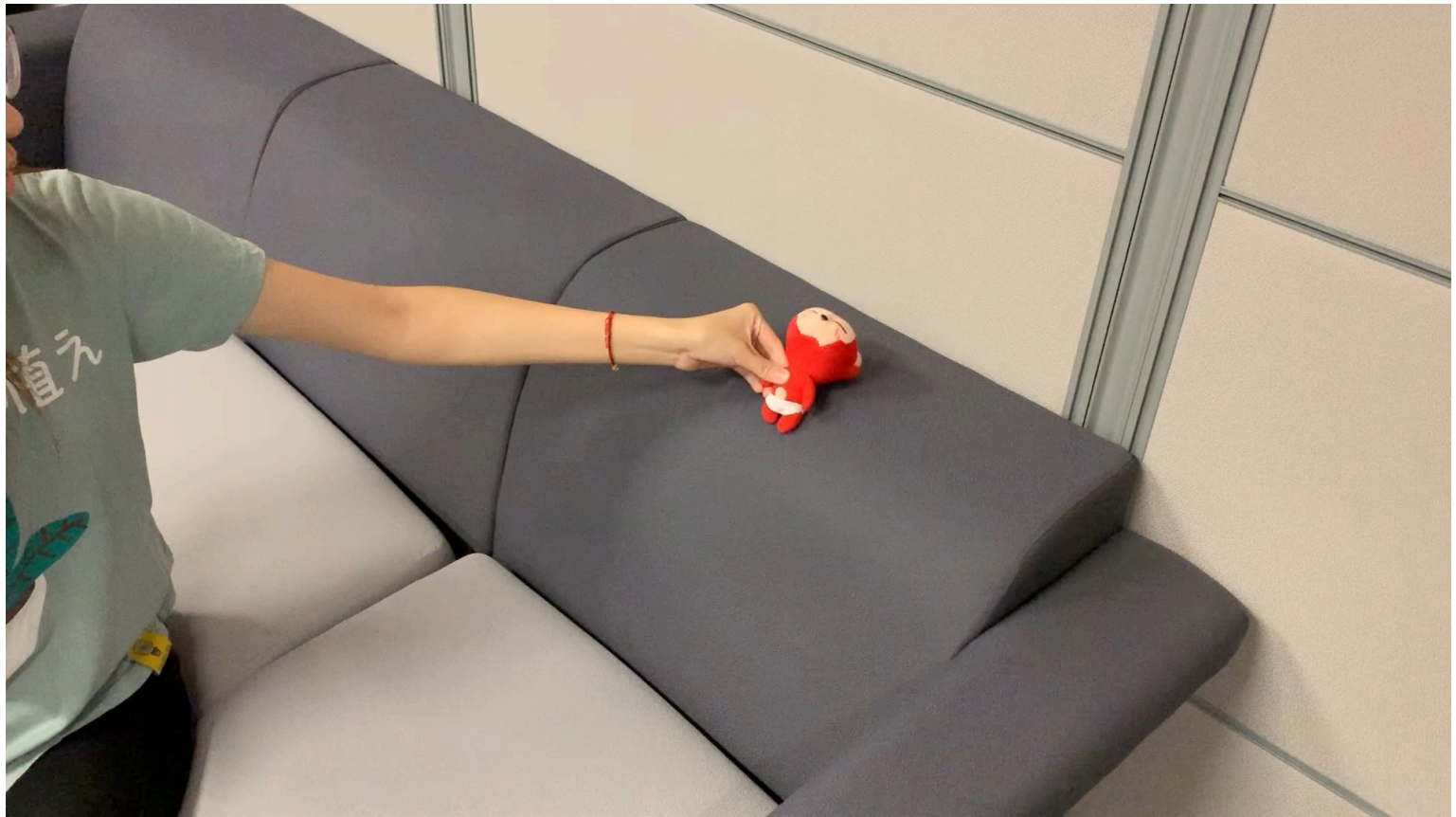
Study I: User-defined Character Motions

Study II: User-defined Motion Gestures

Study I: User-defined Character Motions

- Give users a **physical doll**, let them design and perform character motions.





Result of Study I

- Collect 43 motions in total, filter out 14 uncommon motions (frequency < 2), form the motion list **consisting of 29 remaining motions.**

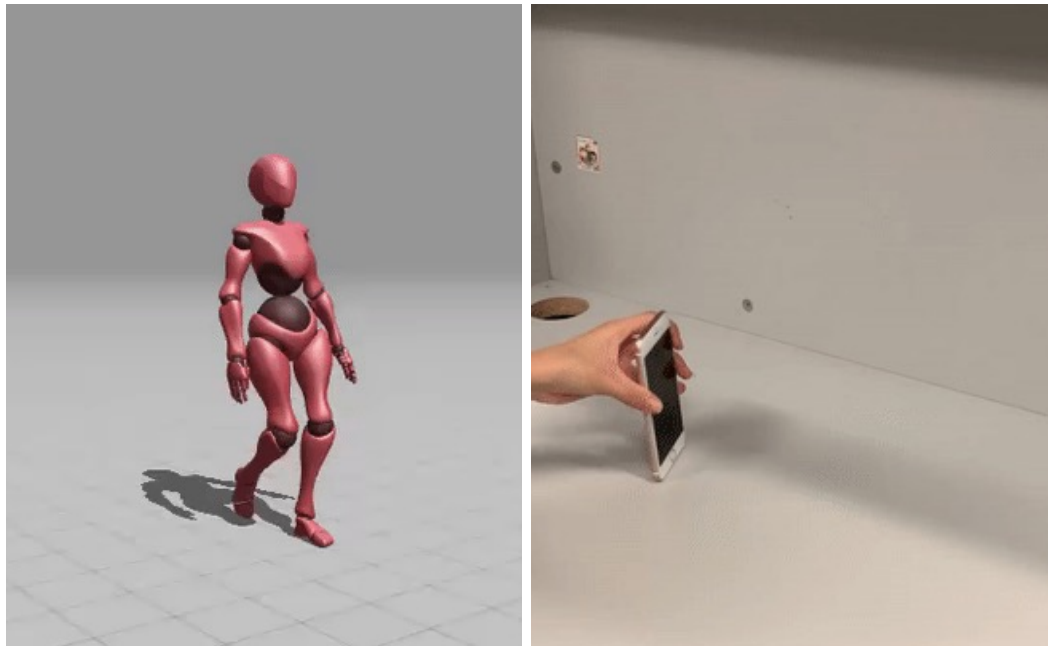
No.	Motion	Frequency	No.	Motion	Frequency	No.	Motion	Frequency
1	Jump	36	16	Fall	3	31	Pole vault	1
2	Climb	17	17	Glide	3	32	Swim	1
3	Walk	15	18	Crawl	3	33	Split	1
4	Slide	9	19	Roll	3	34	Tai Ji	1
5	Lie down	8	20	Flip	3	35	Have a shower	1
6	Get up	8	21	Turn a circle	3	36	Shake hand	1
7	Run	6	22	Hit the wall	2	37	Shake a tree or flower	1
8	Pop head	6	23	Cartwheel	2	38	Bend over	1
9	Sit down	6	24	Fall down	2	39	Tango	1
10	Stand up	6	25	Circle around pole	2	40	Ballet	1
11	Swing	6	26	Wirewalk	2	41	Hip-Hop	1
12	Jump with switching feet	4	27	Skate	2	42	Free dance 1	1
13	Pull	4	28	Fly	2	43	Free dance 2	1
14	Push	4	29	Stomp	2			
15	Climb over	3	30	Walk sideway	1			

