MAKING WITH A SOCIAL PURPOSE

Jon Froehlich | Assistant Professor | Computer Science

HCIL Human Computer Interaction Laboratory

MAKEABILITY LAB

COMPUTER SCIENCE
UNIVERSITY OF MARYLAND

UNIVERSITY OF MARYLAND


MAKEABILITY LAB
http://makeabilitylab.io


HCIL
MAKEABILITY LAB


Aqua-Bound
WERNER
230
HCIL
Reebok
MAKEABILITY LAB

Our Mission

DESIGN, BUILD, & STUDY INTERACTIVE TOOLS & TECHNIQUES TO ADDRESS PRESSING SOCIETAL CHALLENGES

MAKEABILITY LAB

FOUR FOCUS AREAS

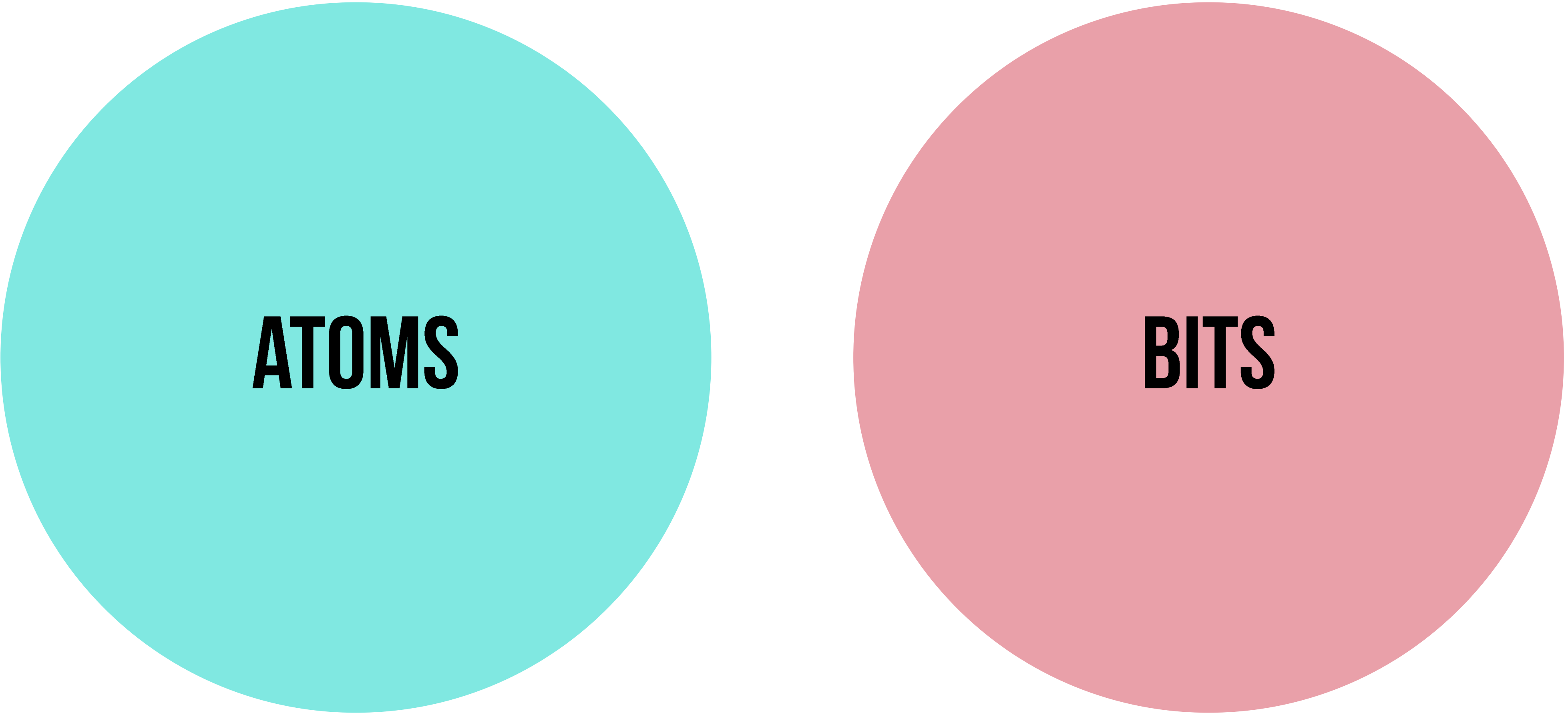
ENVIRONMENTAL SUSTAINABILITY

HEALTH & WELLNESS

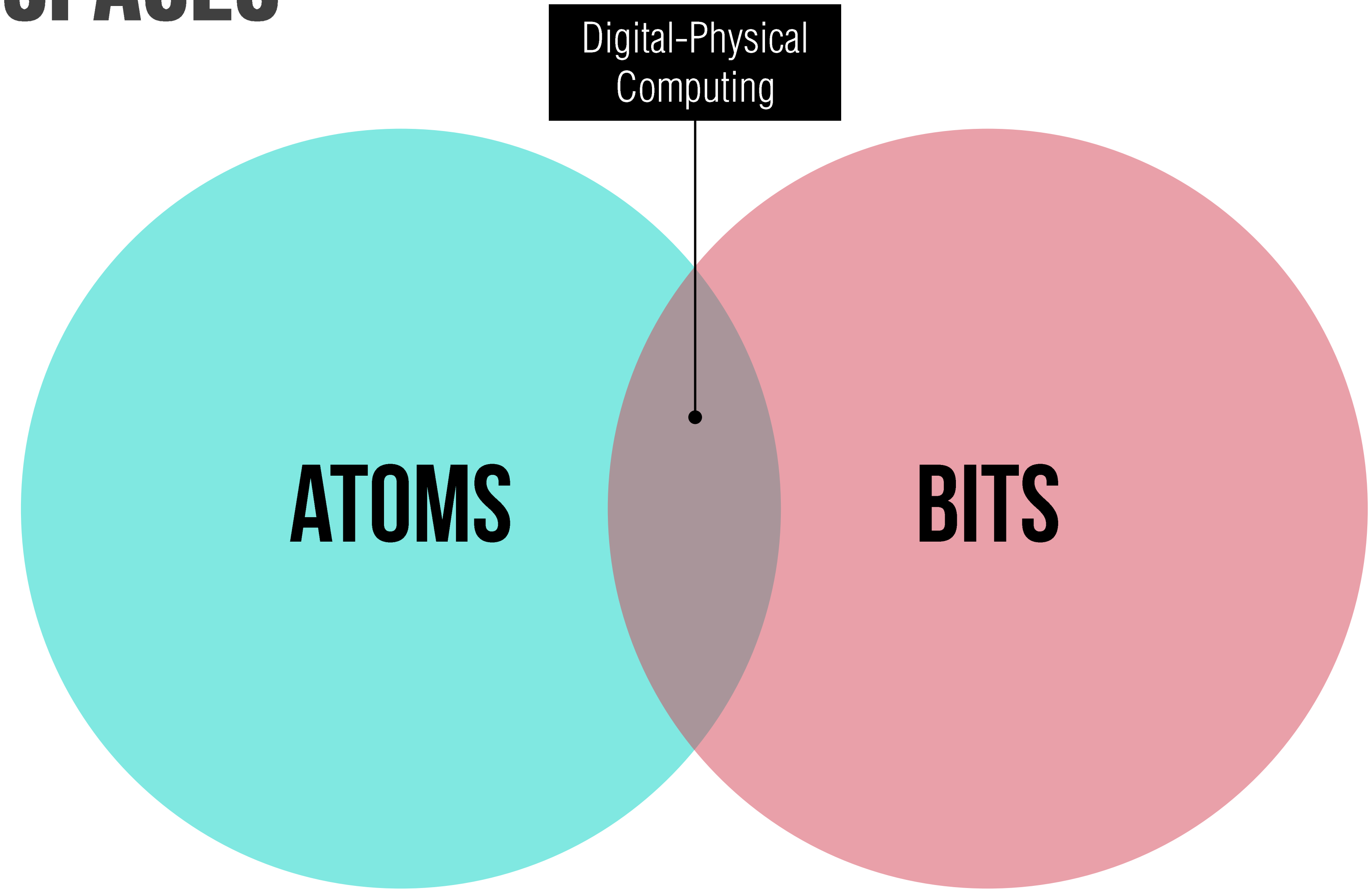
ACCESSIBILITY

STEM EDUCATION

PROBLEM SPACES

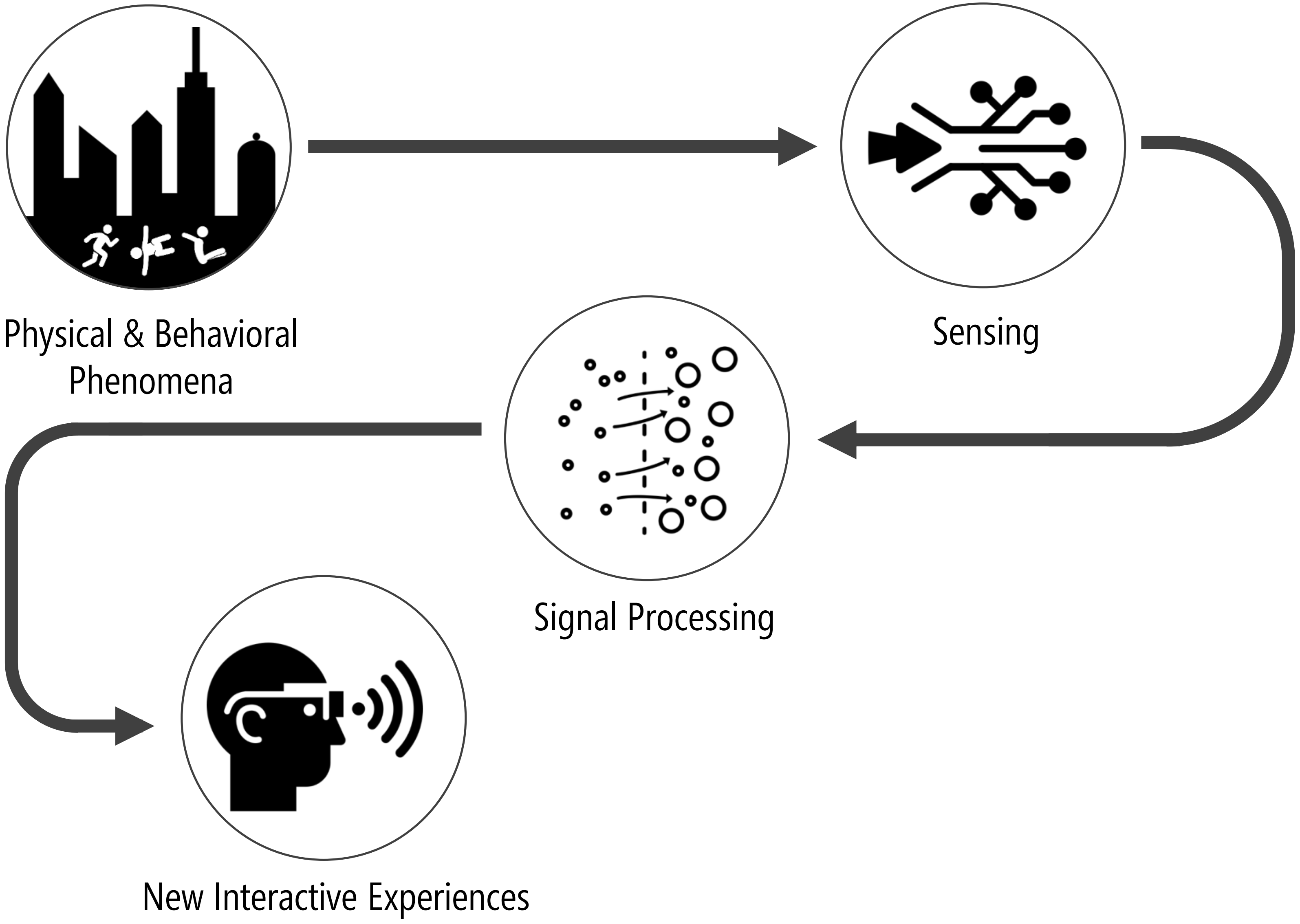


PROBLEM SPACES



MAKEABILITY LAB

APPROACH



MAKEABILITY LAB

FOUR FOCUS AREAS

ENVIRONMENTAL SUSTAINABILITY

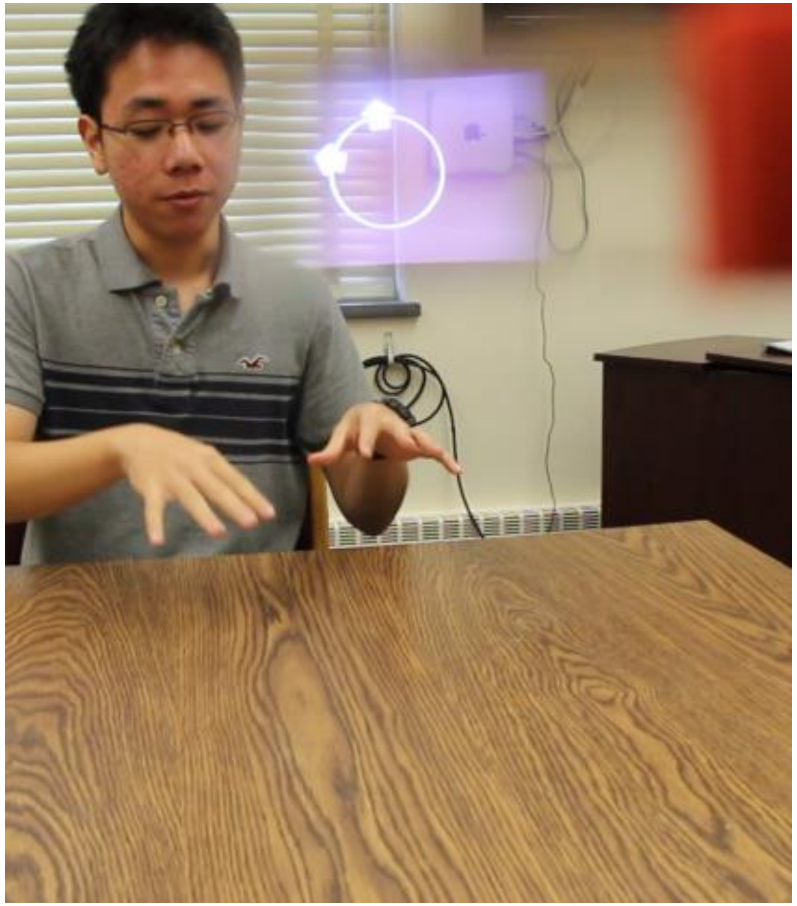
HEALTH & WELLNESS

ACCESSIBILITY

STEM EDUCATION

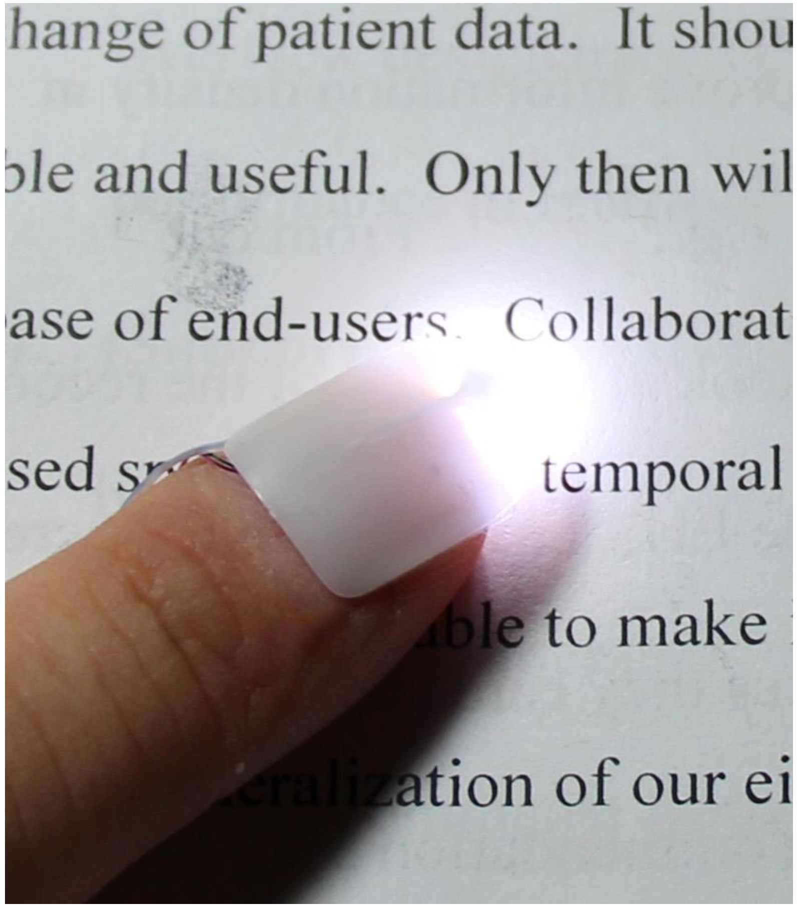
THREAD 1: ACCESSIBILITY

IMPROVING ACCESS TO THE PHYSICAL WORLD



GLASSEAR

[CHI’15]



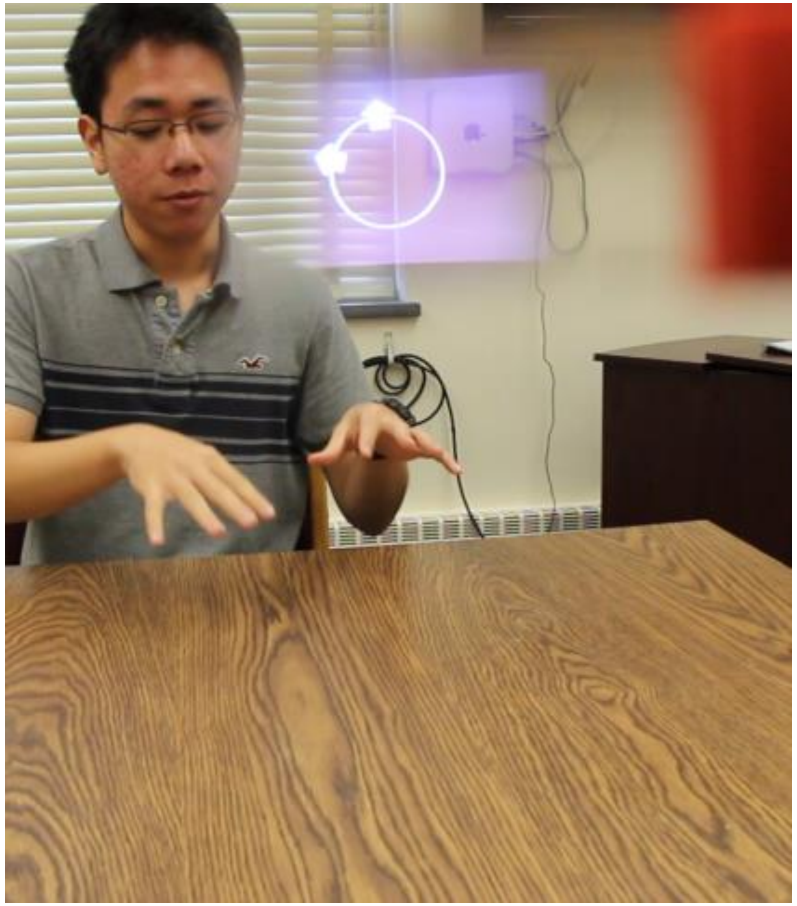
HANDSIGHT

[ACVR’14, ASSETS’15, GI’16, TACCESS’16]

PROJECT SIDEWALK

[ASSETS’12, CHI’13, HCOMP’13, ASSETS’13, UIST’14, TACCESS’15, SIGACCESS’15, CHI’16]

IMPROVING ACCESS TO THE PHYSICAL WORLD



GLASSEAR
[CHI'15]

How can we…
we sense & visualize sound information on an HMD to improve sound awareness for people who are deaf or hard of hearing?