Study II: User-defined Motion Gestures

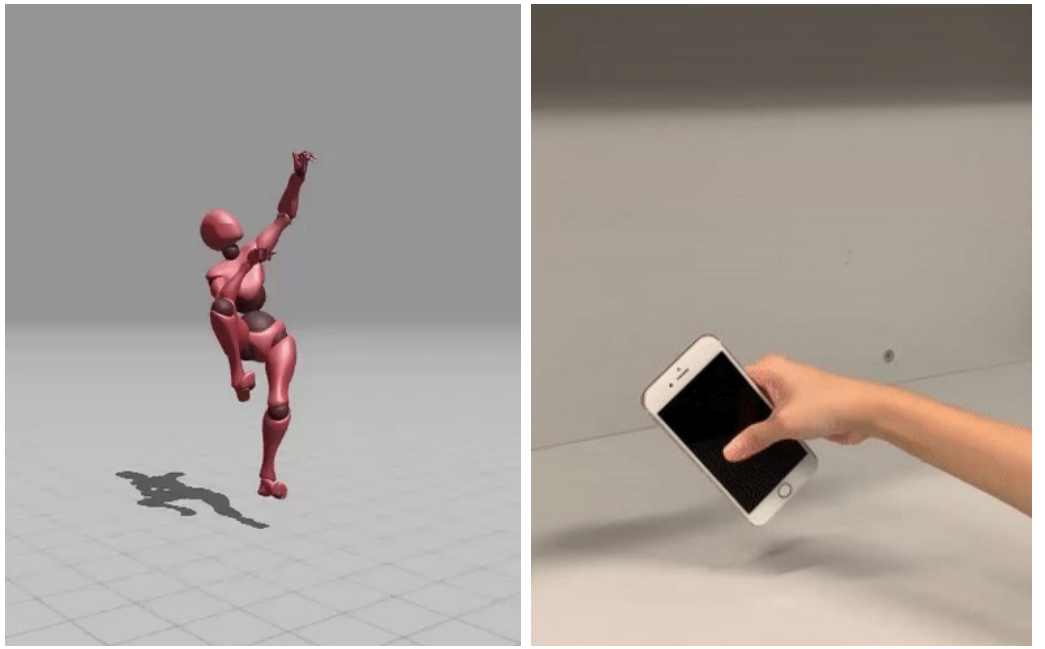
- Give users a **mobile phone**
- Design and perform motion gestures describing the motions from Study I
- Manually categorize gestures
- Select a representative gesture for each motion

Results of Study II

- Examples of representative motion gestures



Walk

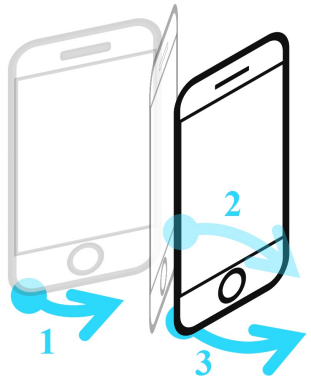


Climb

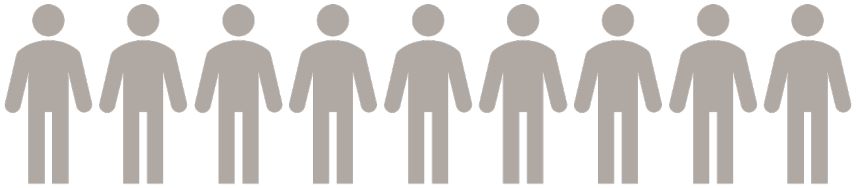
Agreement Rate

- Evaluate the degree of consensus among user-defined gestures

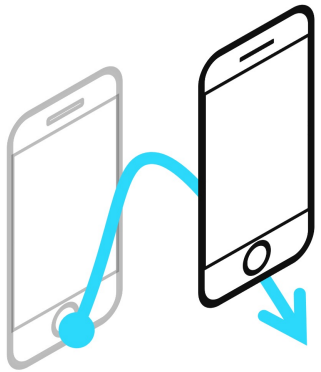
Run



Gesture #1



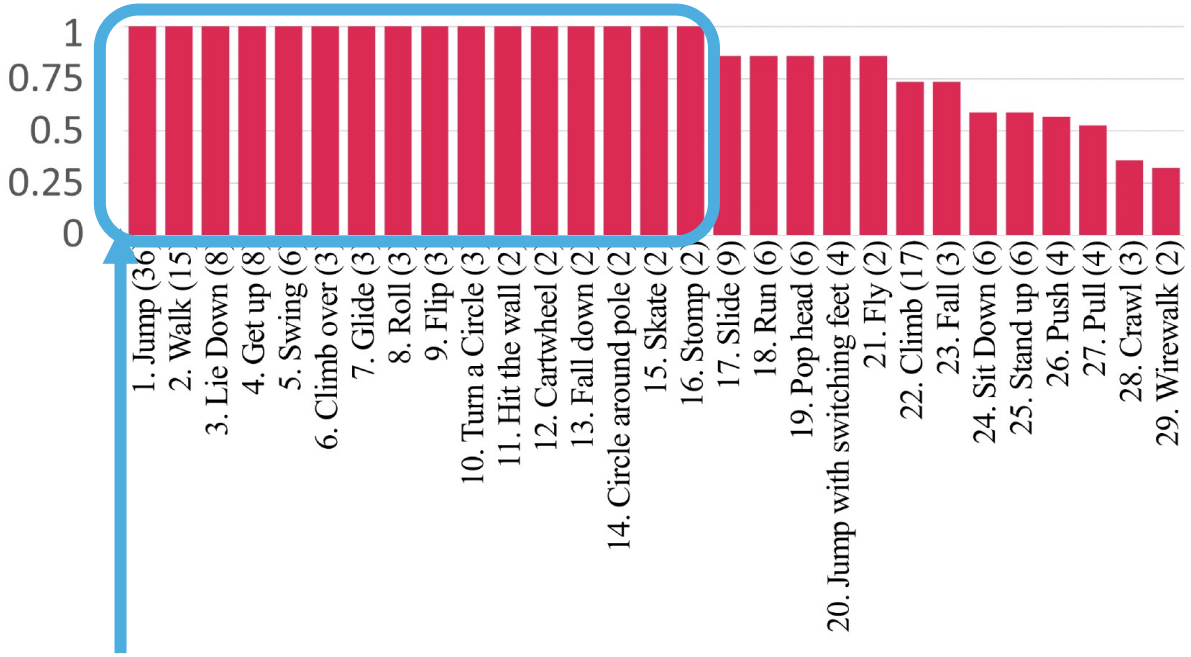
More intuitive!



Gesture #2

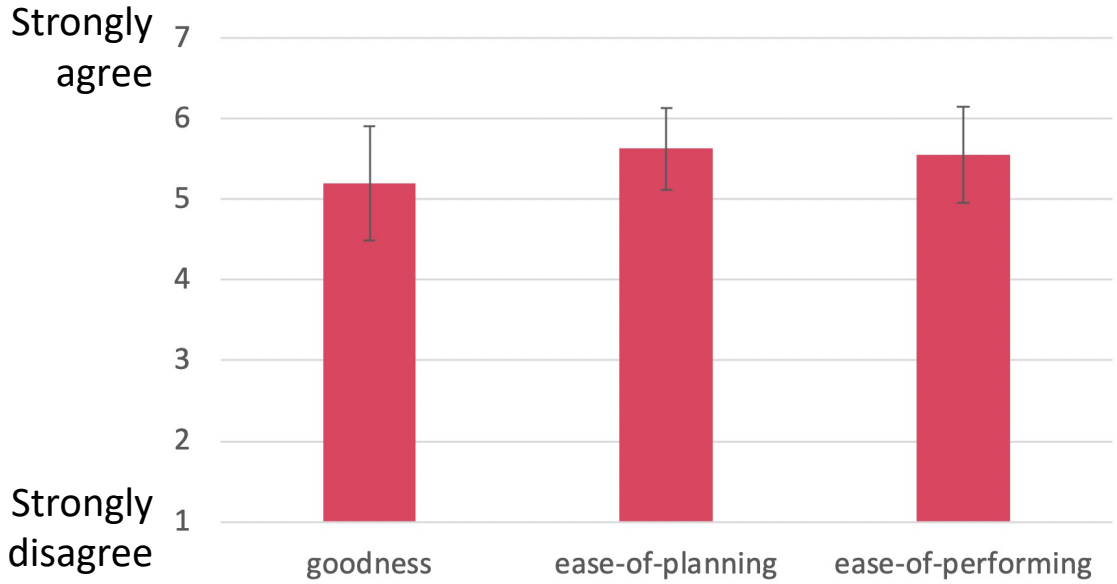
Results of Study II

Agreement Rate



100%: users define the identical gesture for each motion

Subjective Rating

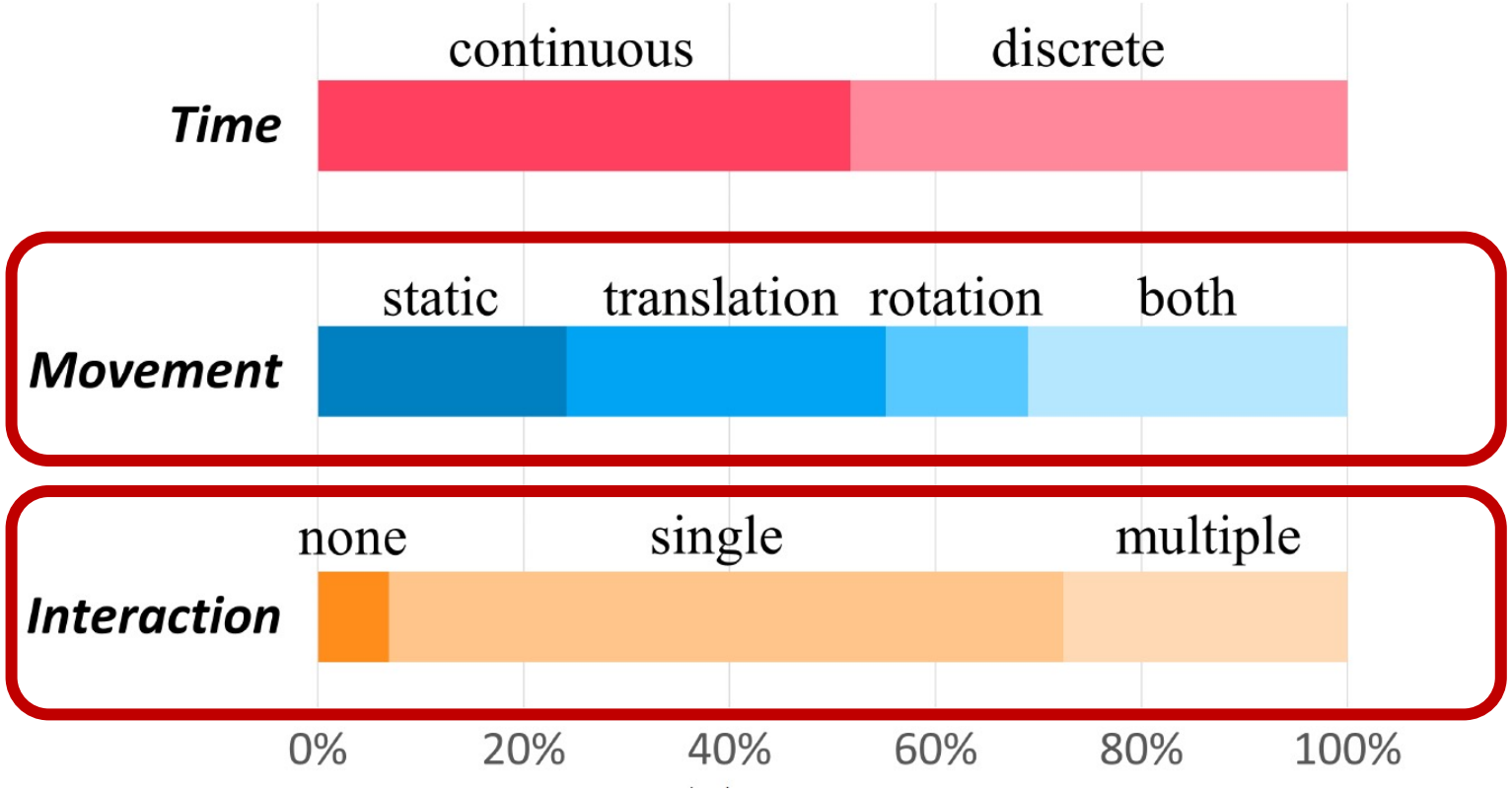


- The higher value, the better

Findings

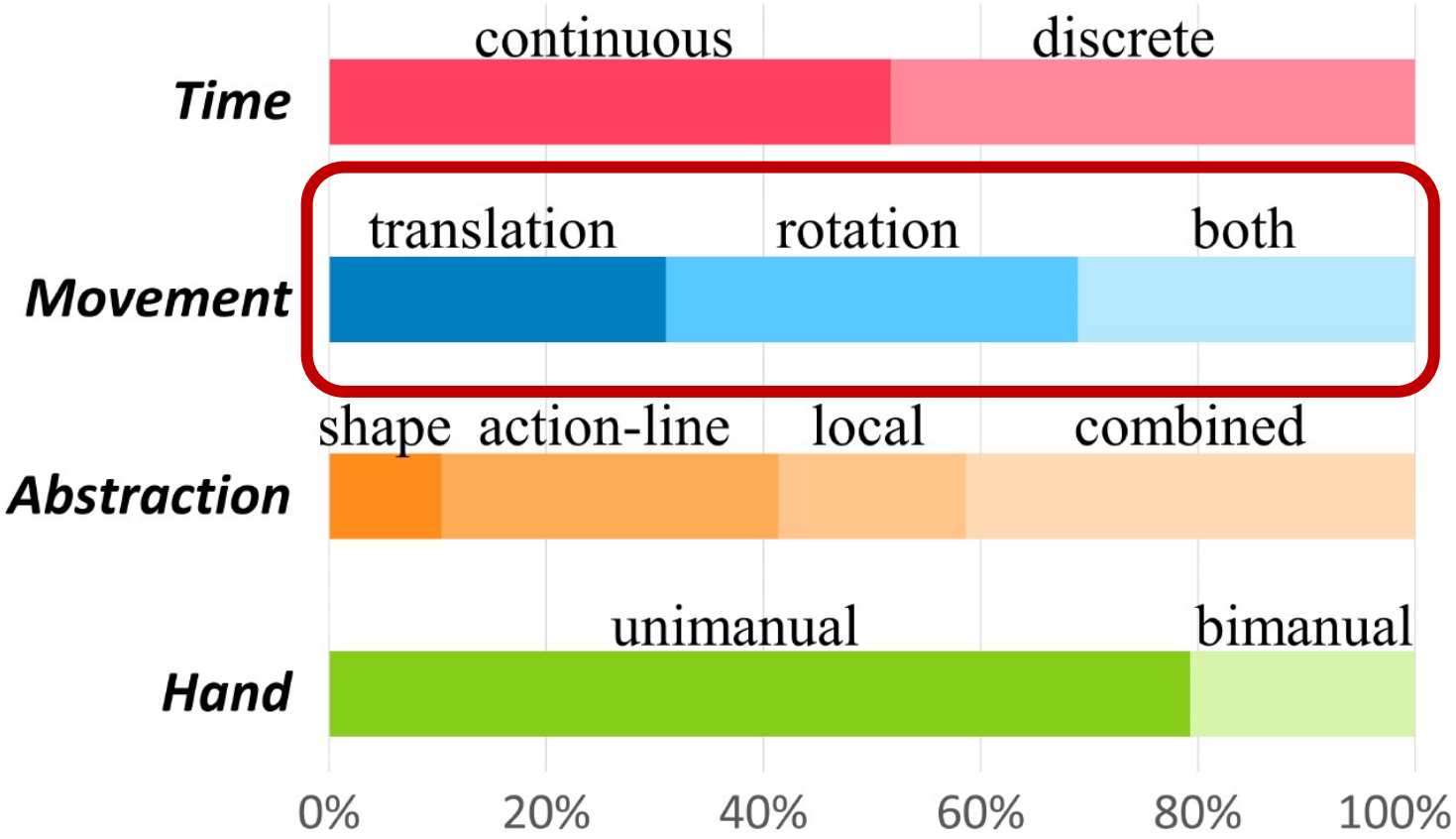
Findings

- Taxonomy of **Motions**

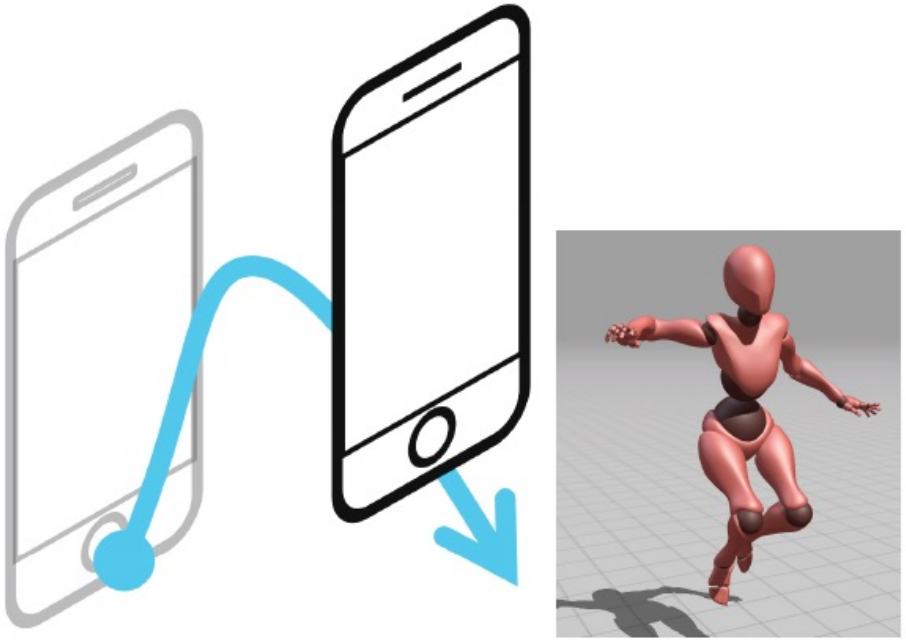


Findings

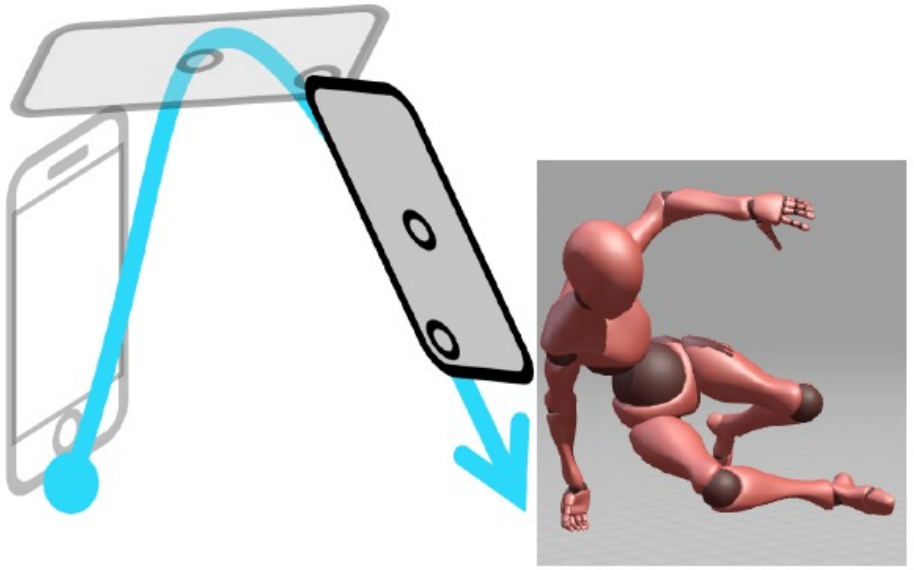
- Taxonomy of **Motion Gestures**
- Expressiveness of 6-DoF Gestures