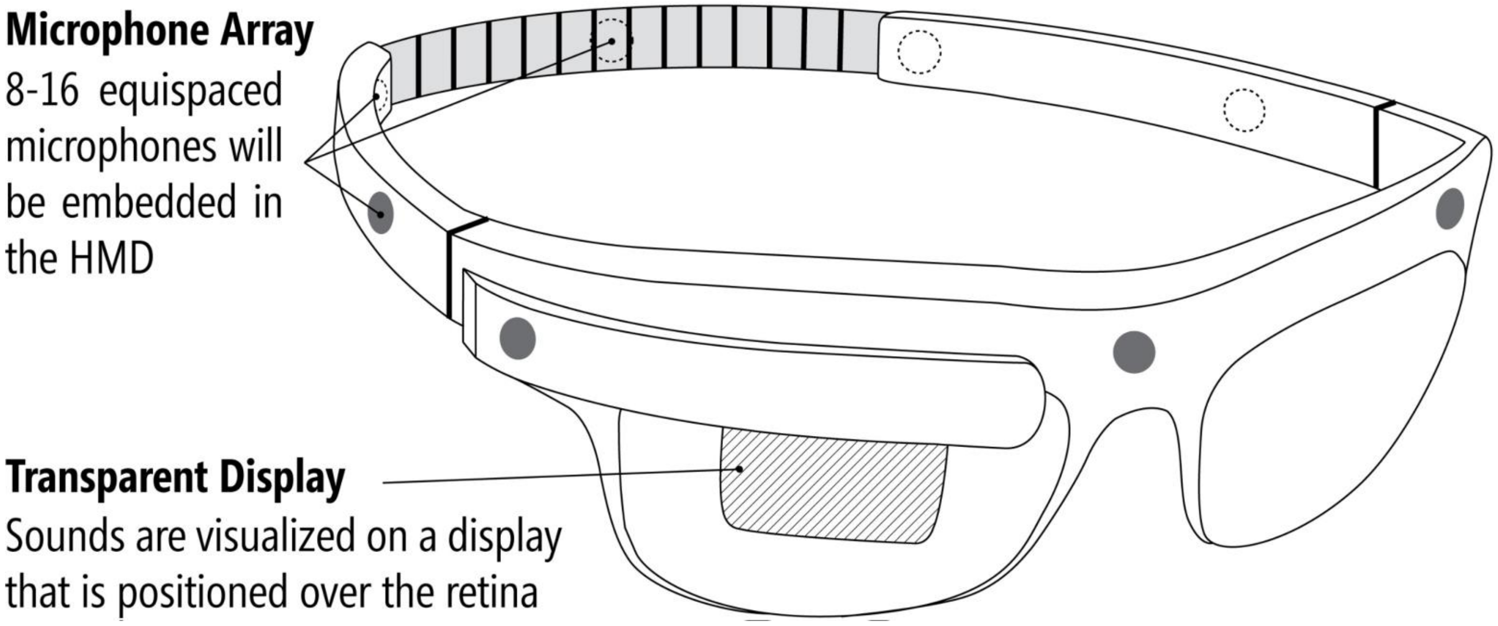

HMD CONVEYS SOUND
DIRECTION & MAGNITUDE


NON-WEARABLE
MICROPHONE ARRAY
HMD DISPLAY

CURRENT & FUTURE WORK

GLASSEAR

Collaborators: Leah Findlater, Ramani Duraiswami, Dmitry Zotkin, Christian Vogler, & Raja Kushalnager



MAJOR OBJECTIVES:

- True wearable design
- Precise localization & sound separation algorithms
- Oral conversation support
- Visualization design

GLASSEAR

THE TEAM

PROFESSORS & RESEARCH ASSOCIATES


Jon Froehlich


Leah Findlater


Ramani Duraiswami


Dmitry Zotkin


Christian Vogler


Raja Kushalnagar

GRAD STUDENT


Dhruv Jain

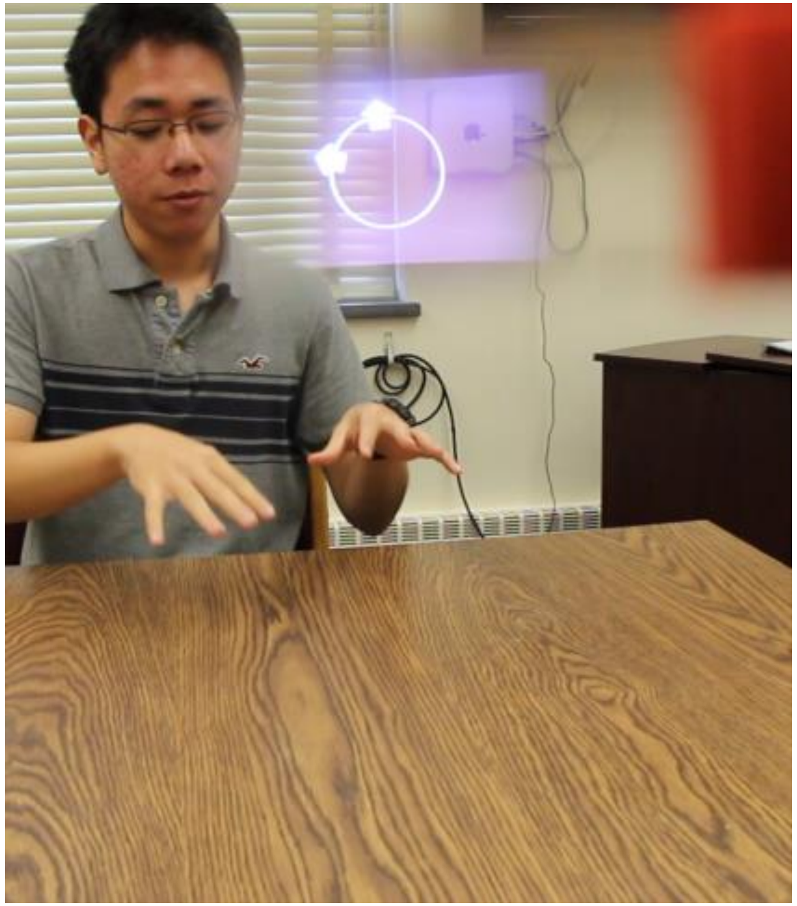
HIGH SCHOOL STUDENTS


Jamie Gilkeson

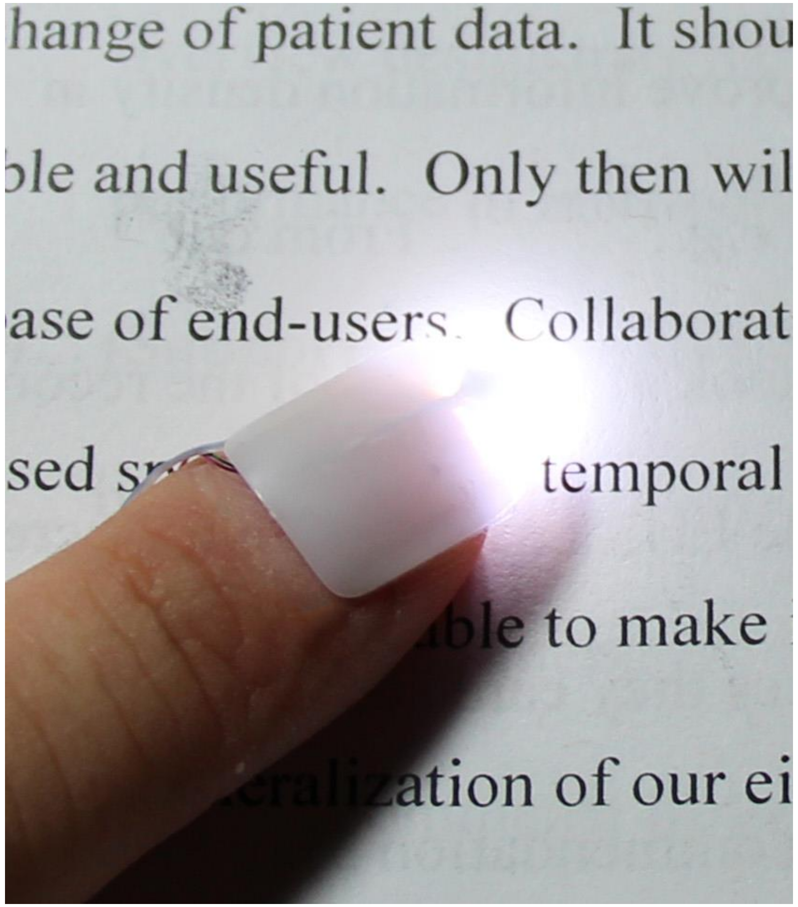

Benjamin Holland

THREAD 1: ACCESSIBILITY

IMPROVING ACCESS TO THE PHYSICAL WORLD



GLASSEAR
[CHI'15]

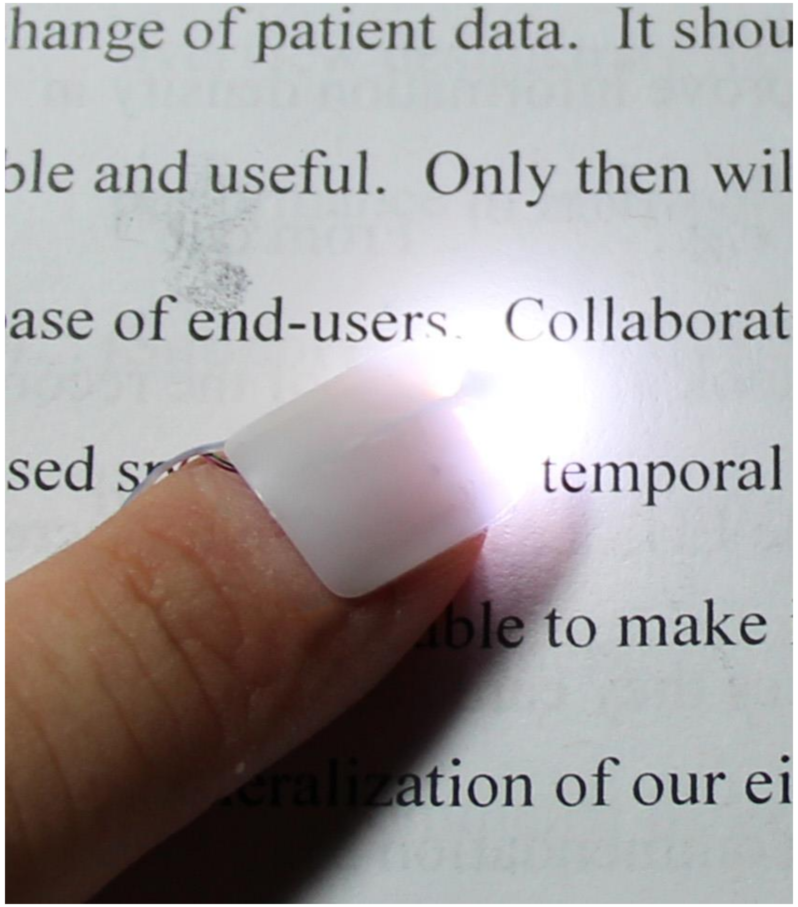


HANDSIGHT
[ACVR'14, ASSETS'15, GI'16, TACCESS'16]

PROJECT SIDEWALK
[ASSETS'12, CHI'13, HCOMP'13, ASSETS'13, UIST'14, TACCESS'15, SIGACCESS'15, CHI'16]

THREAD 1: ACCESSIBILITY

IMPROVING ACCESS TO THE PHYSICAL WORLD

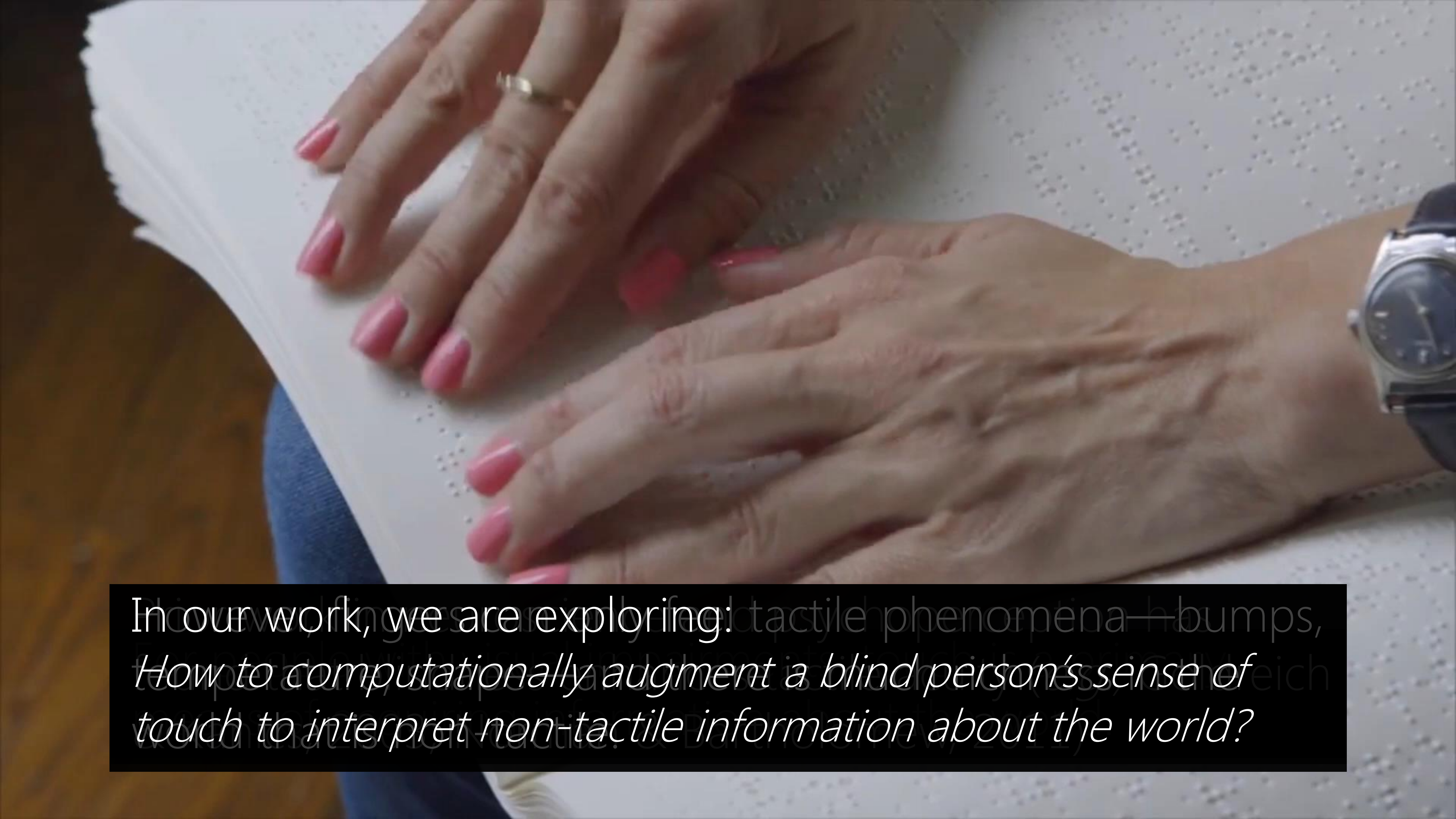


HANDSIGHT

[ACVR'14, ASSETS'15, GI'16, TACCESS'16]

How can we...

we sense & feed back non-tactile information about the physical world *as it is touched*?



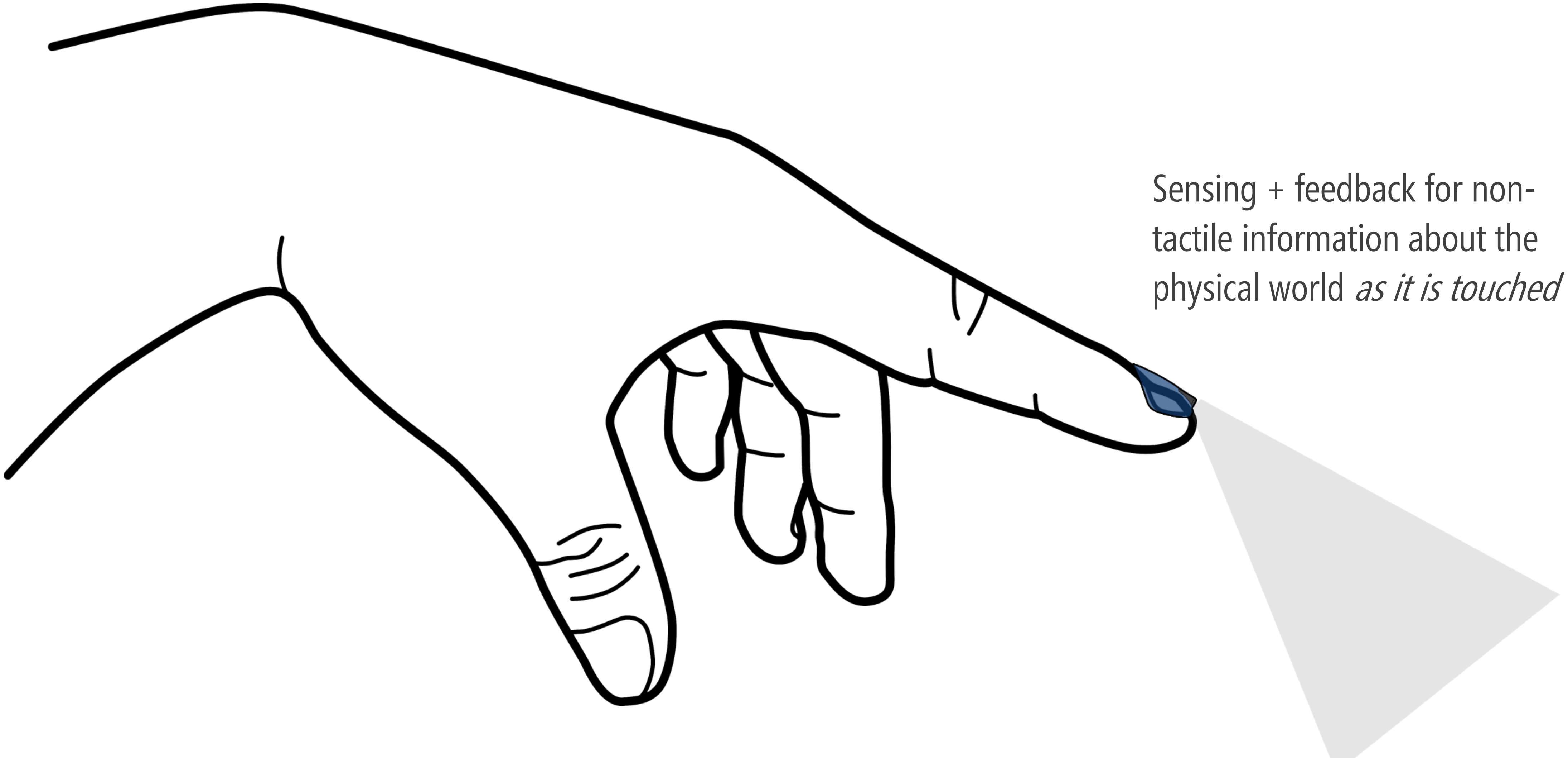
In our work, we are exploring:

How to computationally augment a blind person's sense of touch to interpret non-tactile information about the world?


or touching a piece of clothing and hearing a description
of the underlying fabric

VISION-AUGMENTED TOUCH

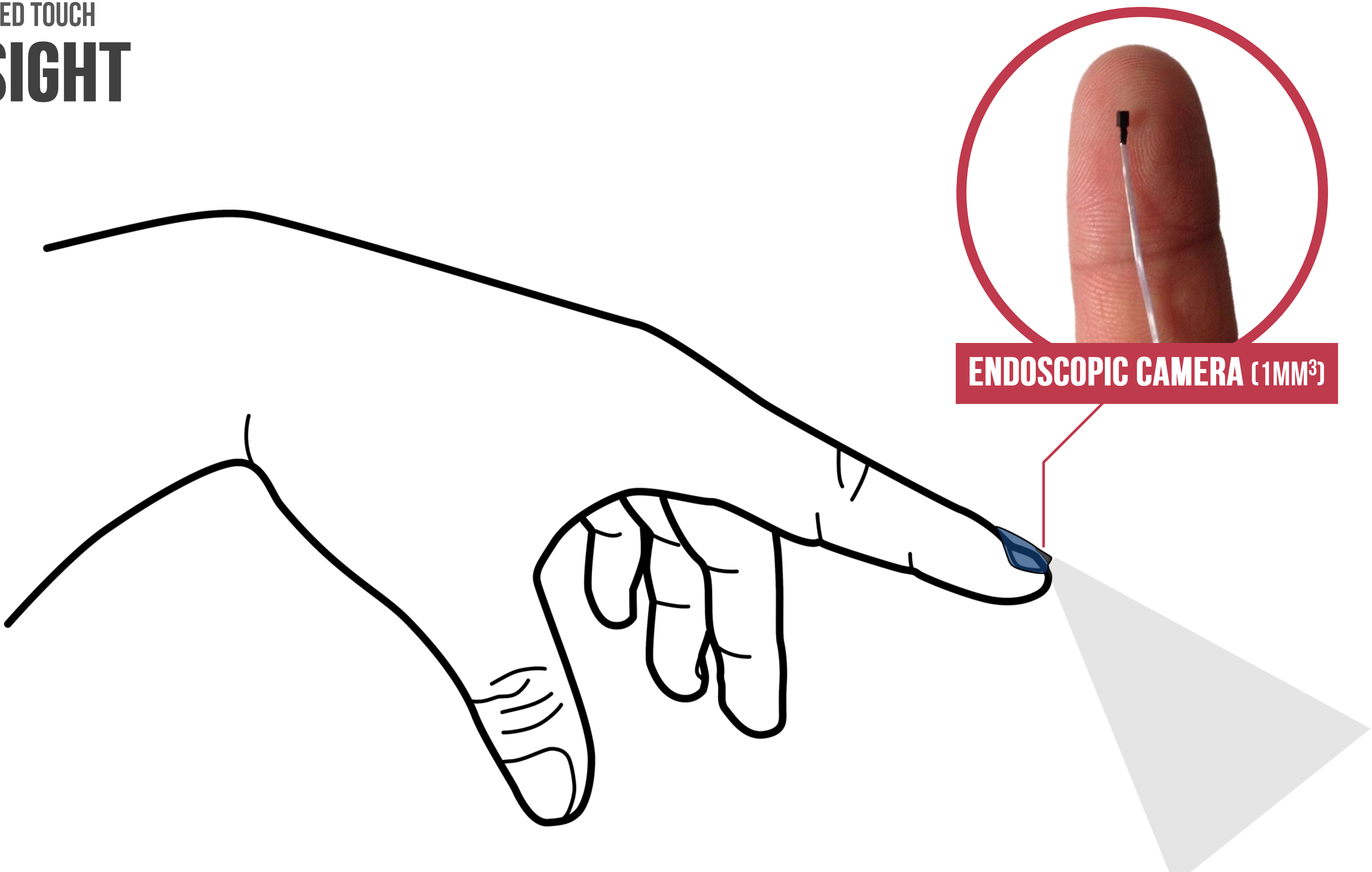
HANDSIGHT



Sensing + feedback for non-tactile information about the physical world *as it is touched*