Findings



Jump



Climb over

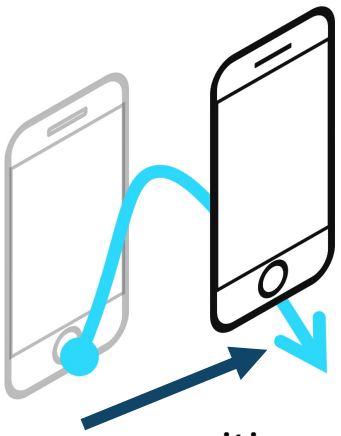
Our System

ARAnimator: Authoring

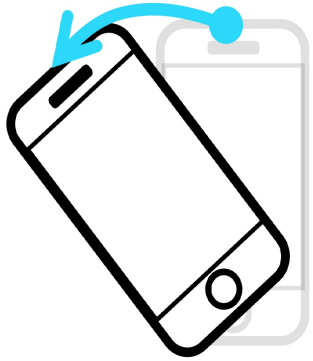
- ARKit: obtain the trajectory of the mobile device in 3D AR space

ARAnimator: Gesture Classification

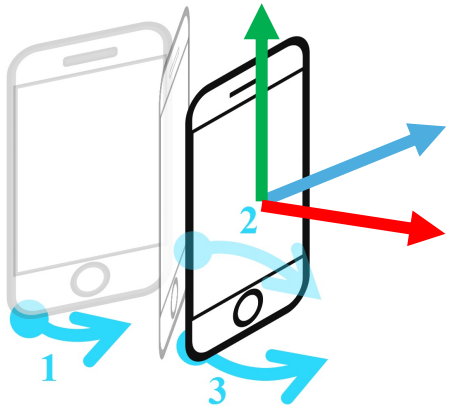
- SVM-based classifier
  - Data collection: recruit 5 participants to perform motion gestures
    - IMU data from ARKit: position + orientation
  - Feature extraction: from the insights of previous studies



position change



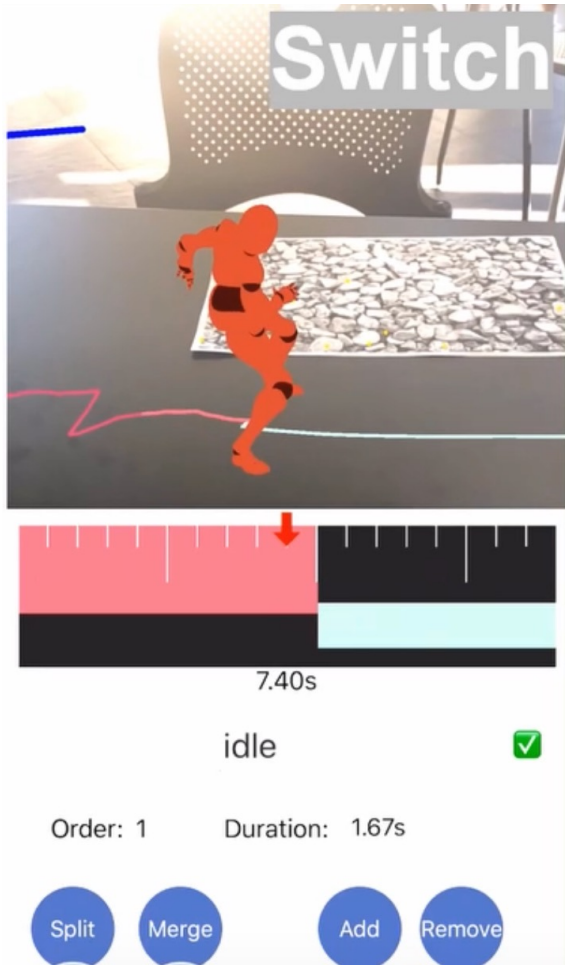
orientation change

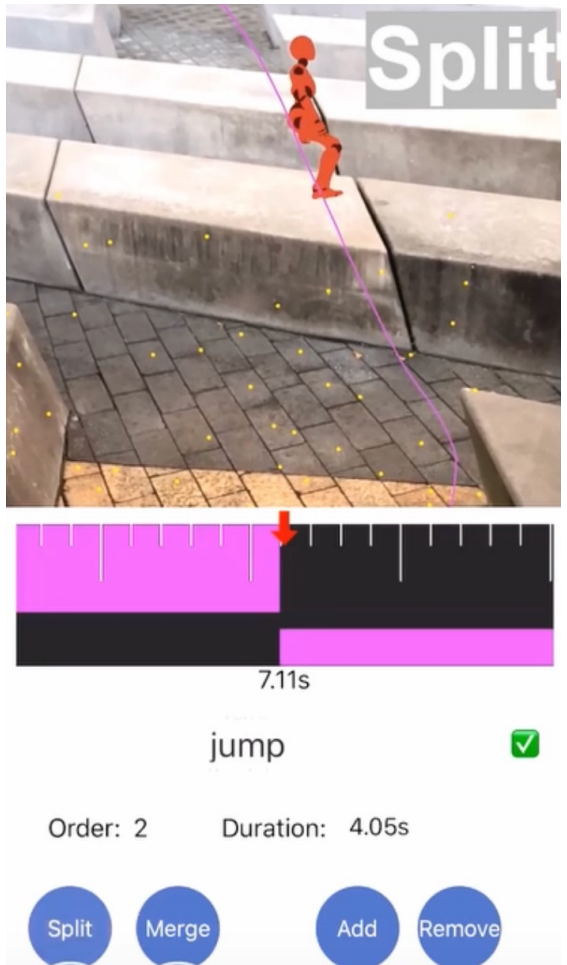


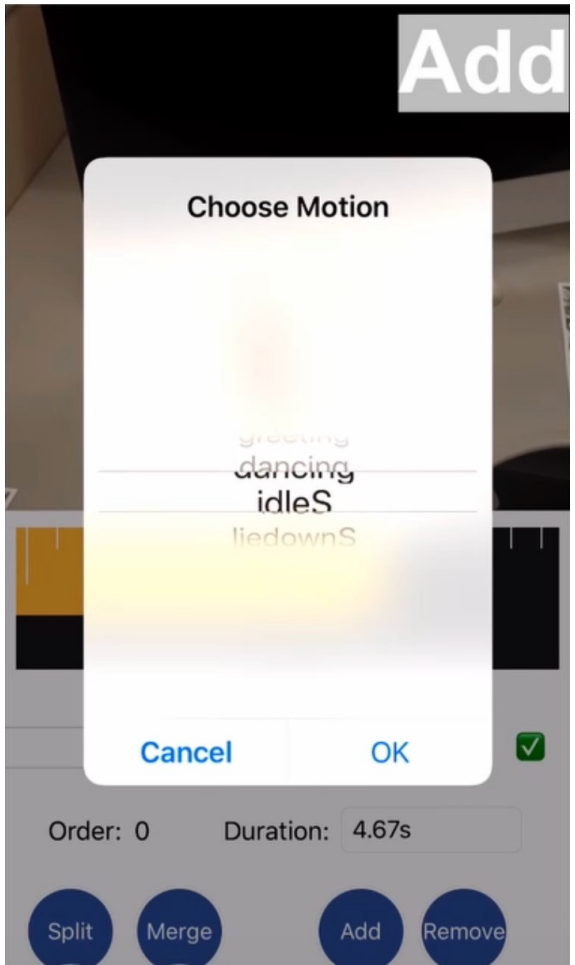
continuous

ARAnimator: Editing

- Interactive editing for fixing classification errors or adding more motions







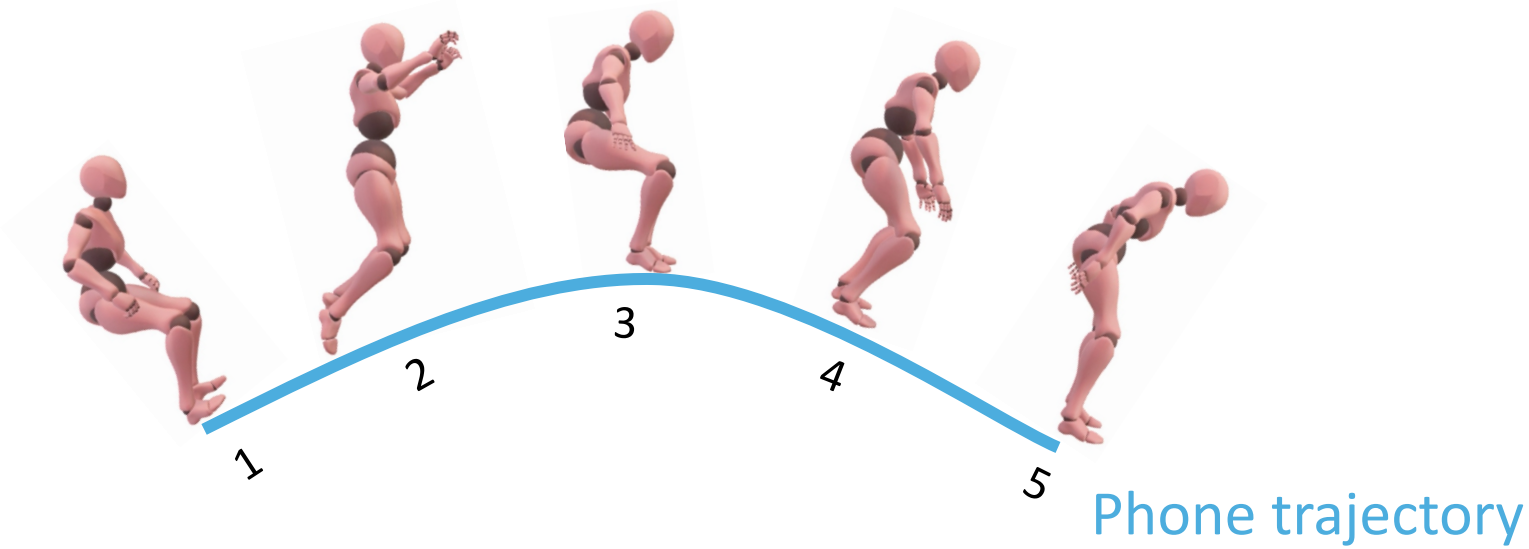
ARAnimator: Animation Synthesis

- Prepare a pre-defined 3D character animation clip for each motion type

Jump

ARAnimator: Animation Synthesis