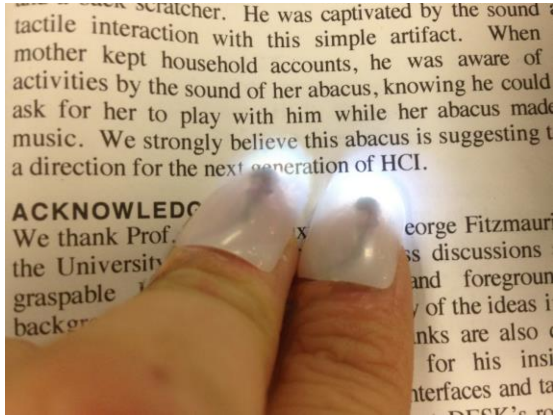
VISION-AUGMENTED TOUCH

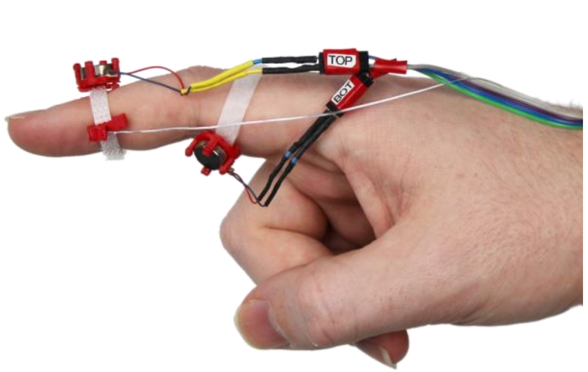
HANDSIGHT

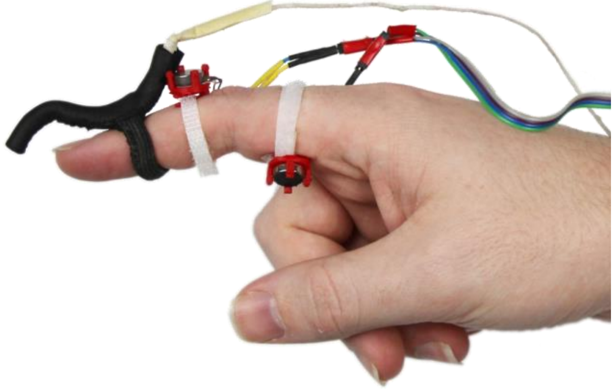


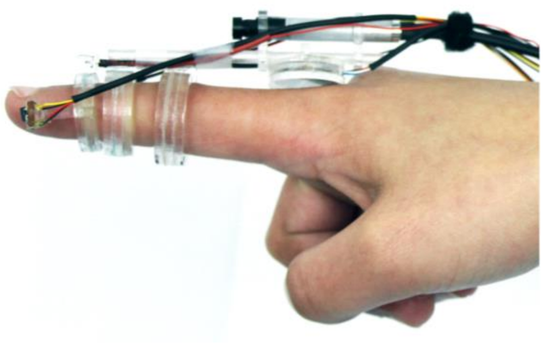
HANDSIGHT

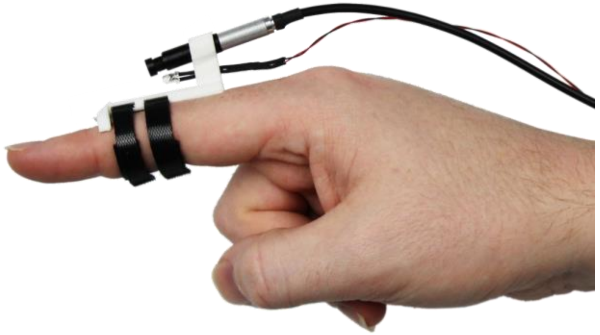
PROTOTYPE EXPLORATIONS

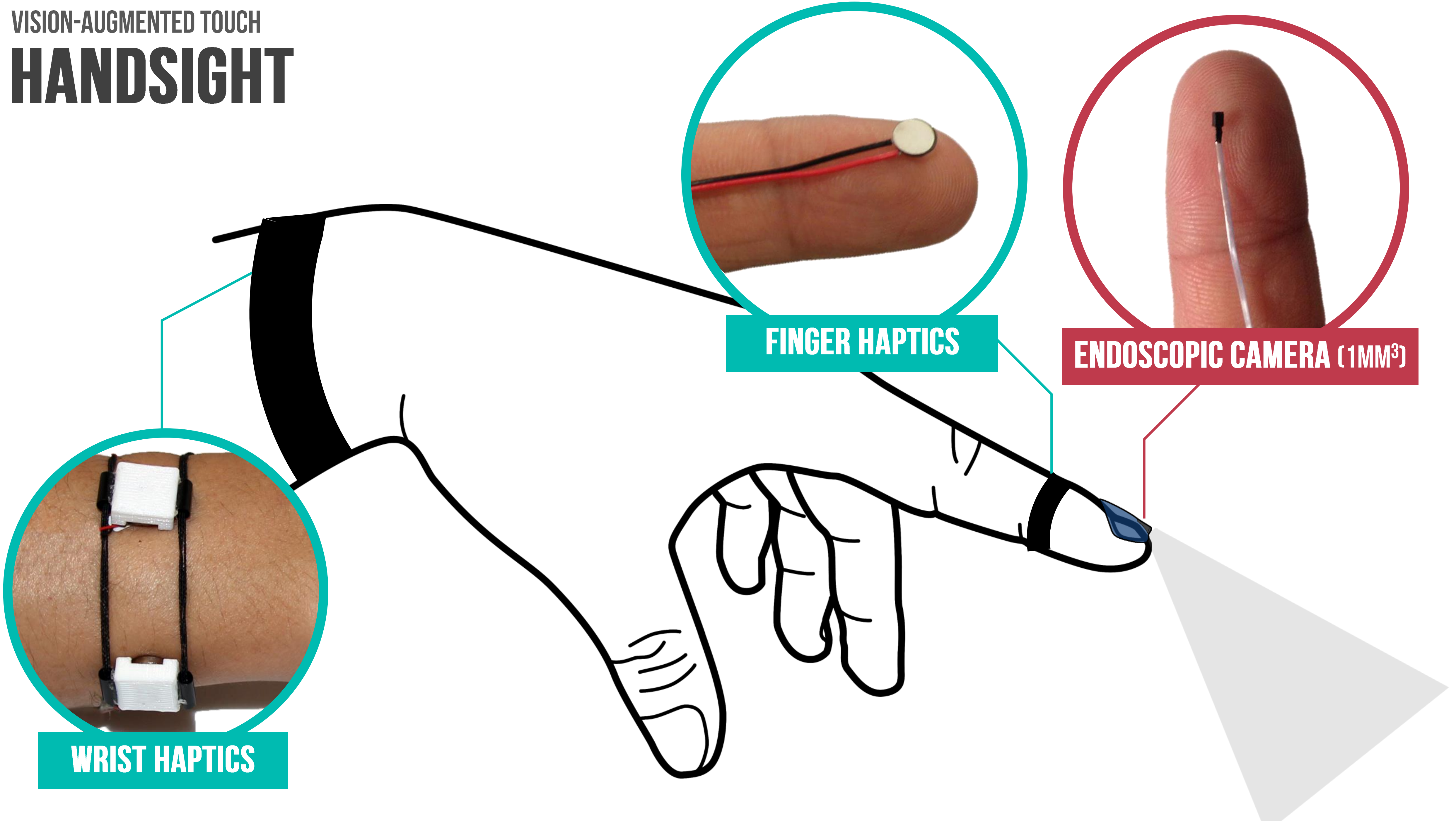


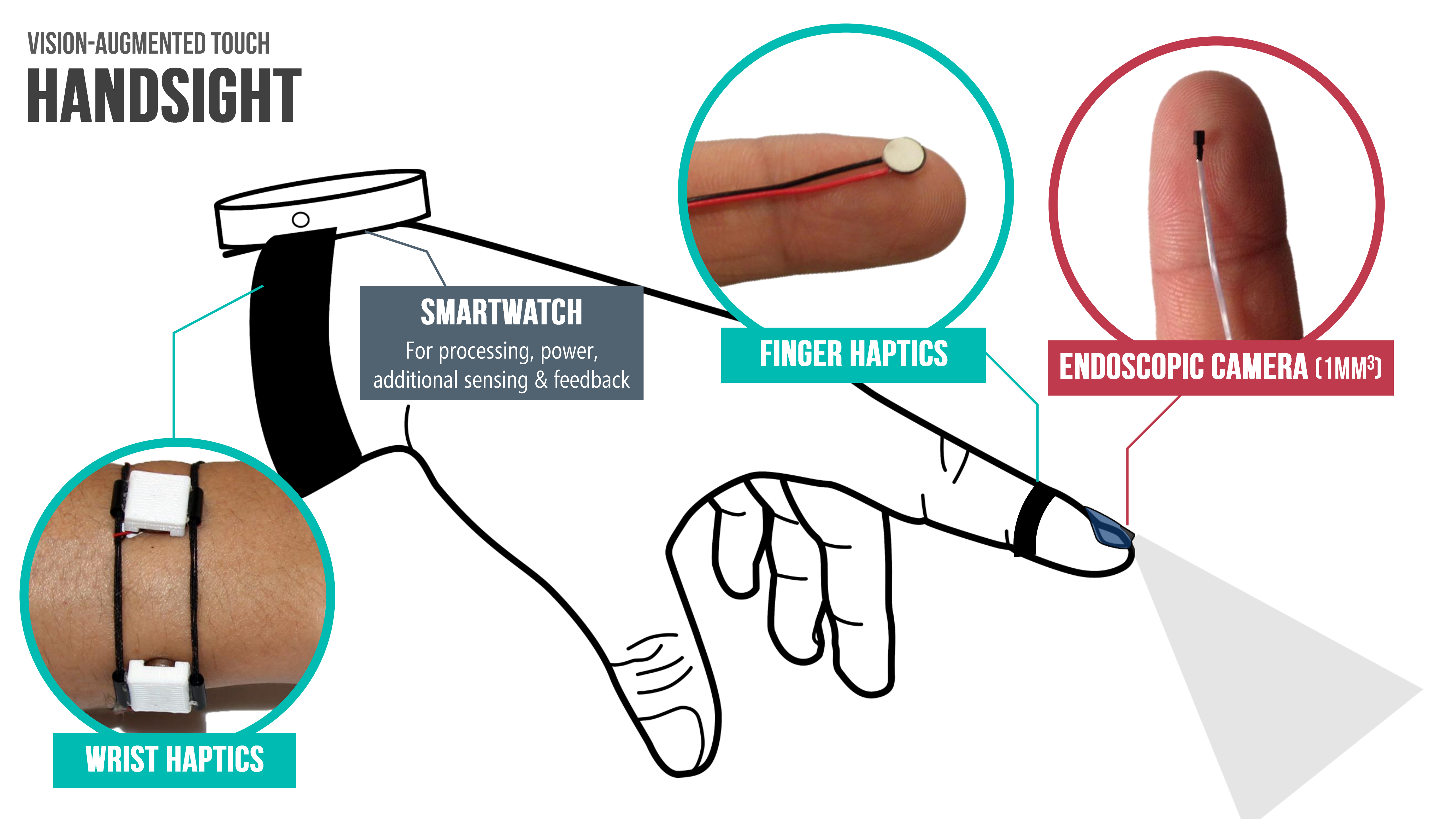









VISION-AUGMENTED TOUCH
HANDSIGHT
FINGER HAPTICS
ENDOSCOPIC CAMERA (1MM³)
WRIST HAPTICS



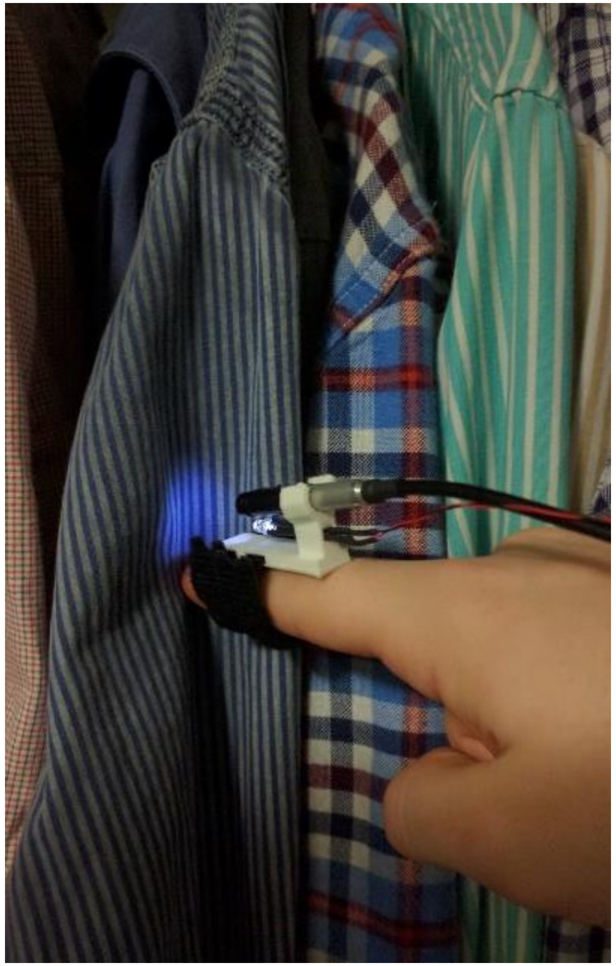
VISION-AUGMENTED TOUCH
HANDSIGHT
SMARTWATCH
For processing, power, additional sensing & feedback
FINGER HAPTICS
ENDOSCOPIC CAMERA (1MM³)
WRIST HAPTICS

HANDSIGHT

FOCUS AREAS

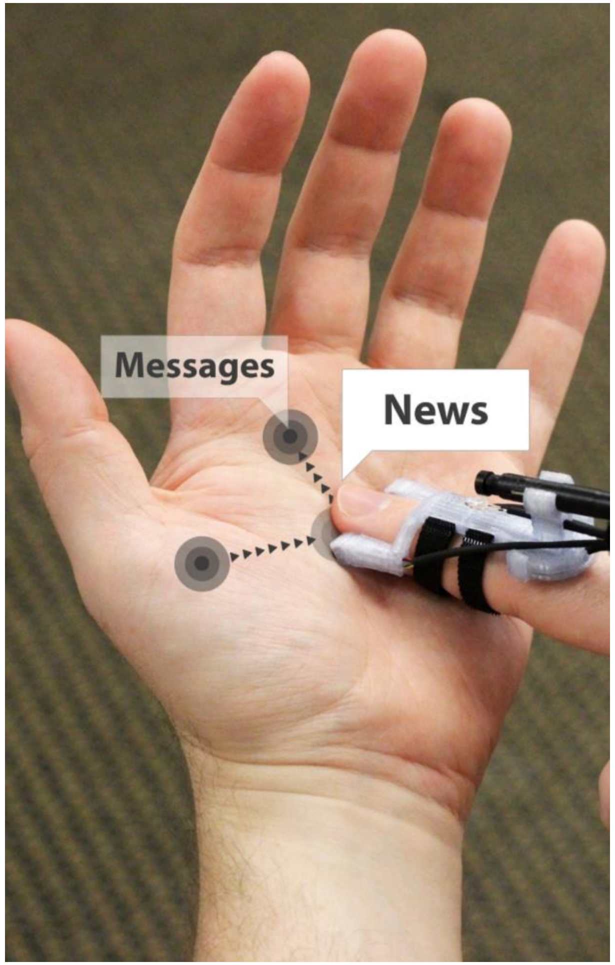
READING SUPPORT

[ACVR'14, TACCESS'15]