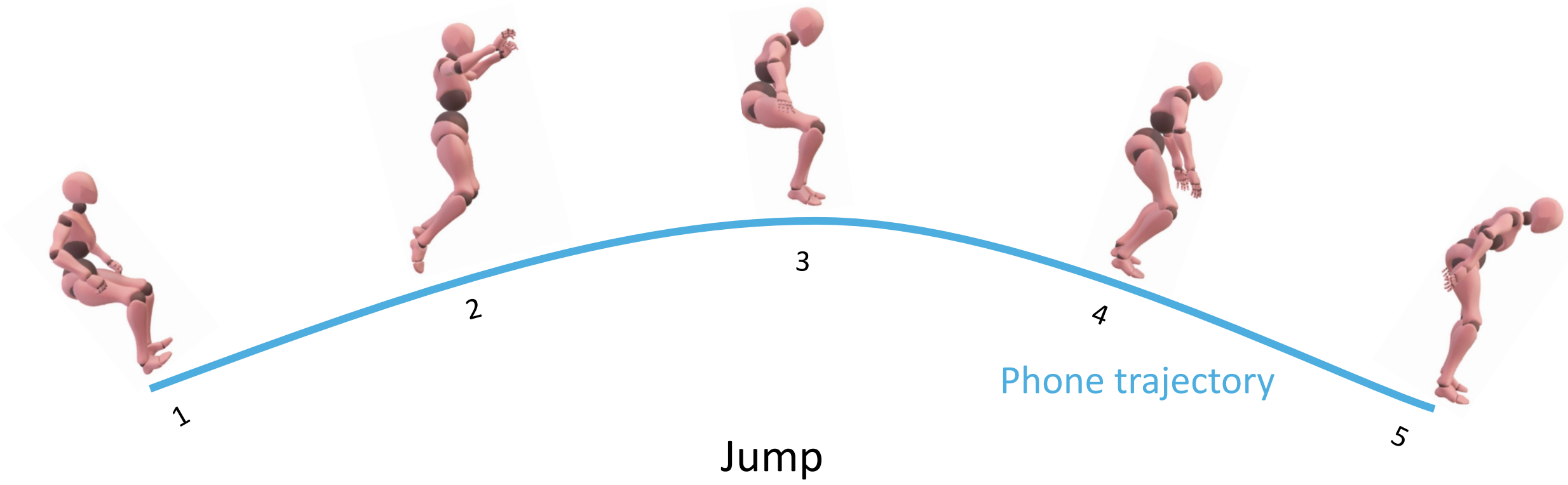
- Translate and/or rotate each animated character along its trajectory



Jump

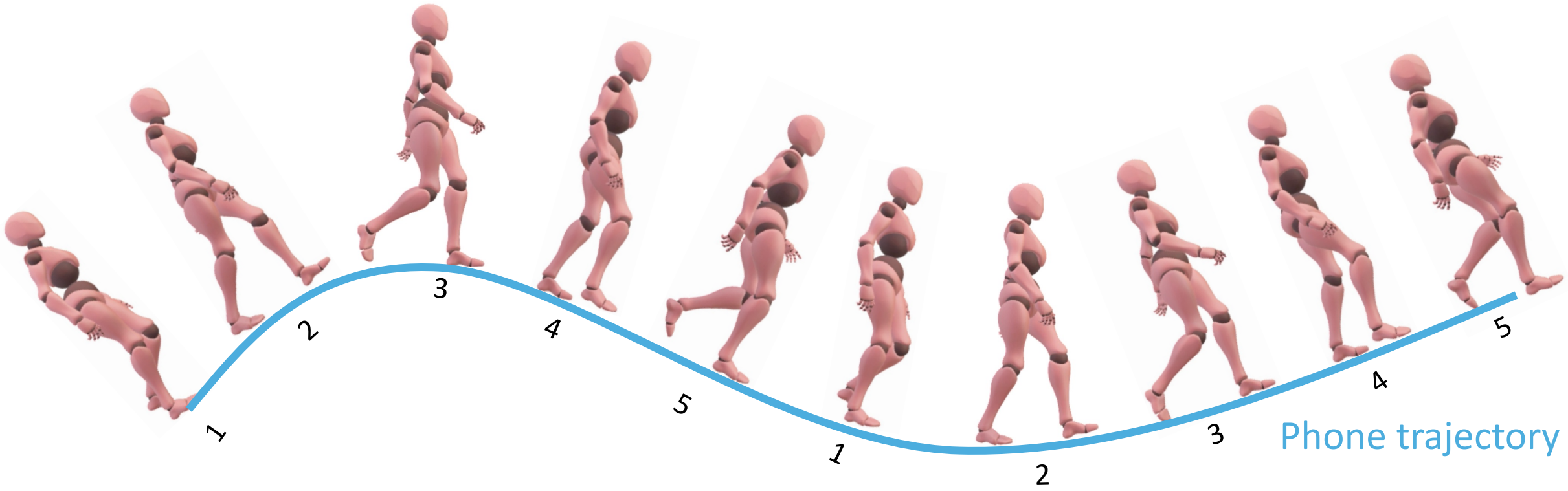
ARAnimator: Animation Synthesis

- Trajectory duration > animation clip duration: normalize the time for **discrete motions**



ARAnimator: Animation Synthesis

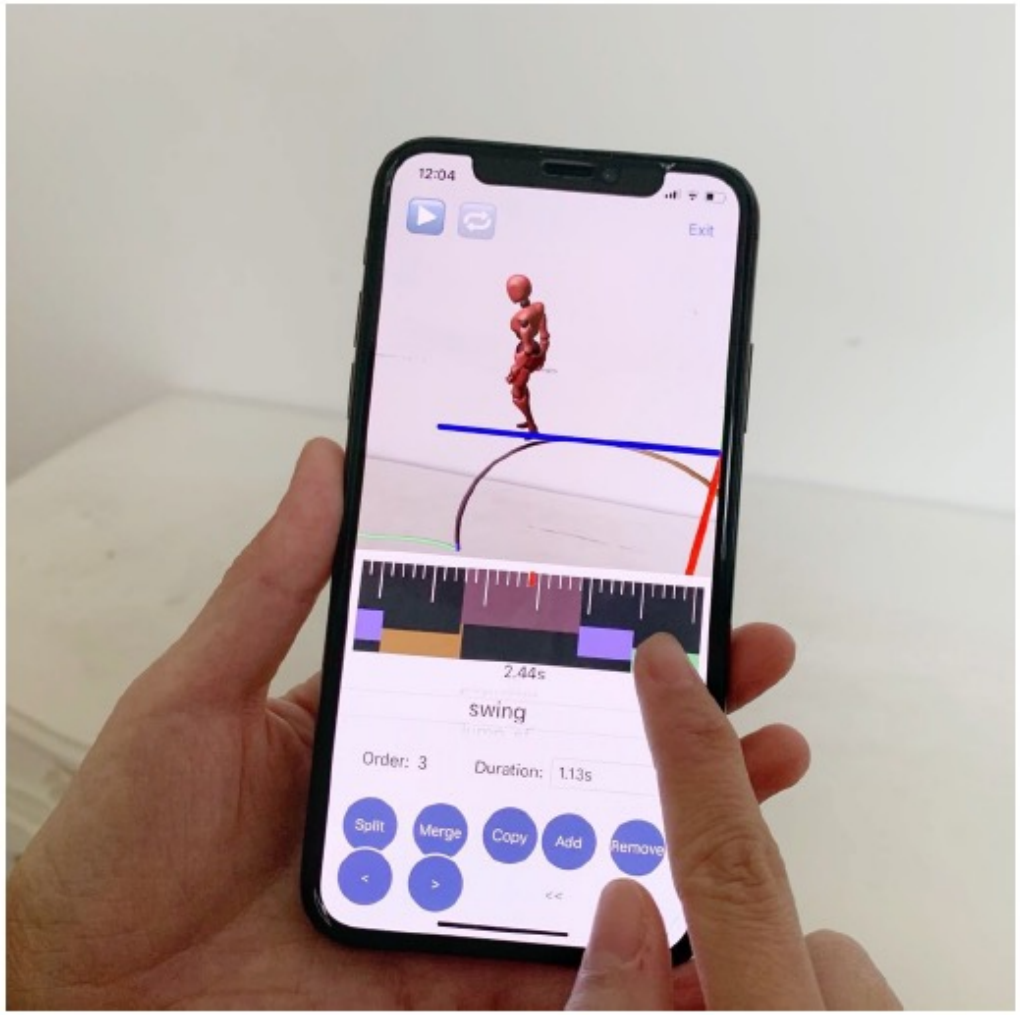
- Trajectory duration > animation clip duration: loop the clips for **continuous motions**