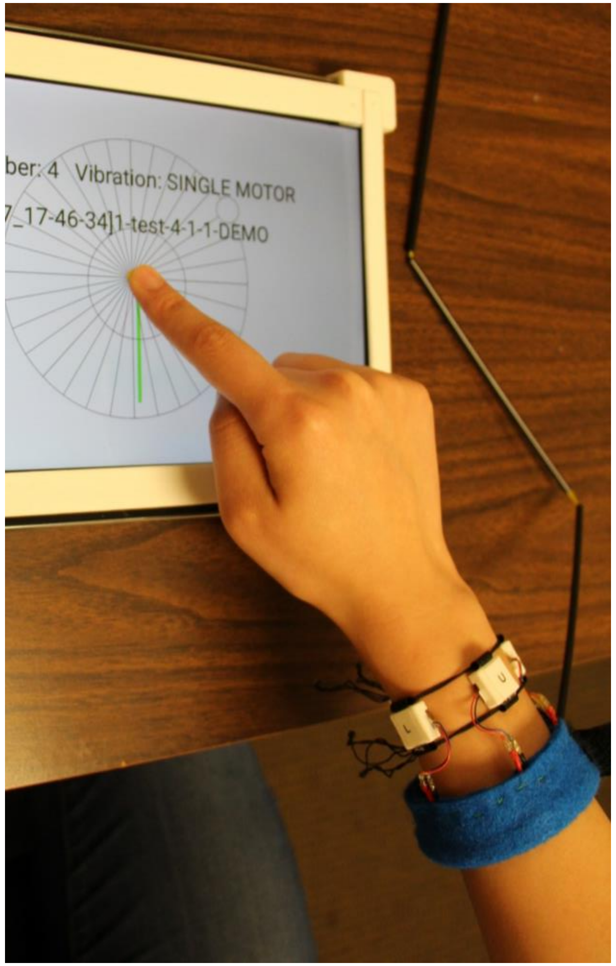
COLOR/TEXTURE RECOGNITION

In progress



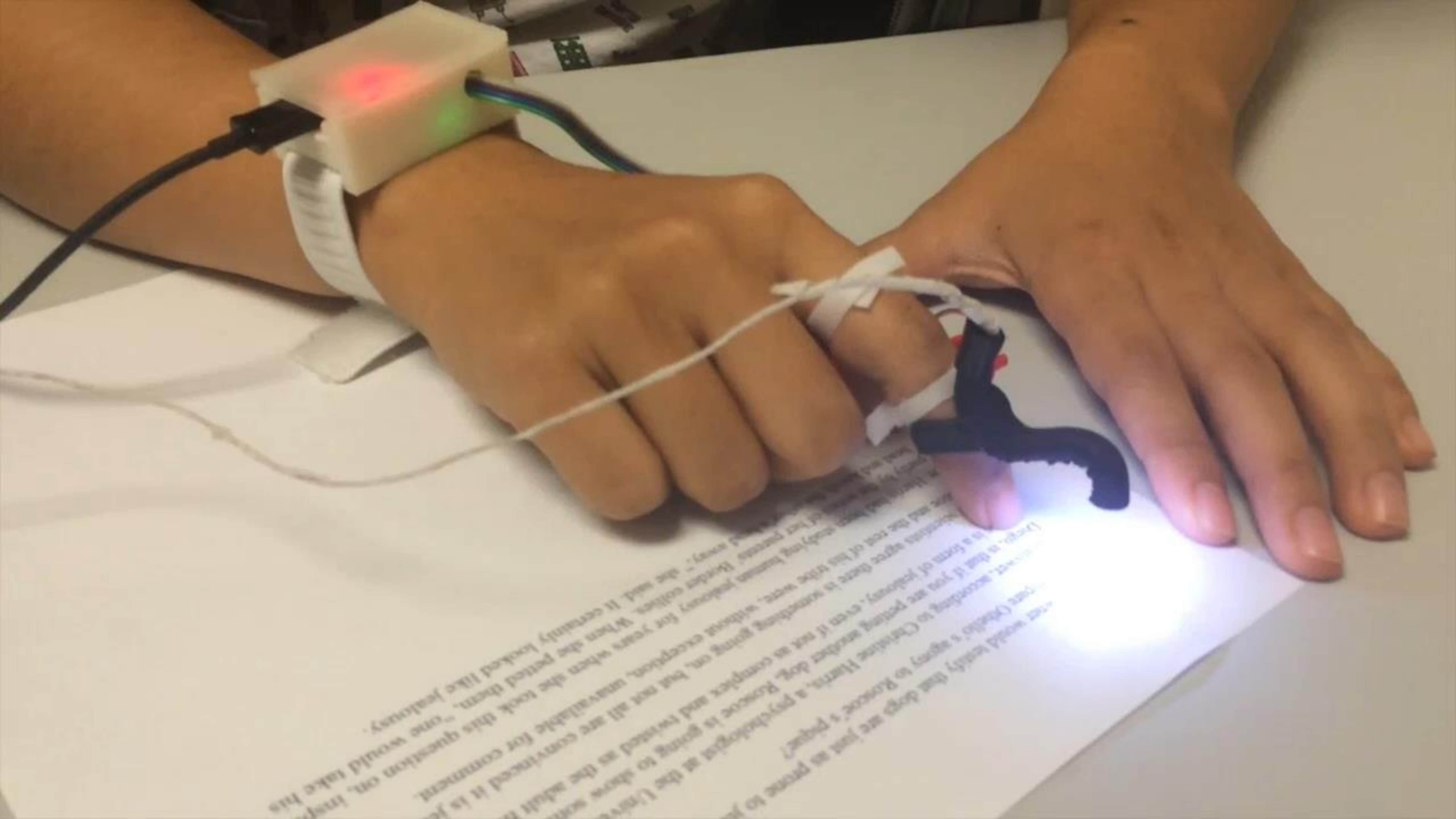
TOUCH-BASED CONTROL

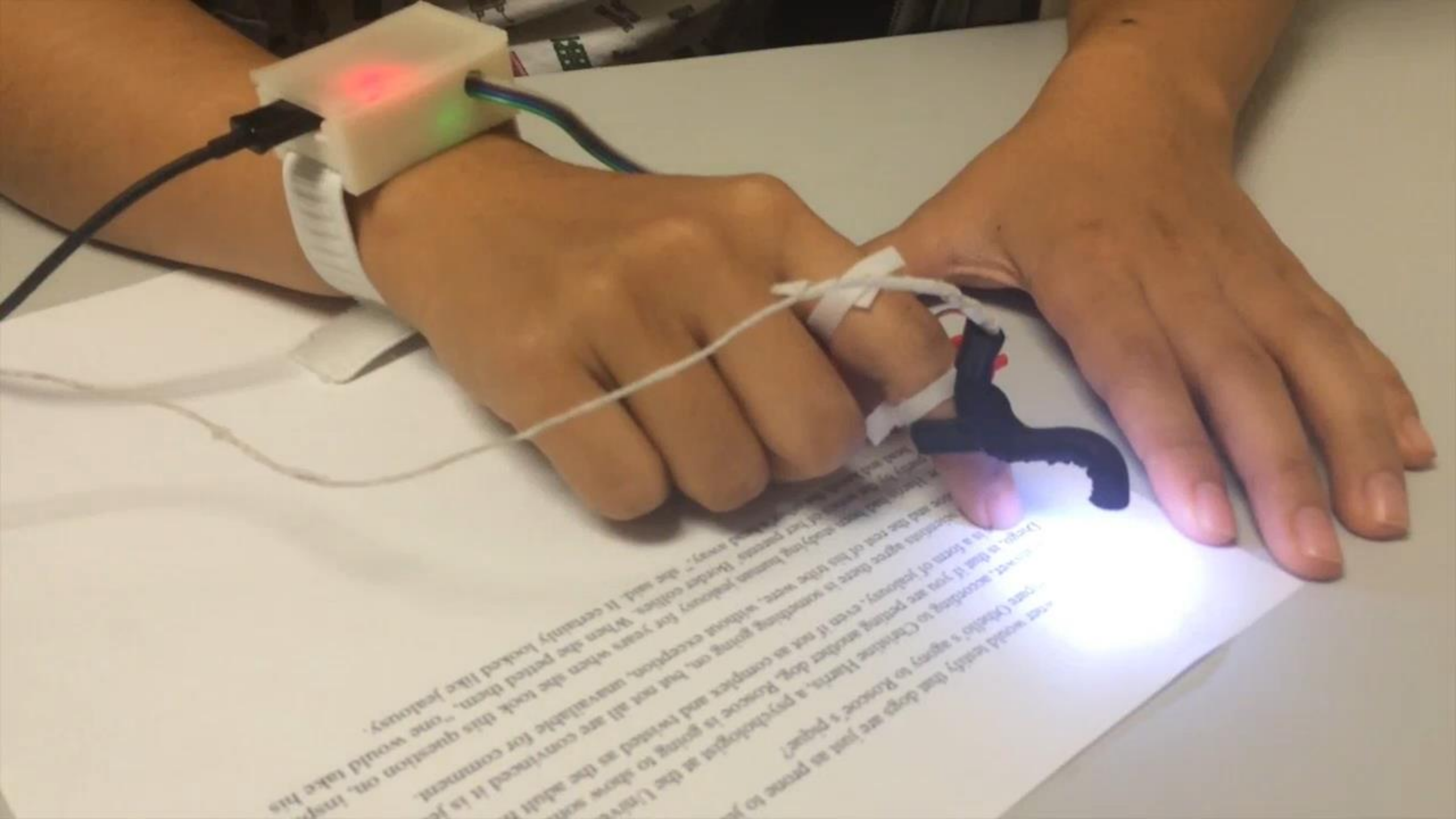
[ICPR'16]



HAPTIC + AUDITORY FEEDBACK

[TACCESS'15, GI'16]





...ordance...
...essed in Gibs...
...neral extended over...
...ossible to talk about perceptio...
...long time to discern: for instance, pe...
a town over a period of days walking around.
strange, consider watching a bird fly close to you...
you recognise it as a red cardinal, and then flying into the...
distance until it is just a black dot against the sky. You
still know that it is the red cardinal, and it is your eyes that
are telling you this, although ... of the later view
alone would not carry that in... would be strained
to say that you had "learned" that ... was a cardinal,
when that learning will be discarded ... oon as it is out of
sight: better to say that your perce... of it was an act
extended over time.) Neve... and in particular
in considering how to su... not so m...
about whether users will ... short
whether they will perce... seconds,
compared to the general act...
say. In what follows we shall u...
affordances perceptible (at lea...
within that sort of time.

...ce however is whe...
...ing e.g. is a doo...
...ecially...

Many ...
very weak ...

Conclusion

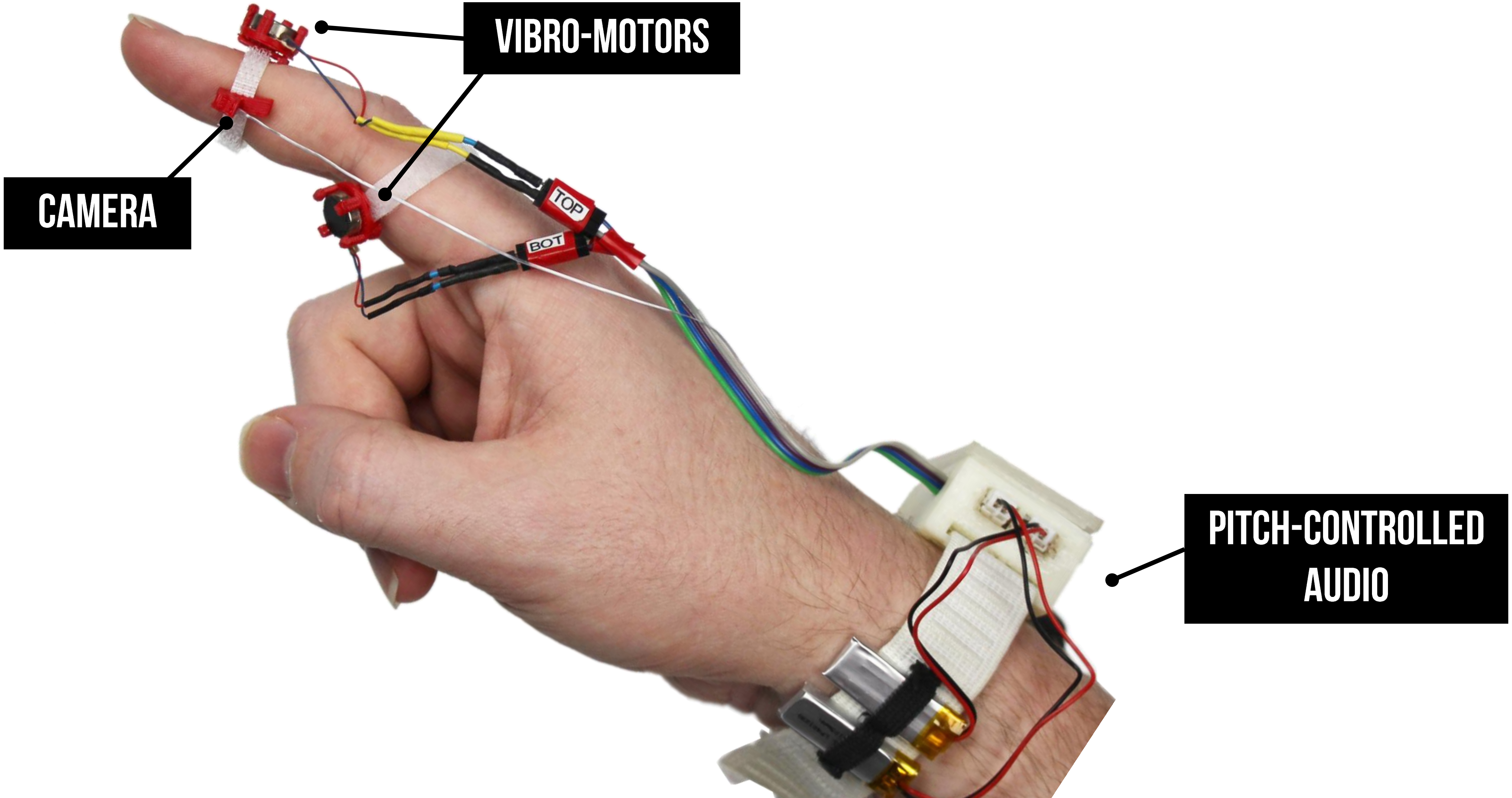
We have run a...
exploration, a...

Each acti...
particular...
user's in...
achiev...
func...