Walk

Our Results

Usability Study



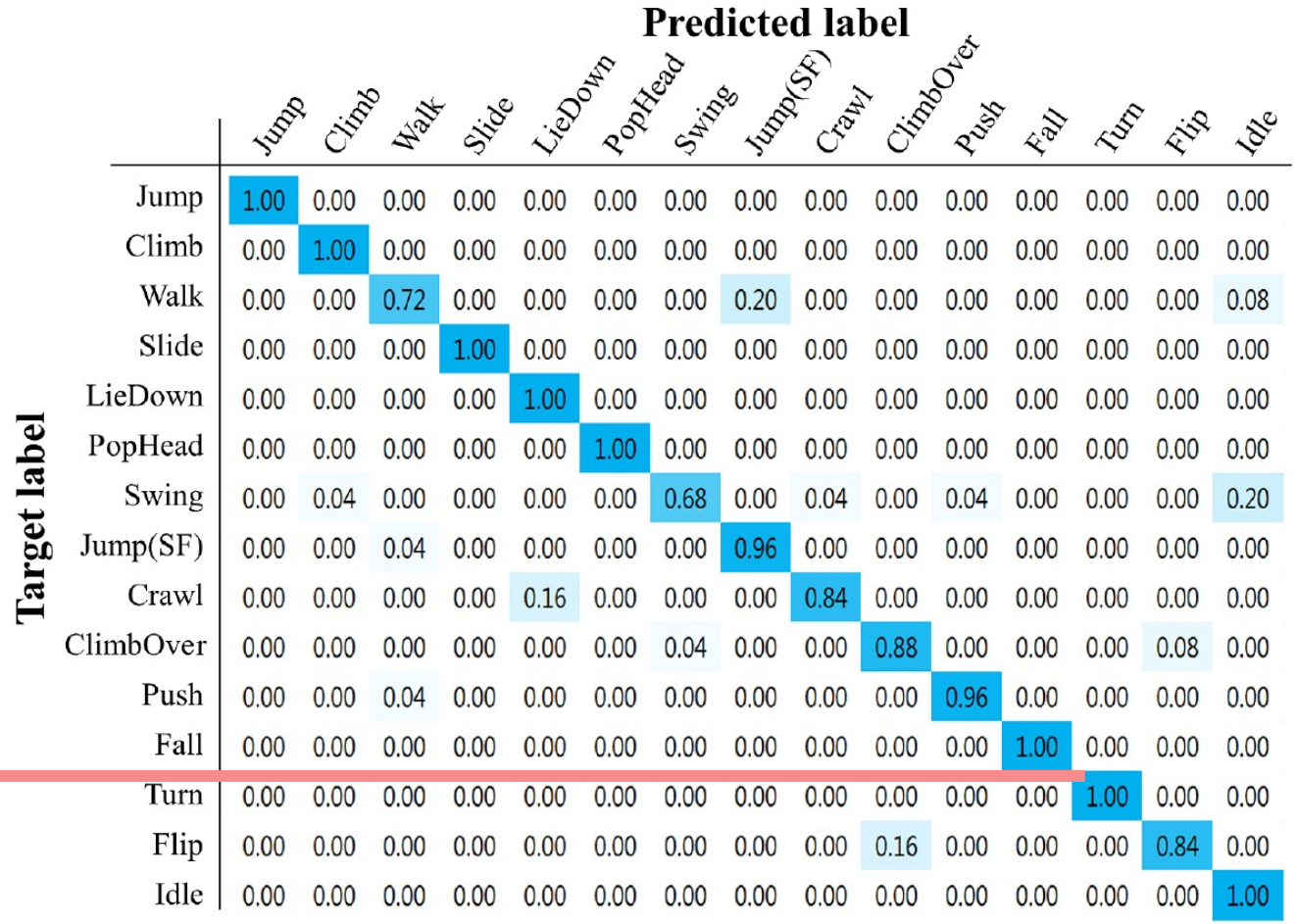
Result 1: Living room

Result 2: Lemmings

Result 3: Flower bed

Quantitative Evaluation on Gesture Classification

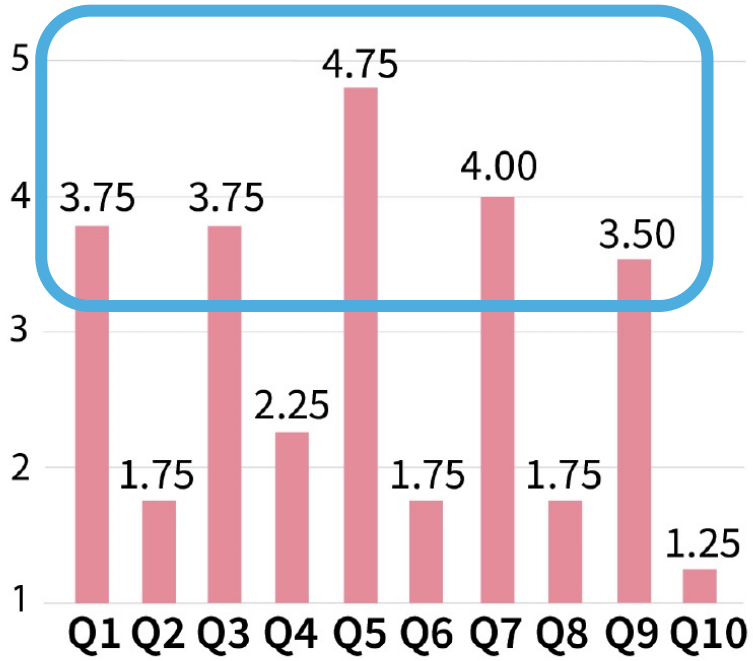
- 5-fold cross-validation
  - Accuracy: M-94.13%, SD-2.76%
- Usability study
  - Accuracy: M-81.77%, SD-21.20%