HANDSIGHT

HAPTIC VS AUDIO LINE GUIDANCE

TACCESS'16



HANDSIGHT

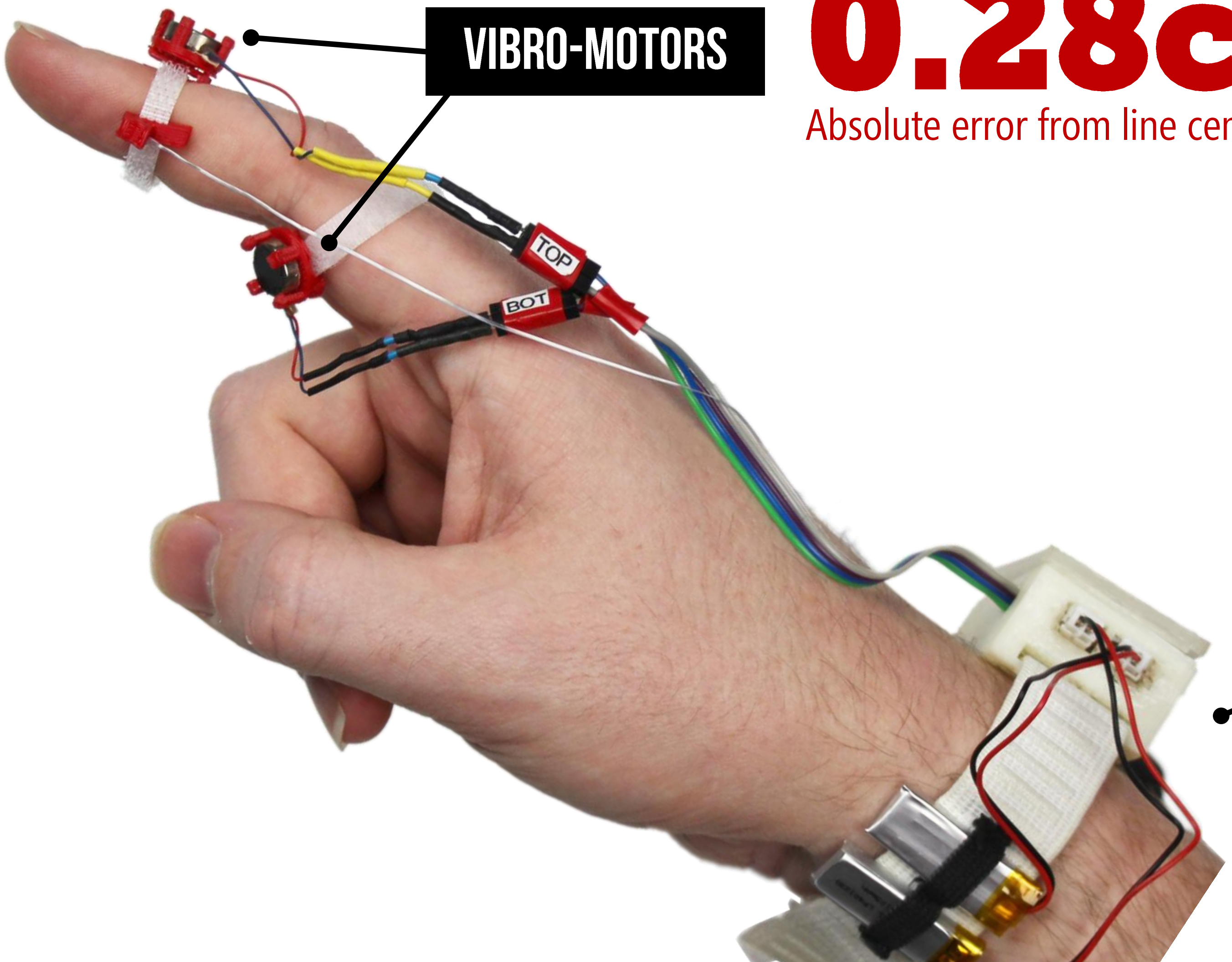
HAPTIC VS AUDIO LINE GUIDANCE

TACCESS'16

HANDSIGHT

HAPTIC VS AUDIO LINE GUIDANCE

TACCESS'16



0.28cm

Absolute error from line center

0.21cm

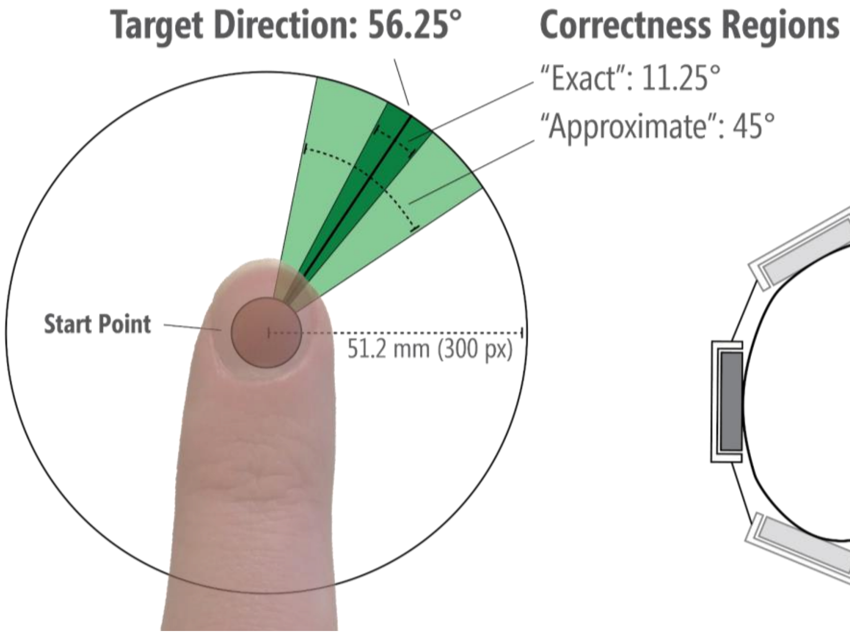
Absolute error from line center

Z_{19}=-2.374, p=.018, r=.54

HANDSIGHT

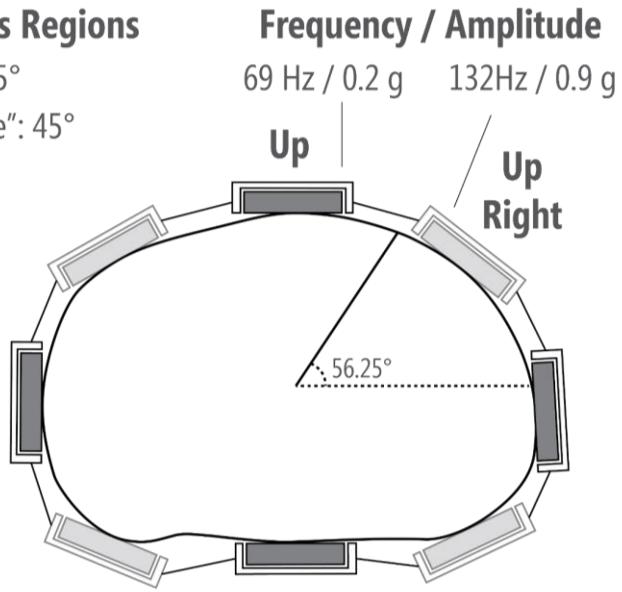
WRIST HAPTICS

GI'16



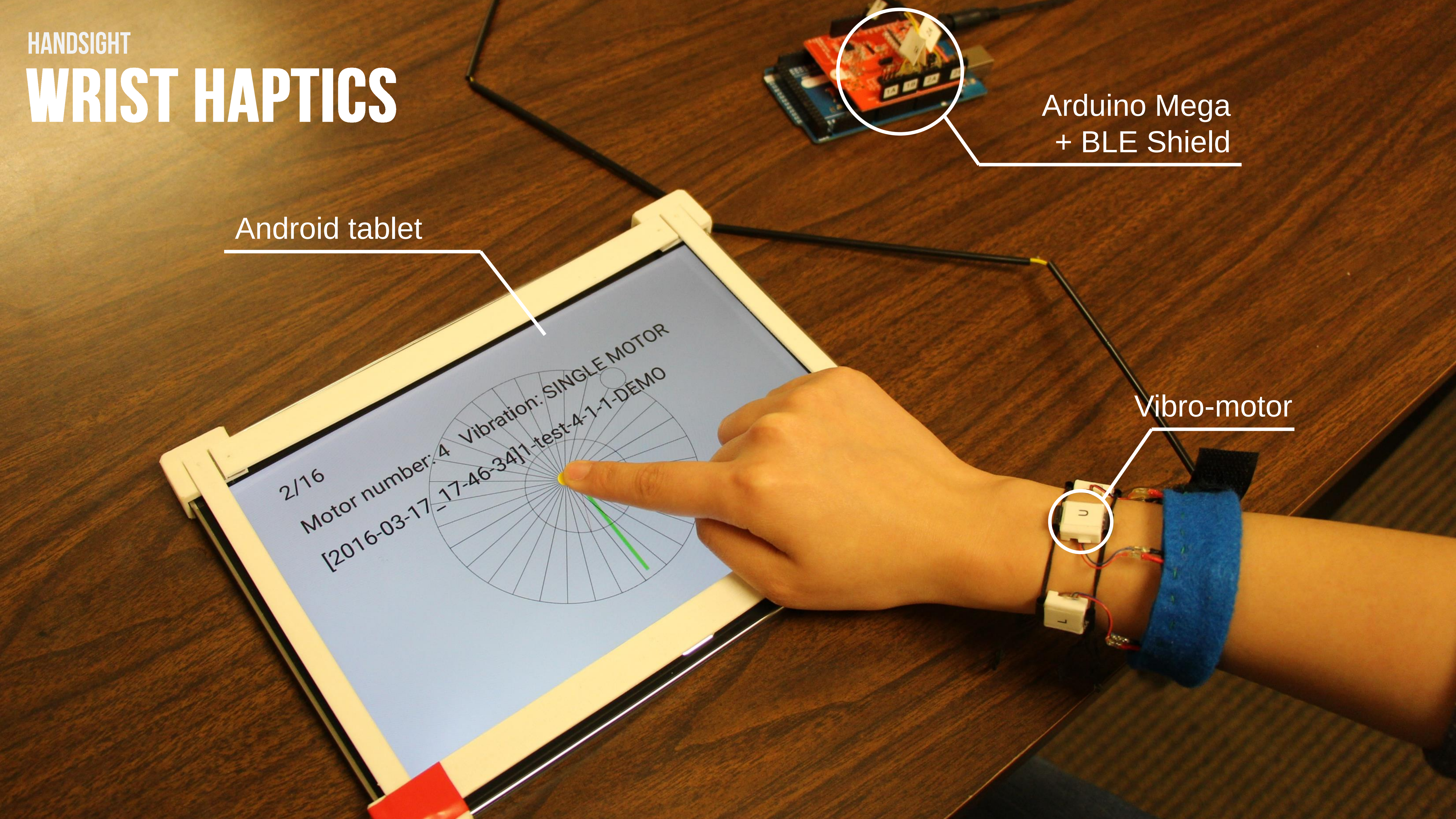
EXAMPLE TRIAL

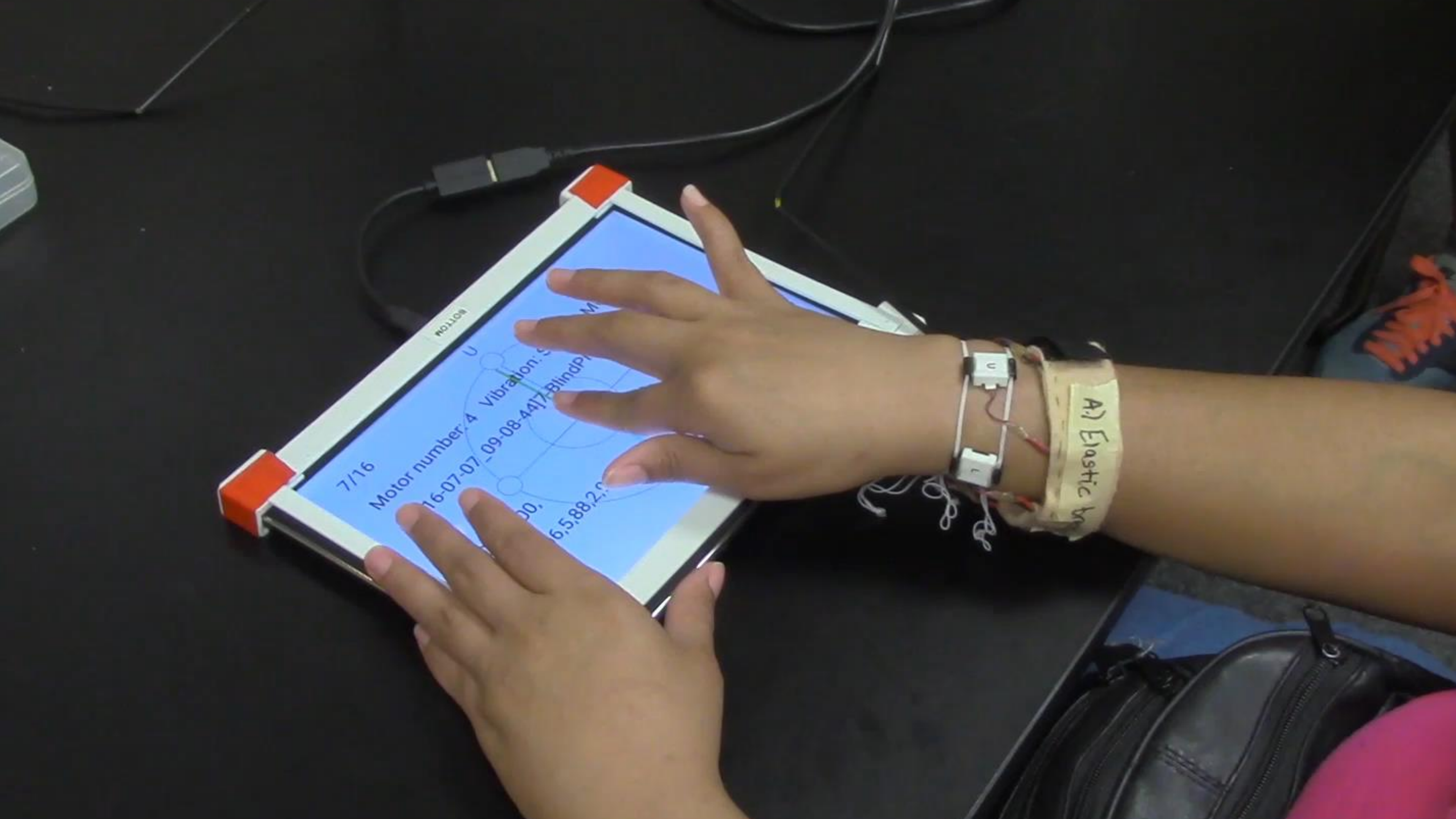
TARGET DIRECTION: 56.25°



CROSS SECTION OF WRIST

8 MOTOR DESIGN


HANDSIGHT
WRIST HAPTICS
Arduino Mega
+ BLE Shield
Android tablet
2/16
Motor number: 4 Vibration: SINGLE MOTOR
[2016-03-17_17-46-34]1-test-4-1-1-DEMO
Vibro-motor

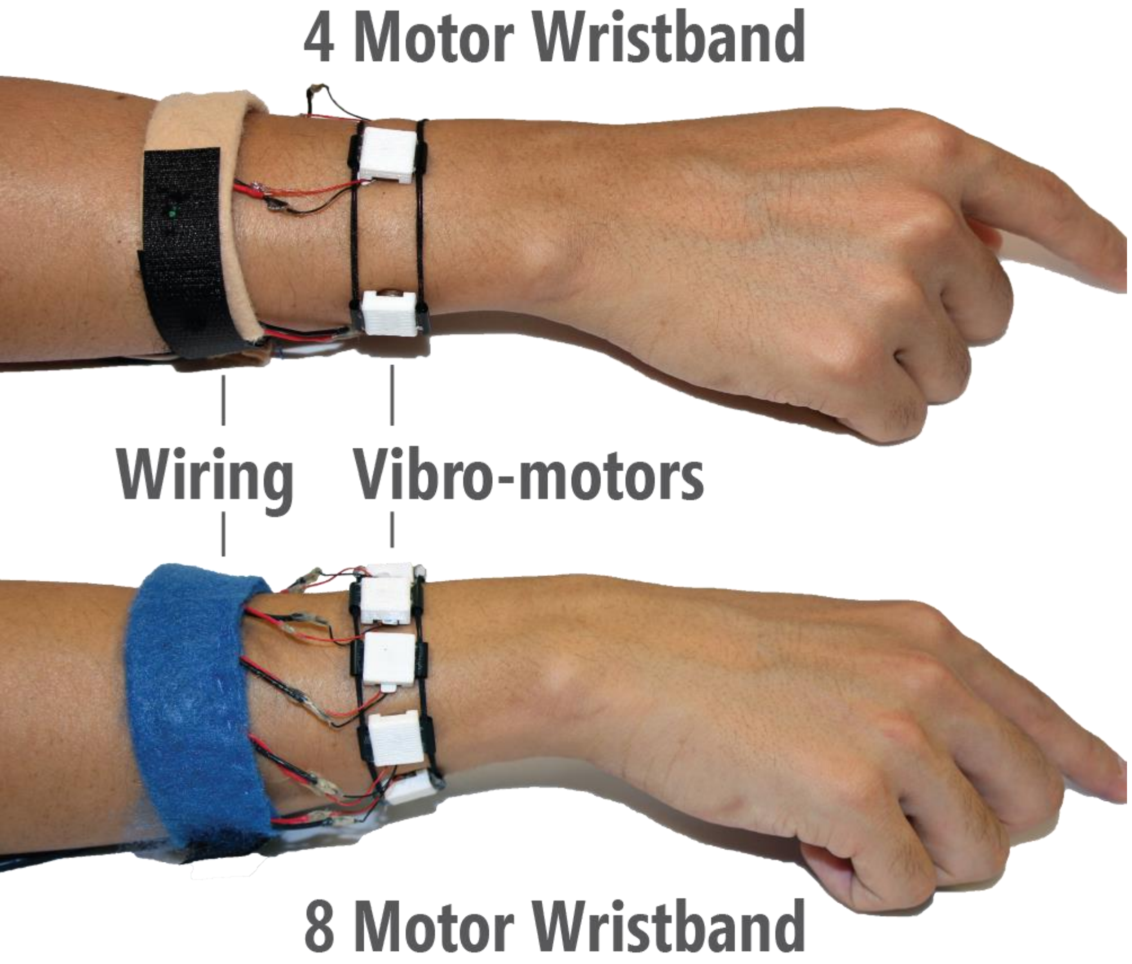


7/16
Motor number: 4
Vibration:
BOTTOM
A.) Elastic

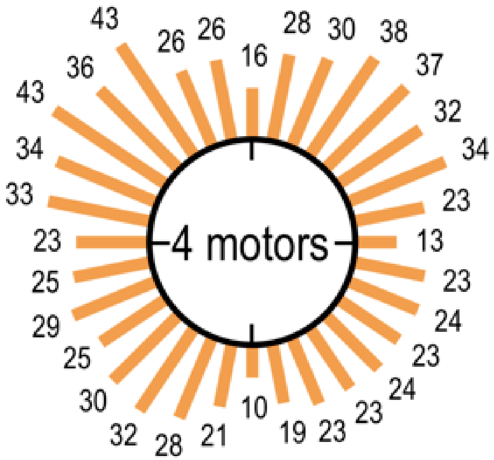
HANDSIGHT

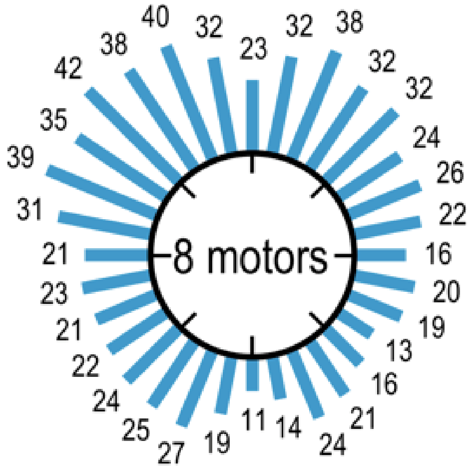
WRIST HAPTIC STUDY RESULTS

GI'16



AVERAGE MOVEMENT ERROR AT EACH TESTED ANGLE





OVERALL AVERAGE MOVEMENT ERROR

25.4°

Directional movement error

23.2°

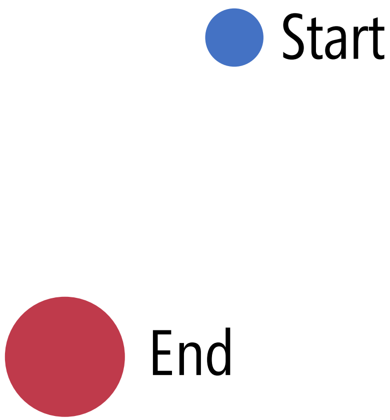
Directional movement error

$t_{17}=-1.95$, $p = .034$, $d = 0.46$

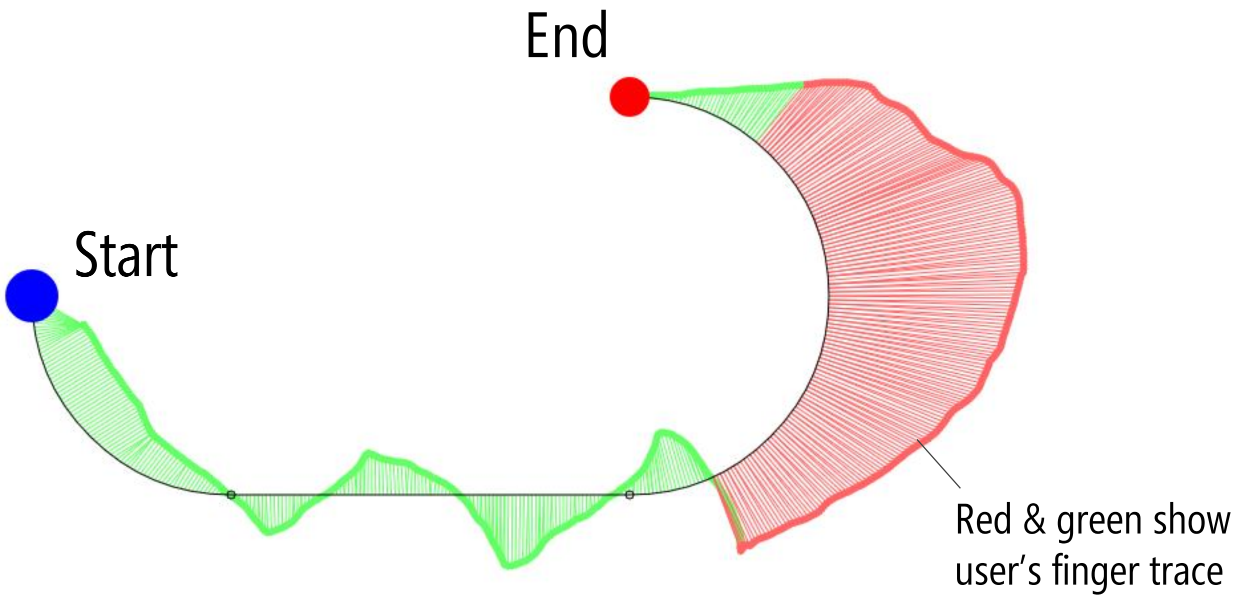
HANDSIGHT

WRIST HAPTICS FOLLOW-UP STUDY

In progress



TARGET FINDING

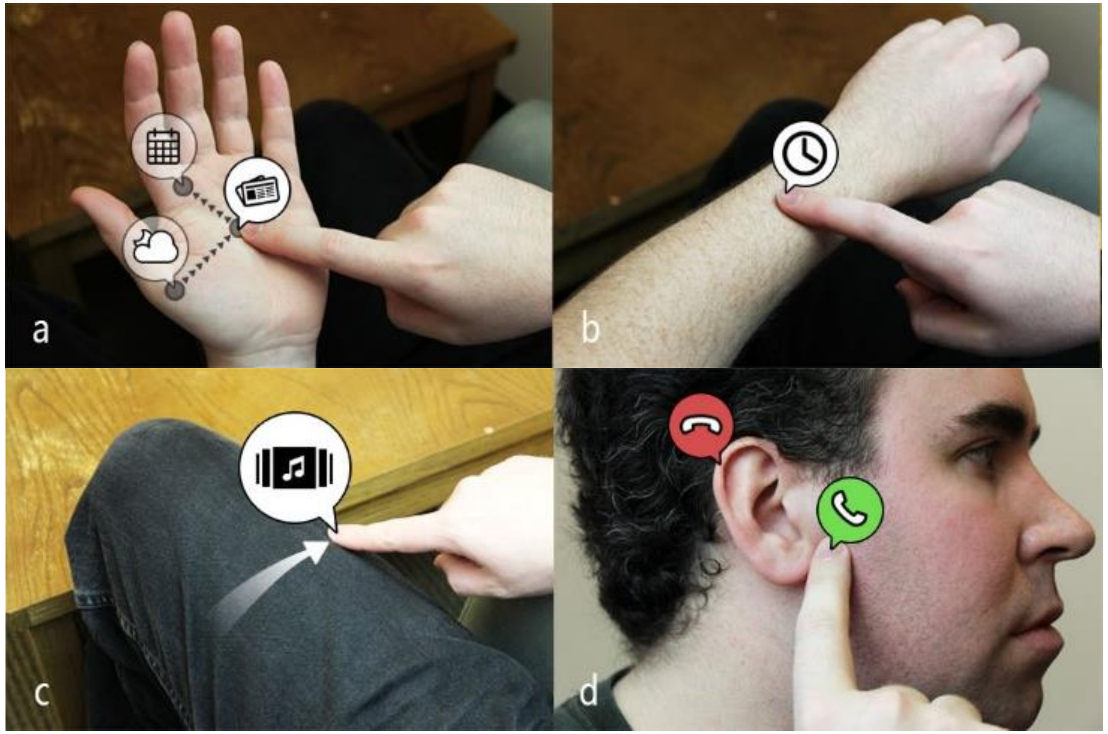


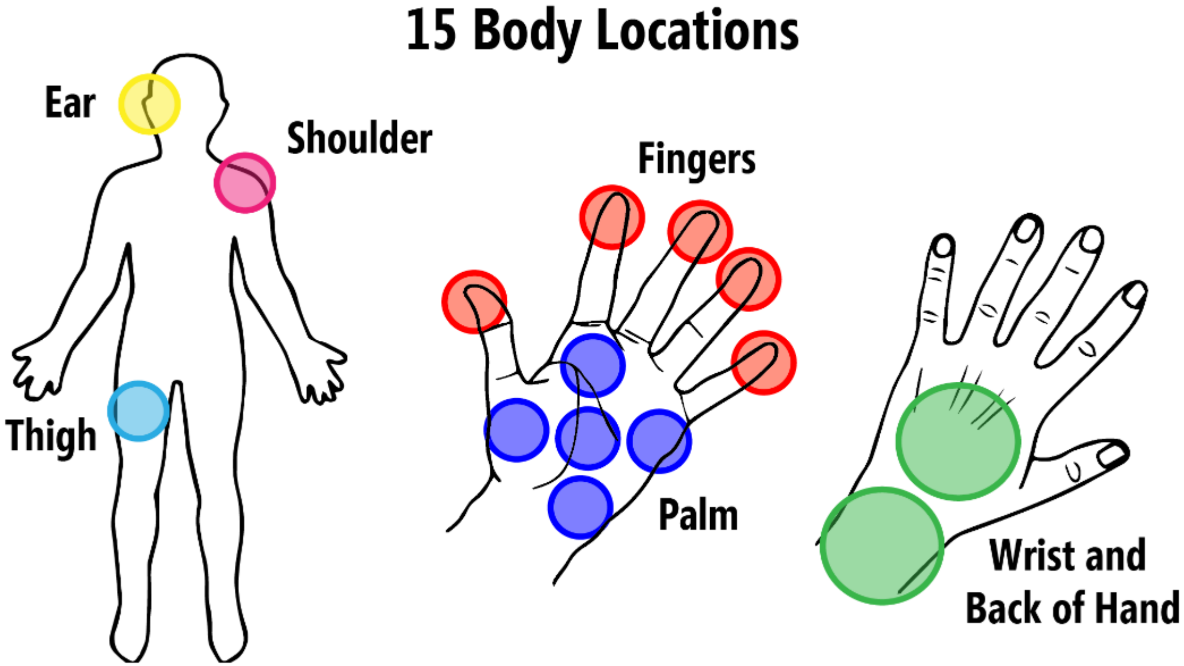
PATH TRACING

HANDSIGHT

ON-BODY INTERACTION FOR VISUALLY IMPAIRED

ICPR'16, two papers in submission






Daily Summary
Clock
Voice Input


Clock
Voice Input
Health & Activities

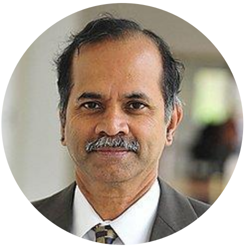
HANDSIGHT

THE TEAM

PROFESSORS & RESEARCH ASSOCIATES


Jon Froehlich


Leah Findlater


Rama Chellappa


David Ross

GRAD STUDENTS


Lee Stearns


Uran Oh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Ruofei Du


Anis Abboud

UNDERGRADUATE STUDENTS


Meena Sengottuvelu


Alex Medeiros


Harry Vancao


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Eric Lancaster


Tony Cheng


Victor Chen


Catherine Jou


Mandy Wang

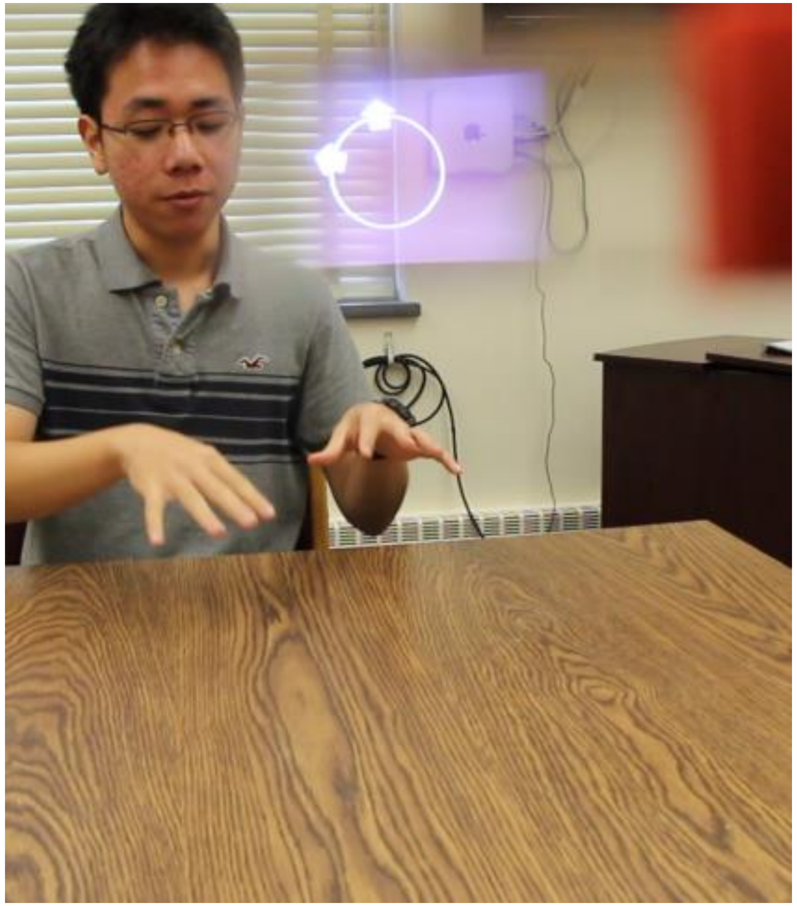
HIGH SCHOOL STUDENTS


Ji Hyuk Bae


Jessica Yin

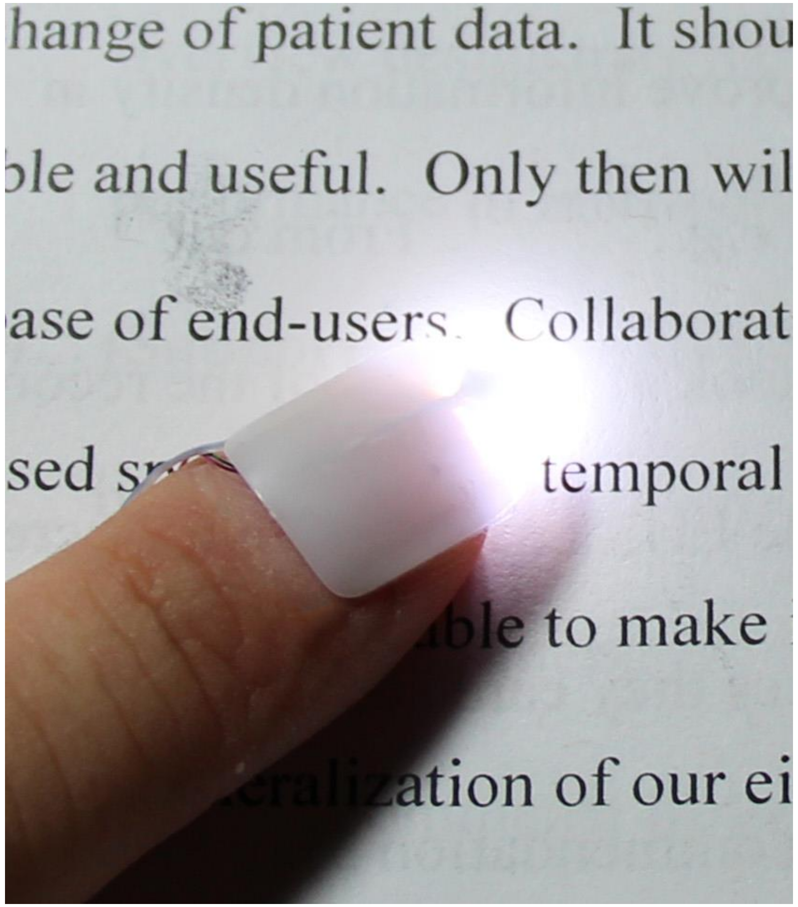

Chuan Chen

IMPROVING ACCESS TO THE PHYSICAL WORLD



GLASSEAR

[CHI'15]



HANDSIGHT

[ACVR'14, ASSETS'15, GI'16, TACCESS'16]

PROJECT SIDEWALK

[ASSETS'12, CHI'13, HCOMP'13, ASSETS'13, UIST'14, TACCESS'15, SIGACCESS'15, CHI'16]

THREAD 1: ACCESSIBILITY

IMPROVING ACCESS TO THE PHYSICAL WORLD

PROJECT SIDEWALK

[ASSETS'12, CHI'13, HCOMP'13, ASSETS'13, UIST'14, TACCESS'15, SIGACCESS'15, CHI'16]

How can we...

develop scalable solutions that map the accessibility of urban infrastructure?

30.6

million U.S. adults have a mobility impairment

Source: US Census, 210


15.2
million use an assistive aid
Source: US Census, 210


CHANEL
CHANEL
CHANEL
CHANEL
ONE WAY
NO PARKING
DIESEL


NO CURB RAMPS
CHANEL
ONE WAY
DIESEL


PHYSICAL OBSTACLES


FedEx
INCOMPLETE SIDEWALKS


SURFACE PROBLEMS


PHYSICAL OBSTACLES
NO CURB RAMP
SURFACE DEGRADATION

Accessible infrastructure has a significant impact on the independence and mobility of citizens

[Thapar *et al.*, 2004 ; Nuernberger, 2008]


Central Av
Tokyo
Salon
GINZA
GINZA

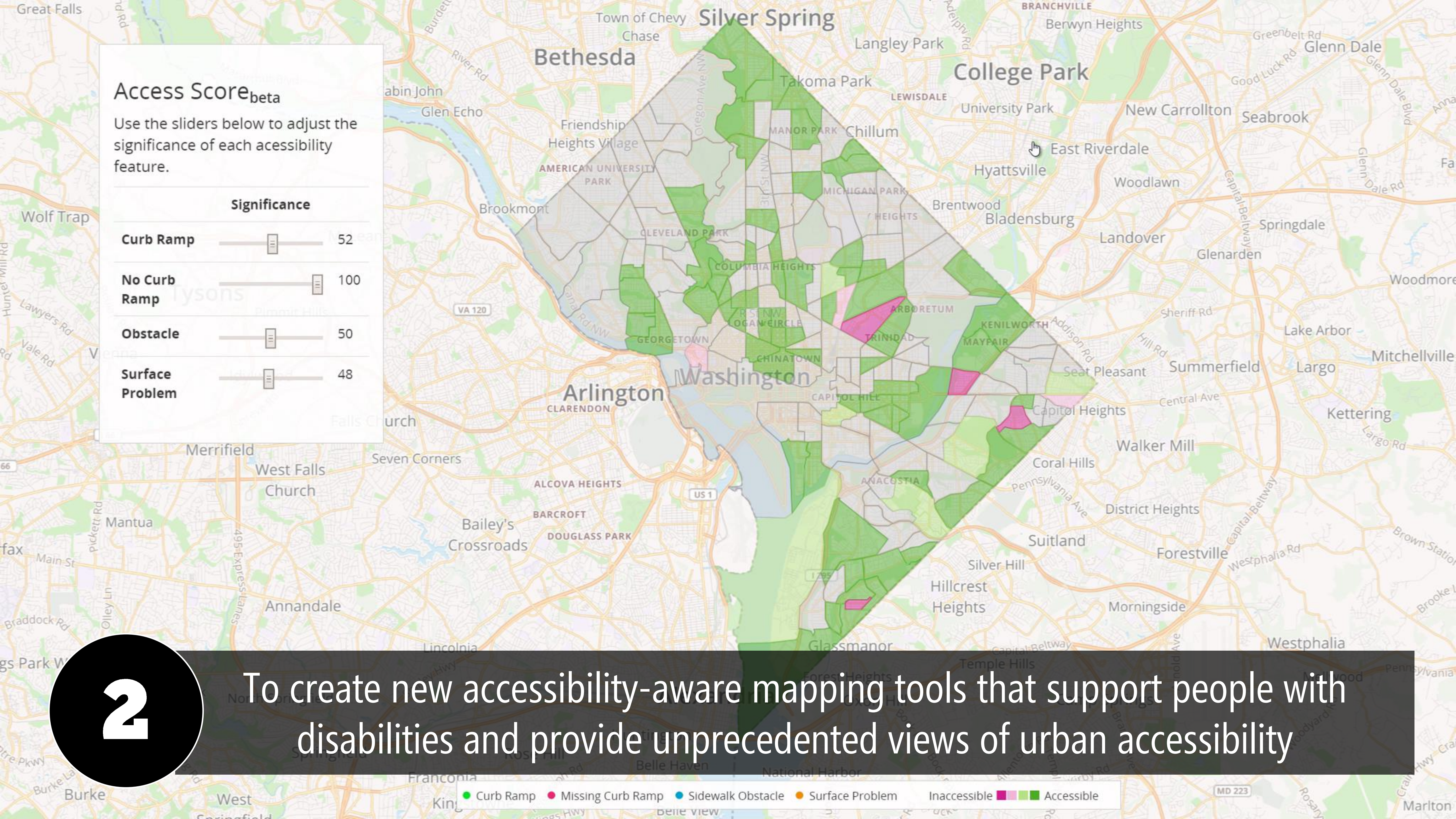
The National Council on Disability noted that there is **no comprehensive information** on "the degree to which sidewalks are accessible" in cities.

National Council on Disability, 2007
The impact of the Americans with Disabilities Act: Assessing the progress toward achieving the goals of the ADA

We are pursuing a **two-fold solution**

1

To develop scalable methods that mine massive repositories of online map imagery to identify accessibility problems semi-automatically



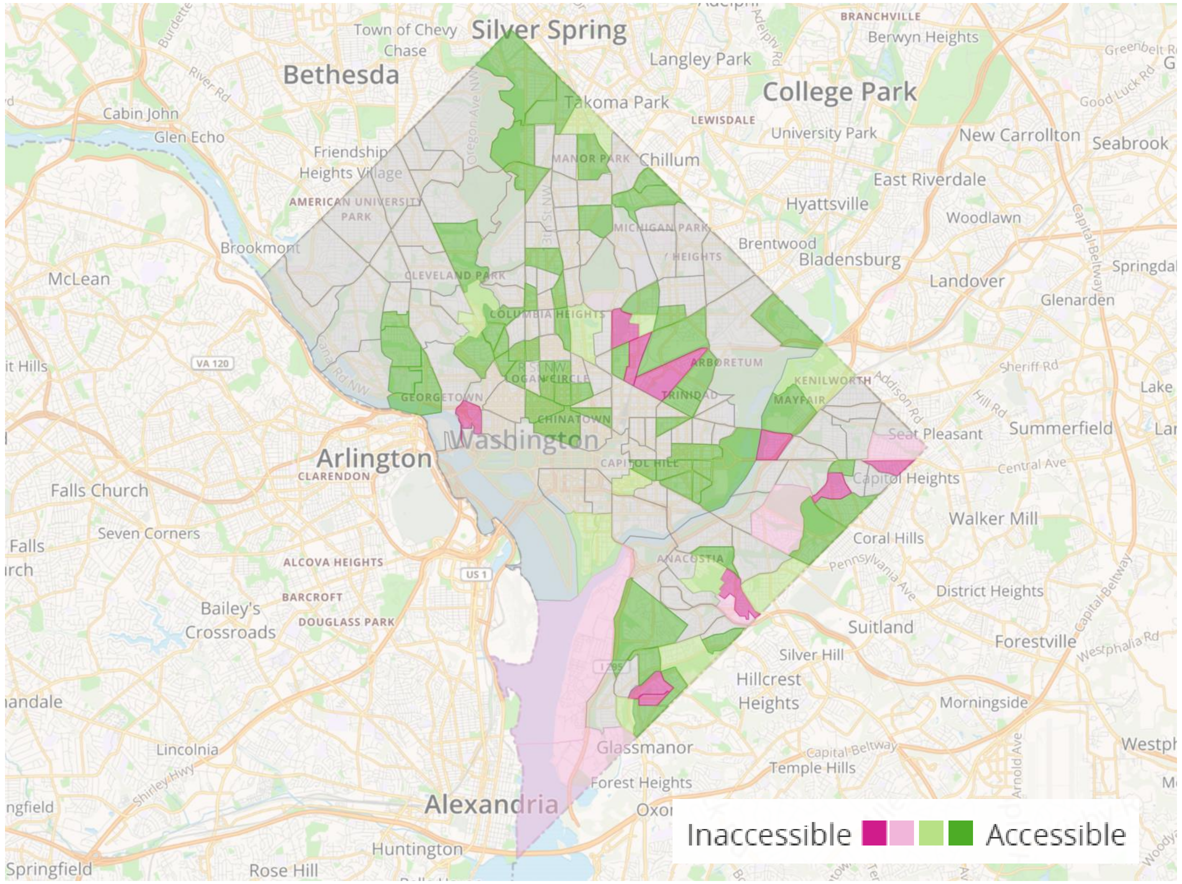
2

To create new accessibility-aware mapping tools that support people with disabilities and provide unprecedented views of urban accessibility

TWO FOCUS AREAS

SCALABLE DATA COLLECTION METHODS

[ASSETS'12, CHI'13, HCOMP'13, ASSETS'13, UIST'14, TACCESS'15]

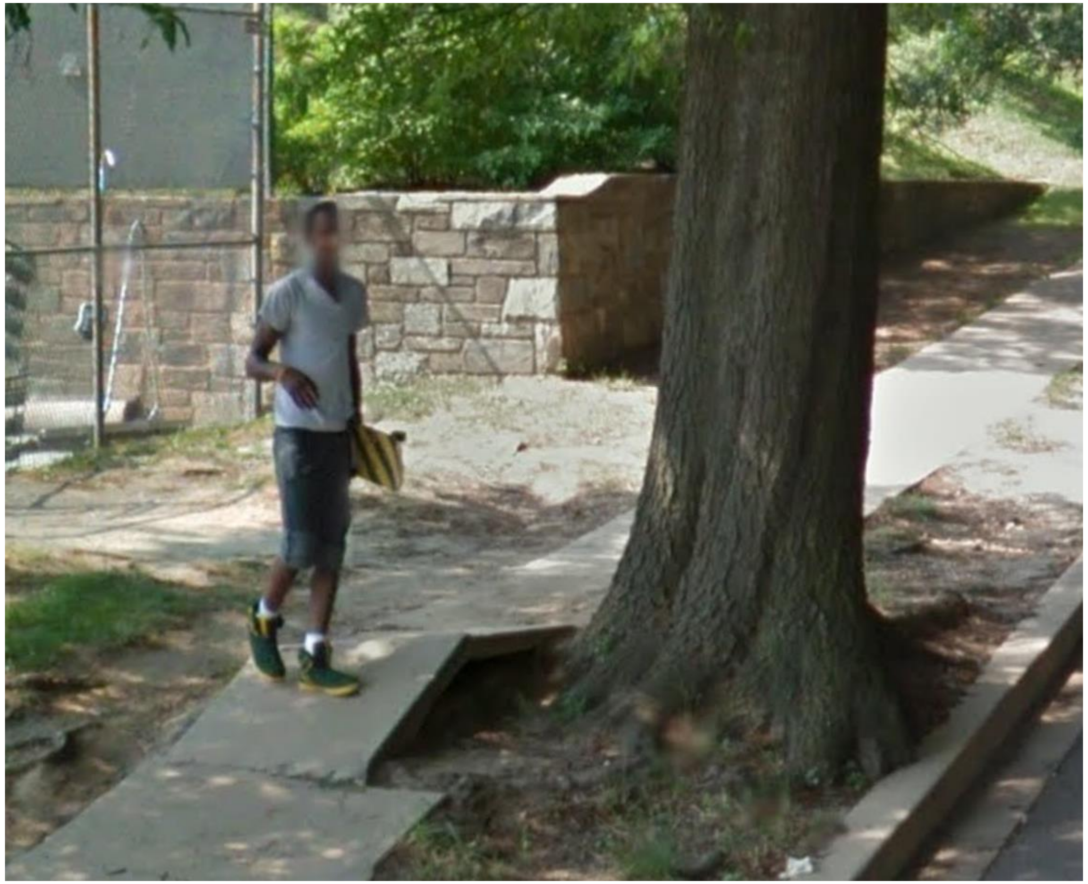


NEW ACCESSIBILITY GIS TOOLS

[SIGACCESS '15, CHI'16]

MAPPING THE ACCESSIBILITY OF THE WORLD

KEY RESEARCH QUESTIONS



SCALABLE DATA COLLECTION METHODS

[ASSETS'12, CHI'13, HCOMP'13, ASSETS'13, UIST'14, TACCESS'15]

1. Is online map imagery a good source for accessibility data?
2. Can we create interactive tools that enable crowd workers to find accessibility problems?
3. How can we leverage computational techniques to scale our approach?

MAPPING THE ACCESSIBILITY OF THE WORLD

THE TEAM

PROFESSORS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GRAD STUDENTS


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Jin Sun


Ladan Najafizadeh


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UNDERGRADUATE STUDENTS


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Niles Rogoff

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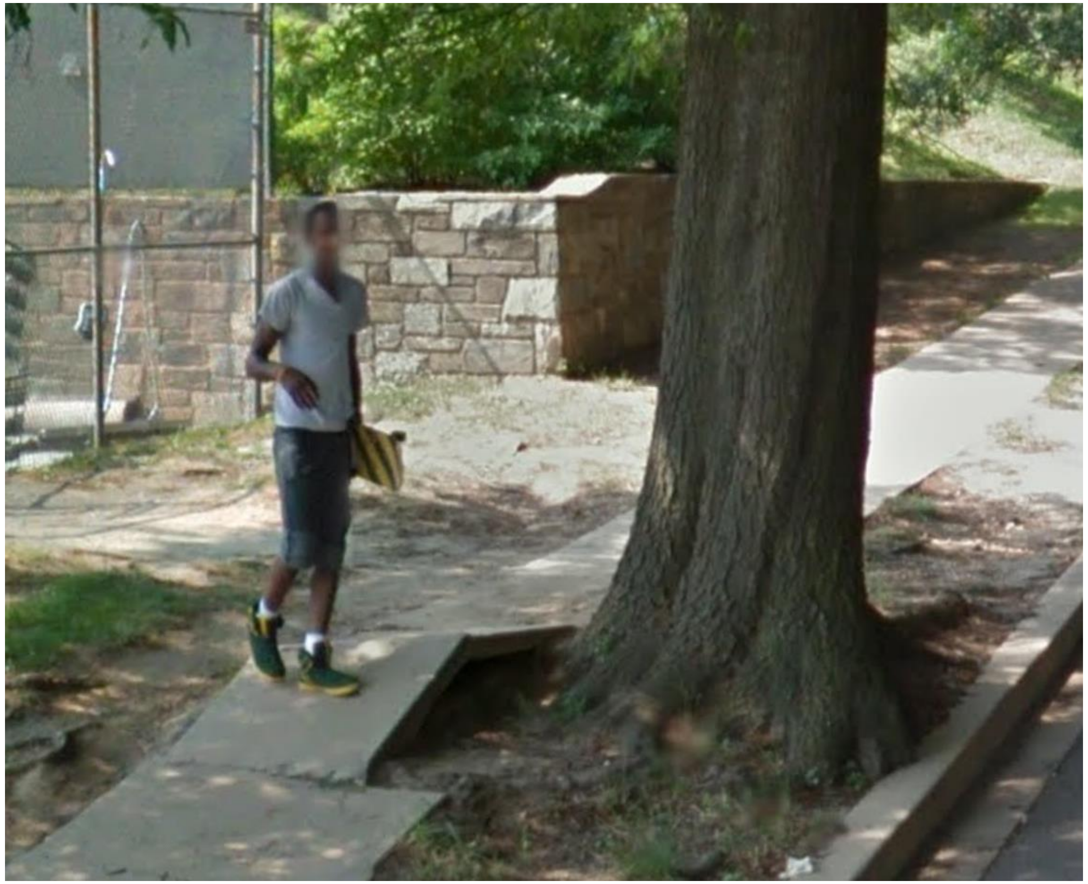

SCALABLE DATA COLLECTION METHODS

[ASSETS'12, CHI'13, HCOMP'13, ASSETS'13, UIST'14, TACCESS'15]

1. Is online map imagery a good source for accessibility data?
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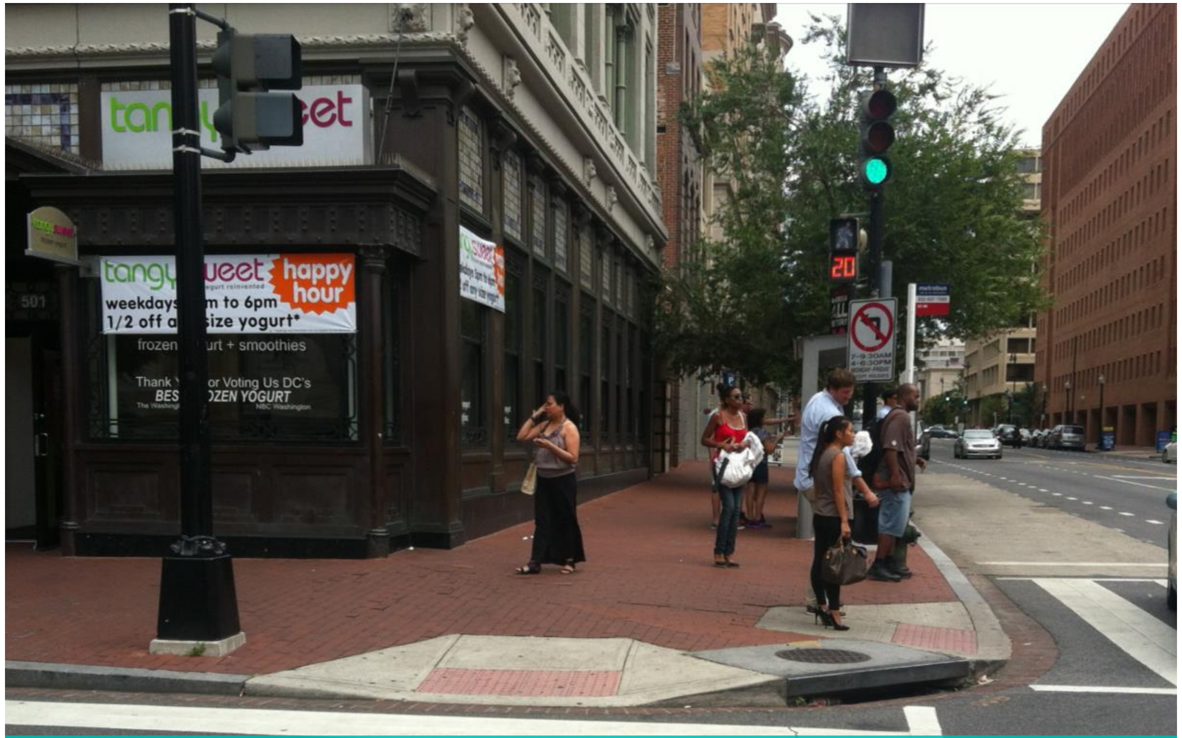
3. How can we leverage computational techniques to scale our approach?