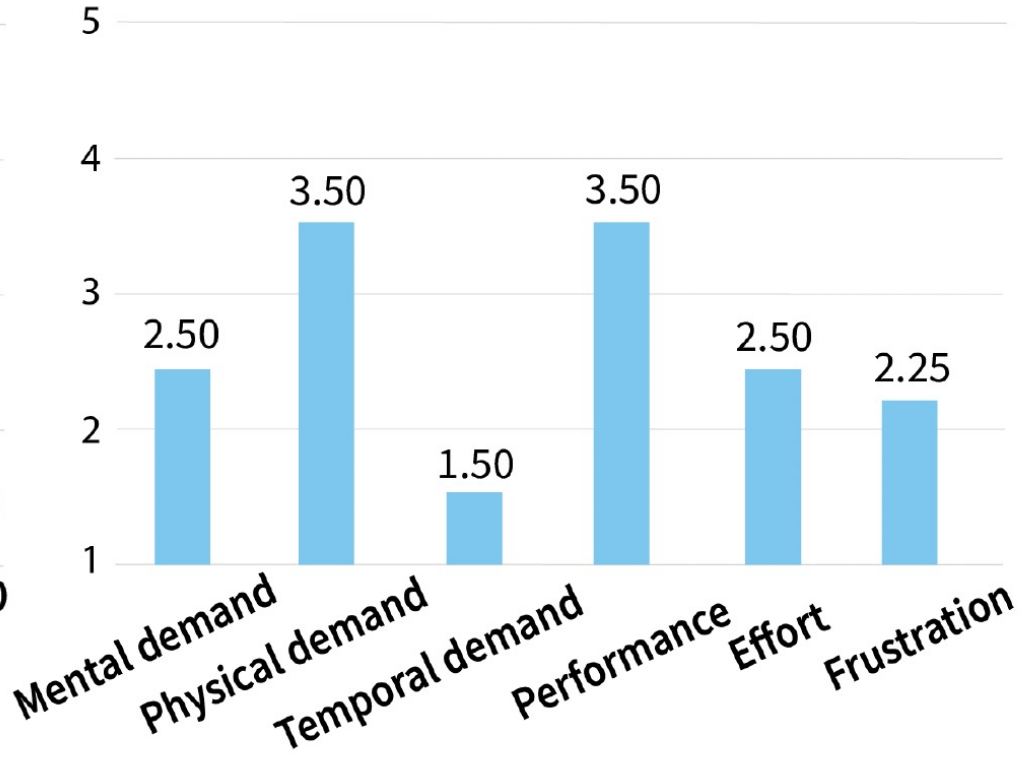
Correctly classified

Normalized confusion matrix

Results of SUS and NASA-TLX



(a) SUS

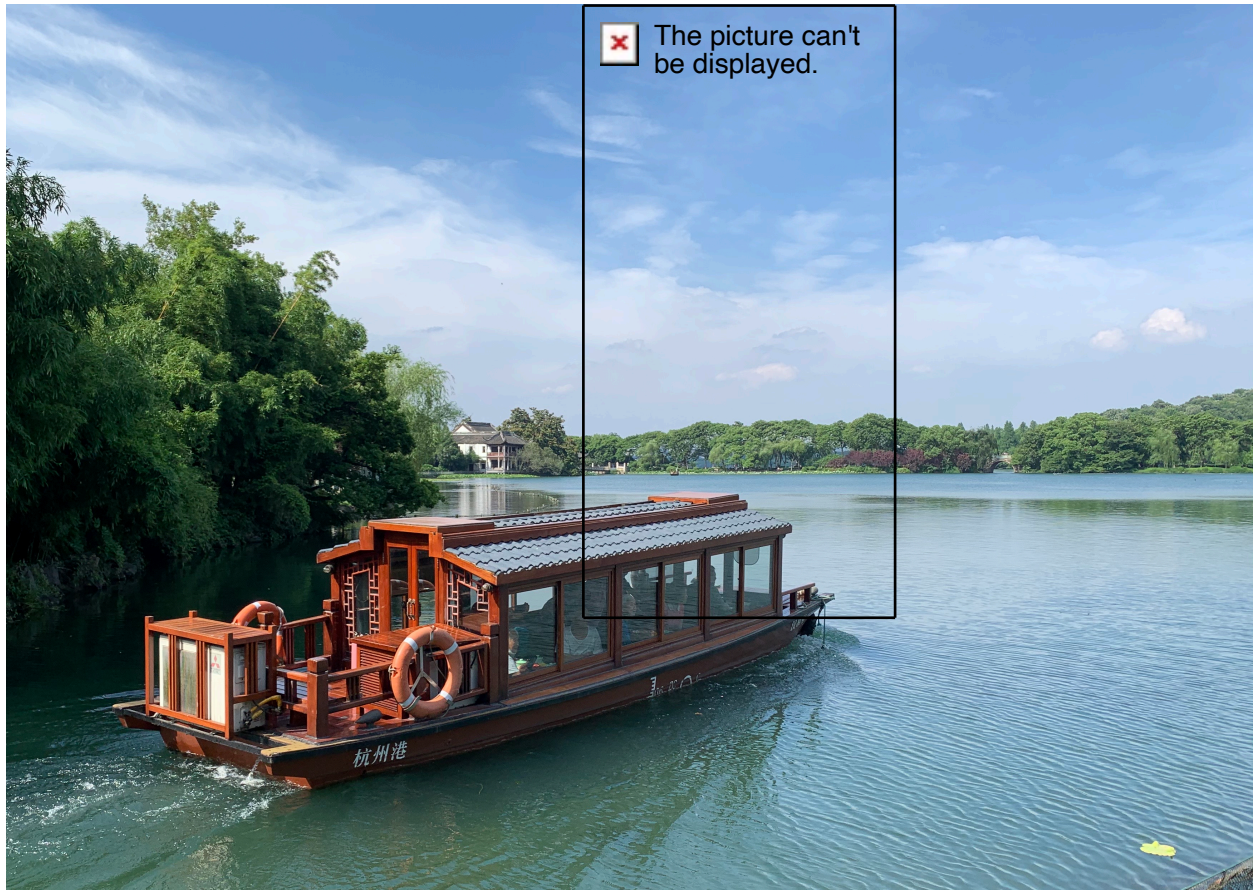


(b) NASA-TLX

- SUS odd-number questions:
  the higher the SUS scores, the better

Limitations and Future Work

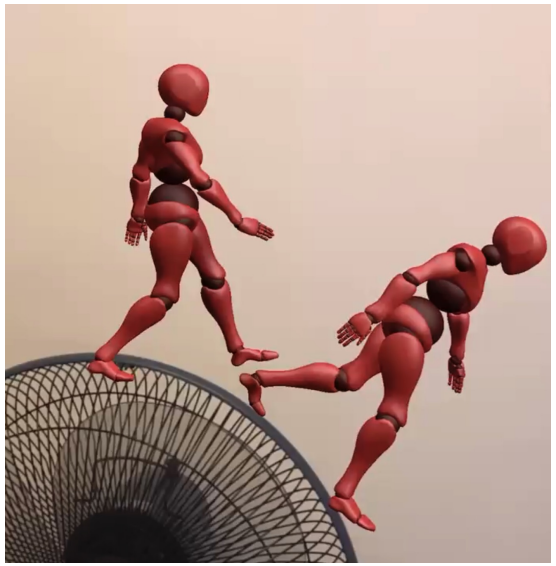
- **Scenario size:** only applicable for small-sized environments
- **Scalability:** only supports a subset of the collected motions
- **Classification:** around 80% classification accuracy in the usability study



Large-scale scene: unreachable by arms

Thank You

- Two elicitation studies: user-defined motions and motion gestures
- ARAnimator: allow novice users to easily create 3D in-situ character animations closely interacting with real environments in mobile AR

- Have questions? Contact us at: huiyehci@gmail.com