IS GSV A GOOD DATASET FOR ACCESSIBILITY AUDITS?

PHYSICAL AUDITS VS. GOOGLE STREET VIEW

179 BUS STOPS

Washington DC & Seattle | 42 km surveyed



273 INTERSECTIONS

Washington DC & Baltimore | 34 km surveyed


PHYSICAL AUDIT PHOTO
M&S GRILL
13th St & F St, NW


GOOGLE SV PHOTO
M&S GRILL


503 7th St NW
503 7th St NW
Washington, District of Columbia
Street View - Aug 2014
GOOGLE SV PHOTO
F St NW
Ford's
Theatre
9th St NW
8th St NW
6th St NW
E St NW
D St NW
Back to Map


PHYSICAL AUDIT PHOTO
happy hour
20

IS GSV A GOOD DATASET FOR ACCESSIBILITY AUDITS?

COMPARISON RESULTS: SPEARMAN RANK COEFFICIENTS

BUS STOPS

vs.

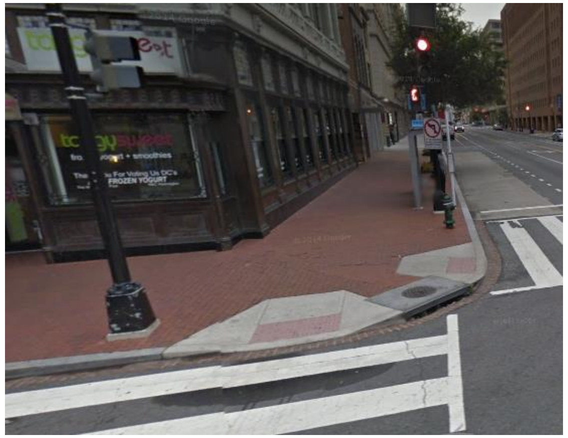
PHYSICAL AUDIT DATA

GSV AUDIT DATA

$\rho = \mathbf{0.88}$

INTERSECTIONS

vs.



PHYSICAL AUDIT DATA

GSV AUDIT DATA

$\rho = \mathbf{0.98}$

All results statistically significant at $p < 0.001$

IS GSV A GOOD DATASET FOR ACCESSIBILITY AUDITS?

ACCESSIBILITY INFRASTRUCTURE CHANGES SLOWLY

AVG IMAGE AGE IN BUS STOP DATASET

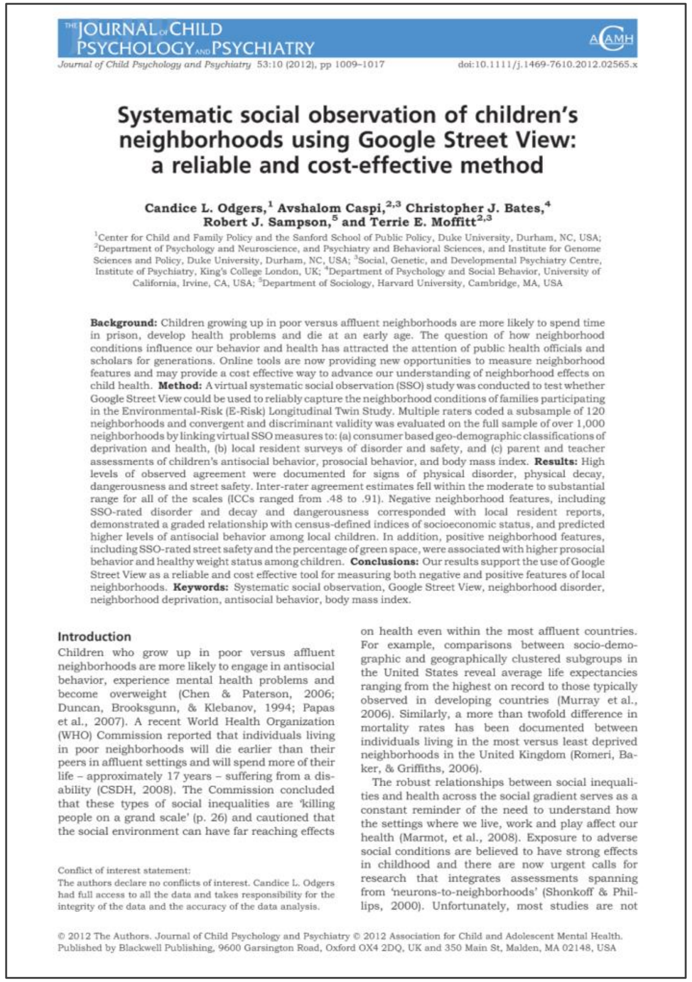
1.7 yrs (SD=0.7)

AVG IMAGE AGE IN INTERSECTION DATASET

1.5 yrs (SD=0.7)

IS GSV A GOOD DATASET FOR ACCESSIBILITY AUDITS?

CONSISTENT WITH FINDINGS FROM OTHER WORK

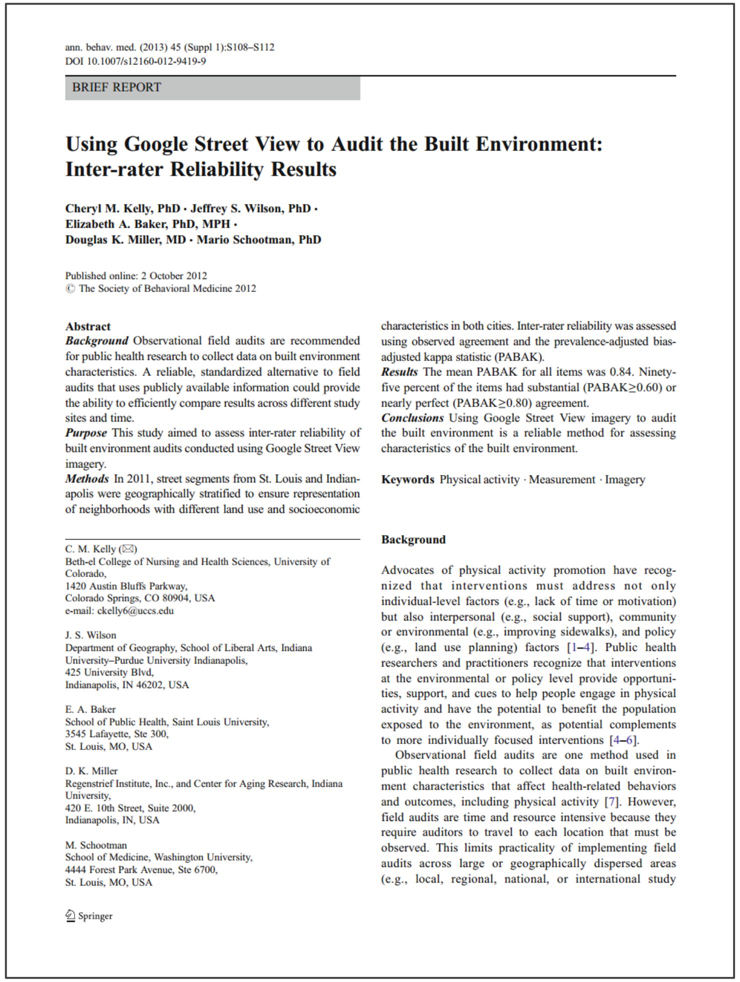


Journal of Child Psychology and Psychiatry 53:10 (2012), pp 1009–1017 doi:10.1111/j.1469-7610.2012.02565.x

Systematic social observation of children's neighborhoods using Google Street View: a reliable and cost-effective method

Candice L. Odgers,[1] Avshalom Caspi,[2,3] Christopher J. Bates,[4] Robert J. Sampson,[5] and Terrie E. Moffitt[2,3]

Background: Children growing up in poor versus affluent neighborhoods are more likely to spend time in prison, develop health problems and die at an early age. The question of how neighborhood conditions influence our behavior and health has attracted the attention of public health officials and scholars for generations. Online tools are now providing new opportunities to measure neighborhood features and may provide a cost effective way to advance our understanding of neighborhood effects on child health. **Method:** A virtual systematic social observation (SSO) study was conducted to test whether Google Street View could be used to reliably capture the neighborhood conditions of families participating in the Environmental-Risk (E-Risk) Longitudinal Twin Study. **Results:** High levels of observed agreement were documented for signs of physical disorder, physical decay, dangerousness and street safety. **Conclusions:** Our results support the use of Google Street View as a reliable and cost effective tool for measuring both negative and positive features of local neighborhoods.



ann. behav. med. (2013) 45 (Suppl 1):S108–S112
DOI 10.1007/s12160-012-9419-9

BRIEF REPORT

Using Google Street View to Audit the Built Environment: Inter-rater Reliability Results

Cheryl M. Kelly, PhD · Jeffrey S. Wilson, PhD · Elizabeth A. Baker, PhD, MPH · Douglas K. Miller, MD · Mario Schootman, PhD

Published online: 2 October 2012
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Abstract

Background Observational field audits are recommended for public health research to collect data on built environment characteristics.

Results The mean PABAK for all items was 0.84.

Conclusions Using Google Street View imagery to audit the built environment is a reliable method for assessing characteristics of the built environment.

Keywords Physical activity · Measurement · Imagery

Assessing the Built Environment Using Omnidirectional Imagery

Jeffrey S. Wilson, PhD, Cheryl M. Kelly, PhD, Mario Schootman, PhD, Elizabeth A. Baker, PhD, Aniruddha Banerjee, PhD, Morgan Clennin, MPH, Douglas K. Miller, MD

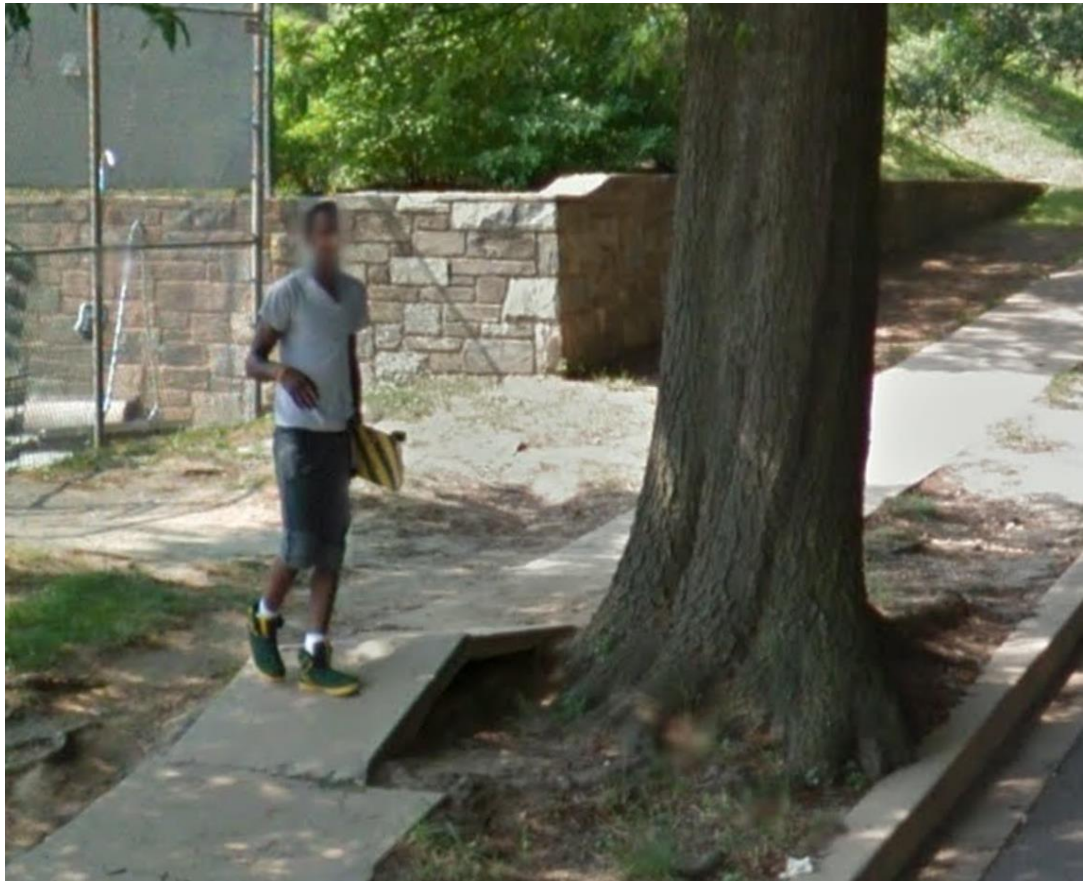
This activity is available for CME credit. See page A4 for information.

(Am J Prev Med 2012;42(2):193–199) © 2012 American Journal of Preventive Medicine

See: Odgers *et al.*, 2012; Wilson *et al.*, 2013; Kelly *et al.*, 2013; Bader, *et al.*, 2017

Google Street View is a reasonable proxy for studying the state of street-level accessibility

KEY RESEARCH QUESTIONS

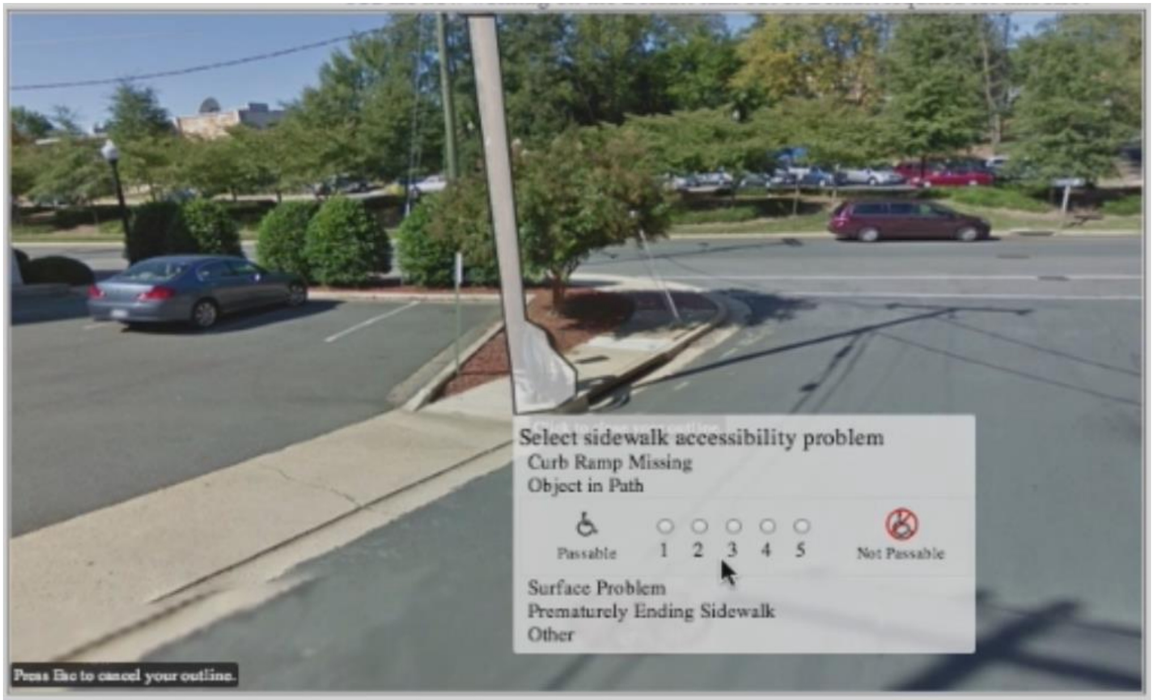


SCALABLE DATA COLLECTION METHODS

[ASSETS'12, CHI'13, HCOMP'13, ASSETS'13, UIST'14, TACCESS'15]

1. Is online map imagery a good source for accessibility data?
2. Can we create interactive tools that enable crowd workers to find accessibility problems?
3. How can we leverage computational techniques to scale our approach?

INITIAL CROWDSOURCING SYSTEM



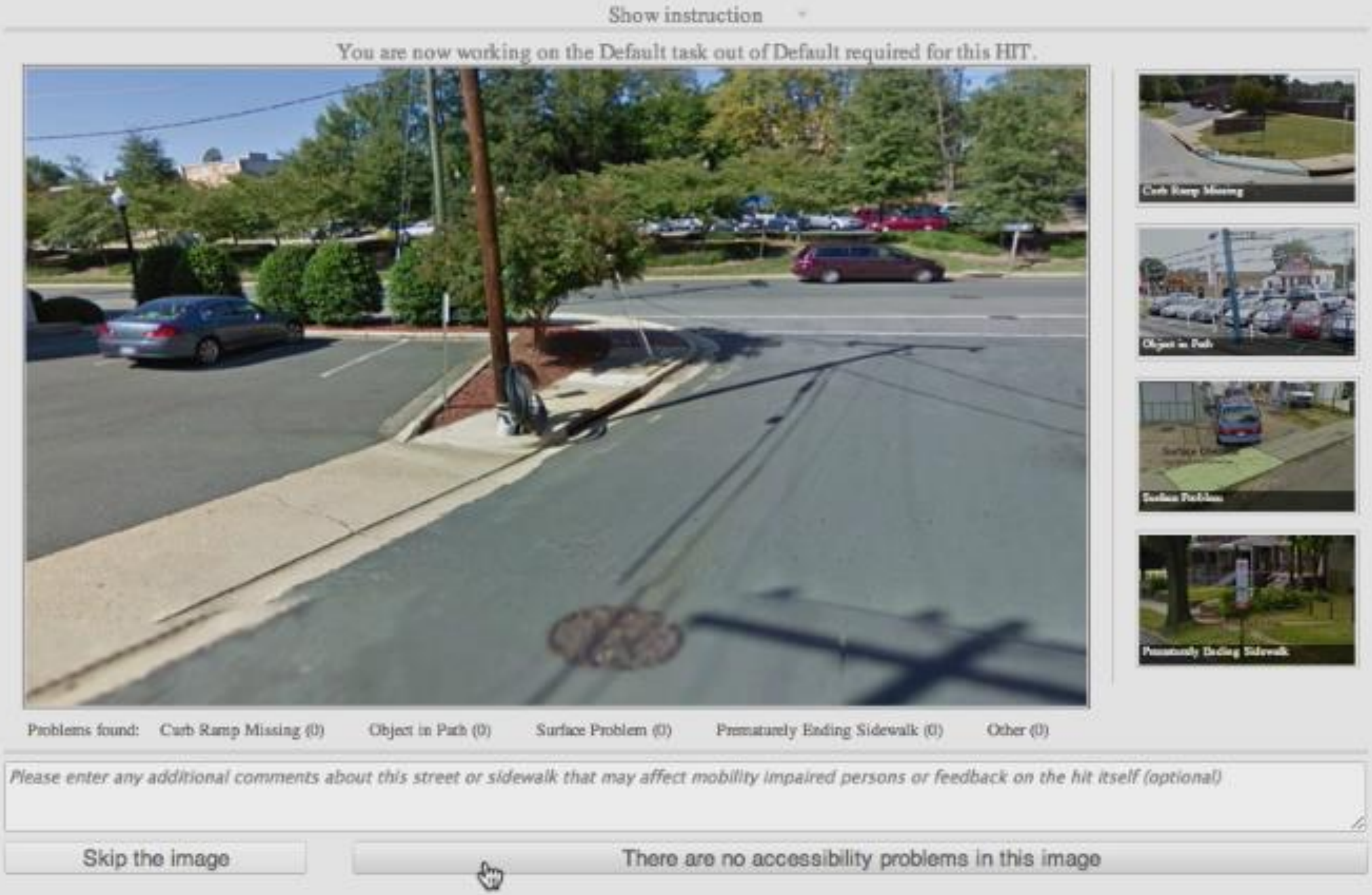
LABELING INTERFACE

VERIFICATION INTERFACE

LABELING INTERFACE

4-STEP PROCESS

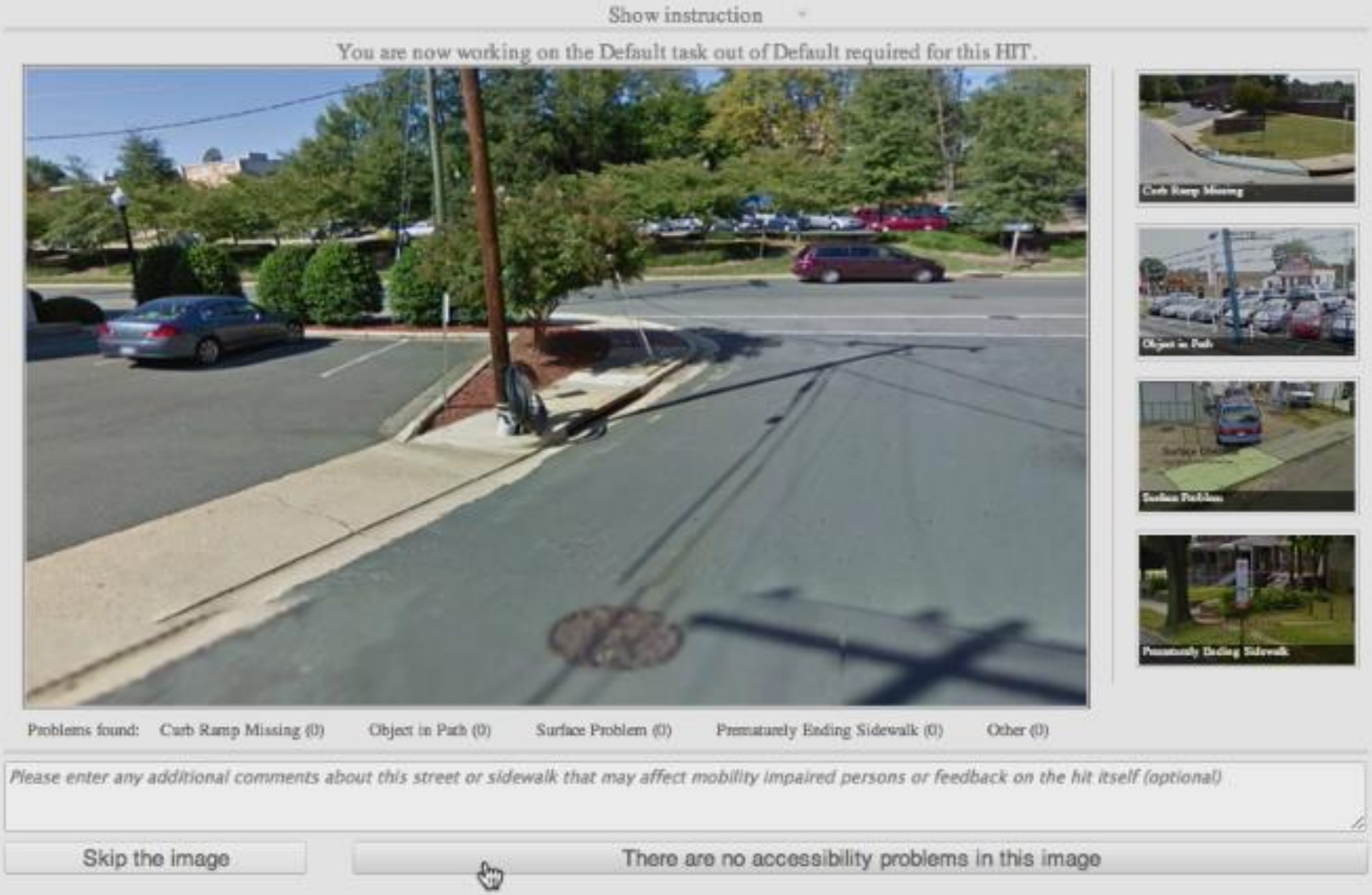
1. Find & label problem



LABELING INTERFACE

4-STEP PROCESS

1. Find & label problem

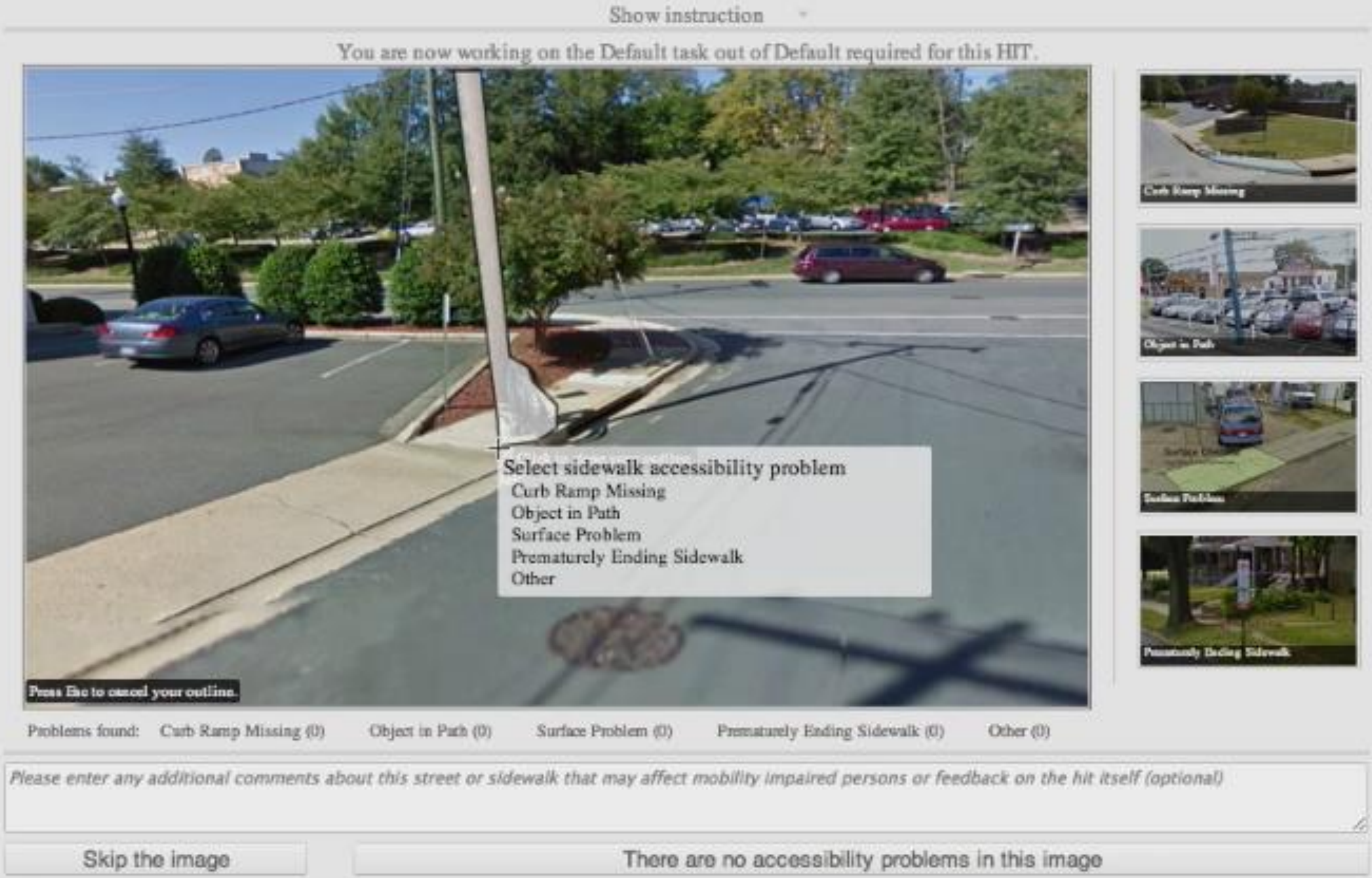


CROWDSOURCING ACCESSIBILITY AUDITS

LABELING INTERFACE

4-STEP PROCESS

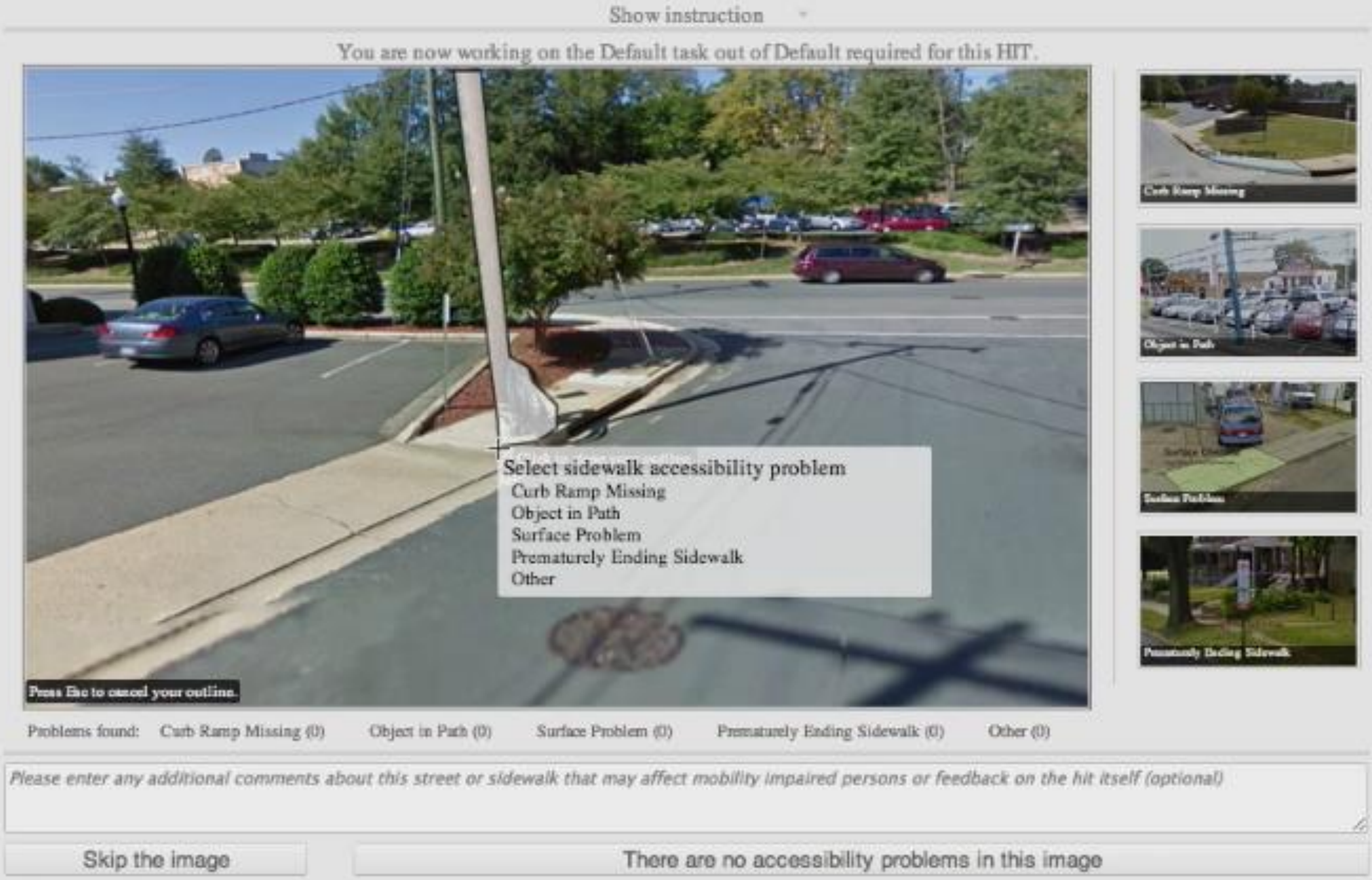
1. Find & label problem
2. Categorize problem



LABELING INTERFACE

4-STEP PROCESS

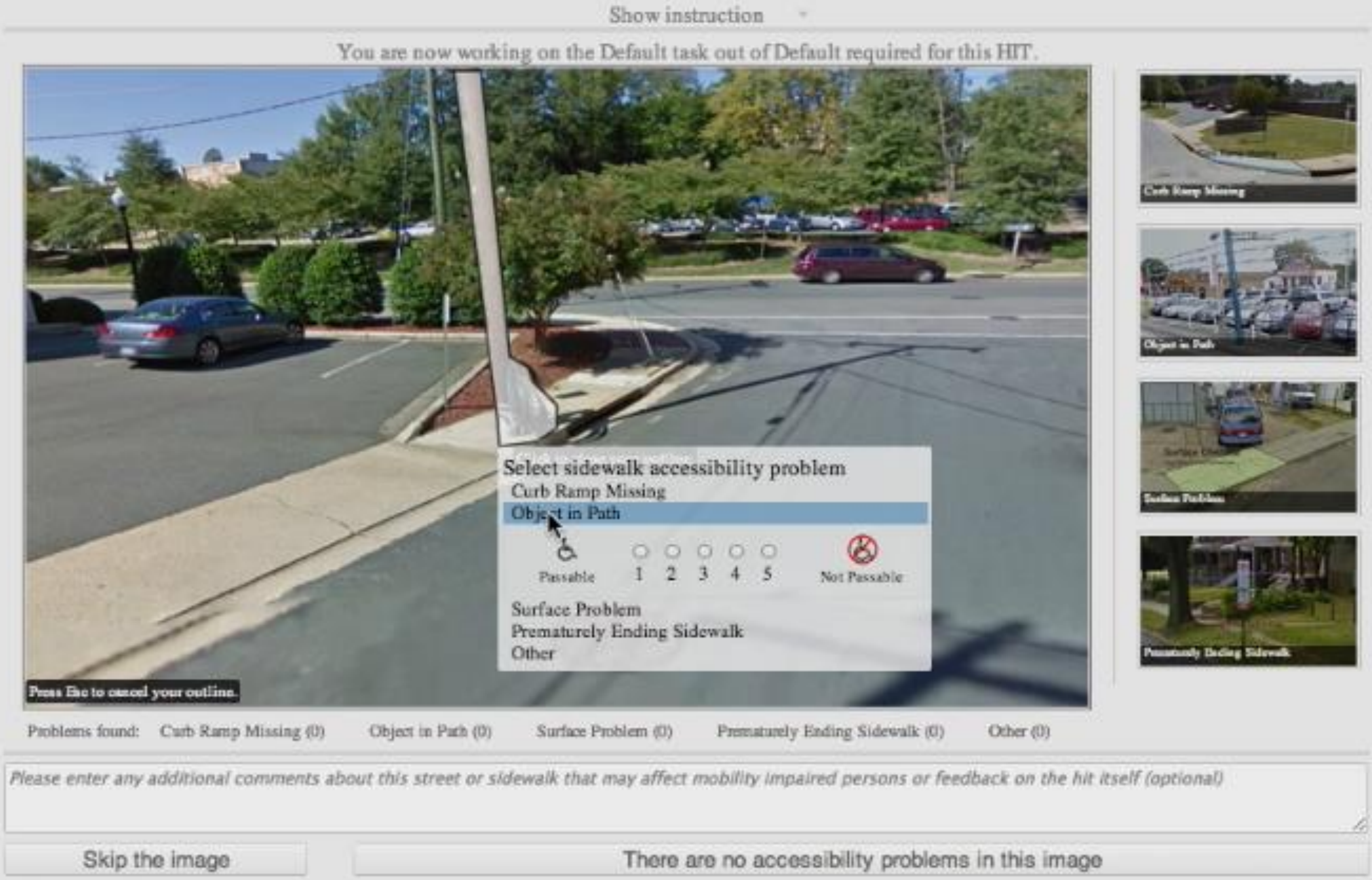
1. Find & label problem
2. Categorize problem



LABELING INTERFACE

4-STEP PROCESS

1. Find & label problem
2. Categorize problem
3. Rate problem severity



LABELING INTERFACE

4-STEP PROCESS

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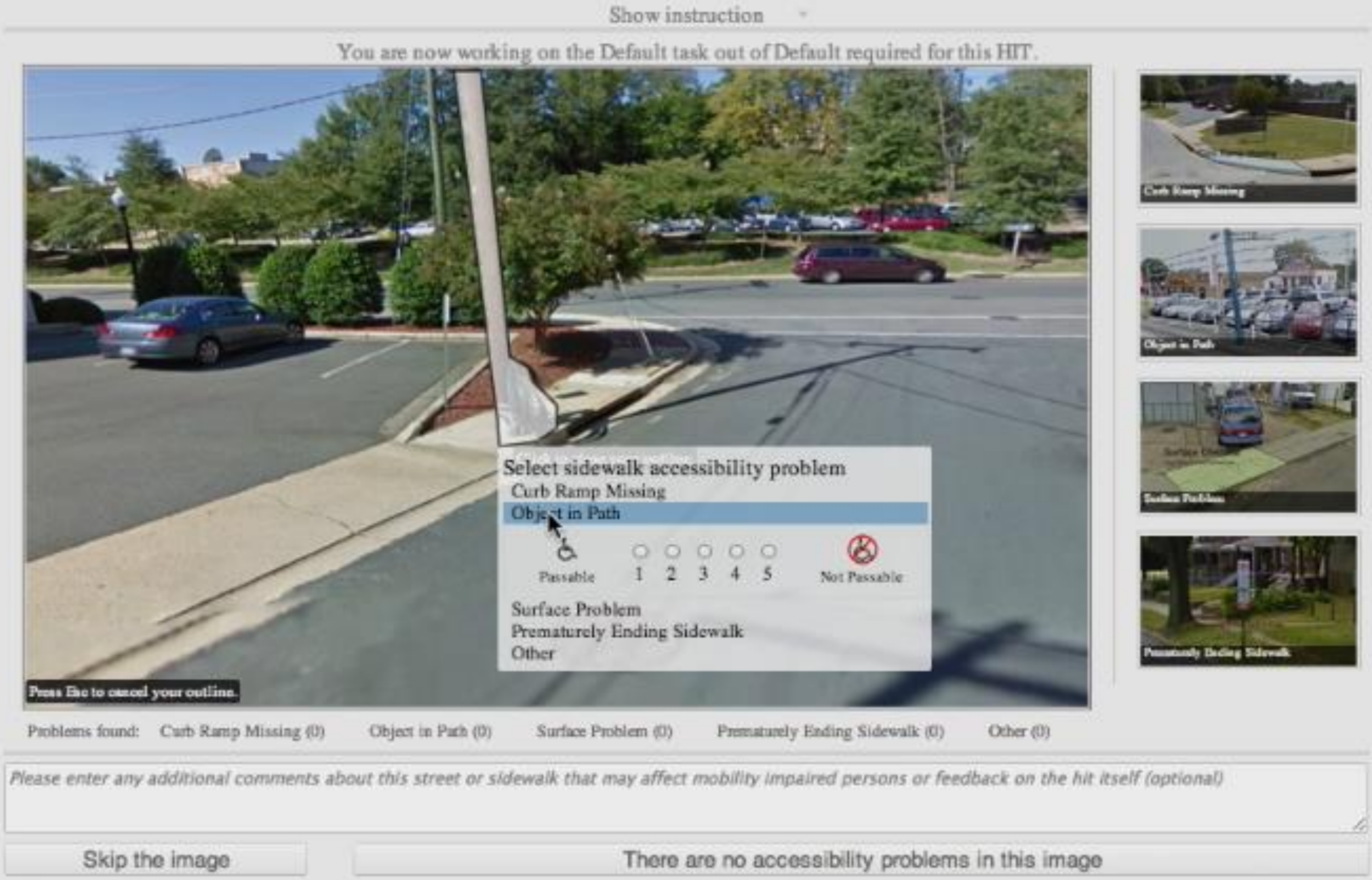
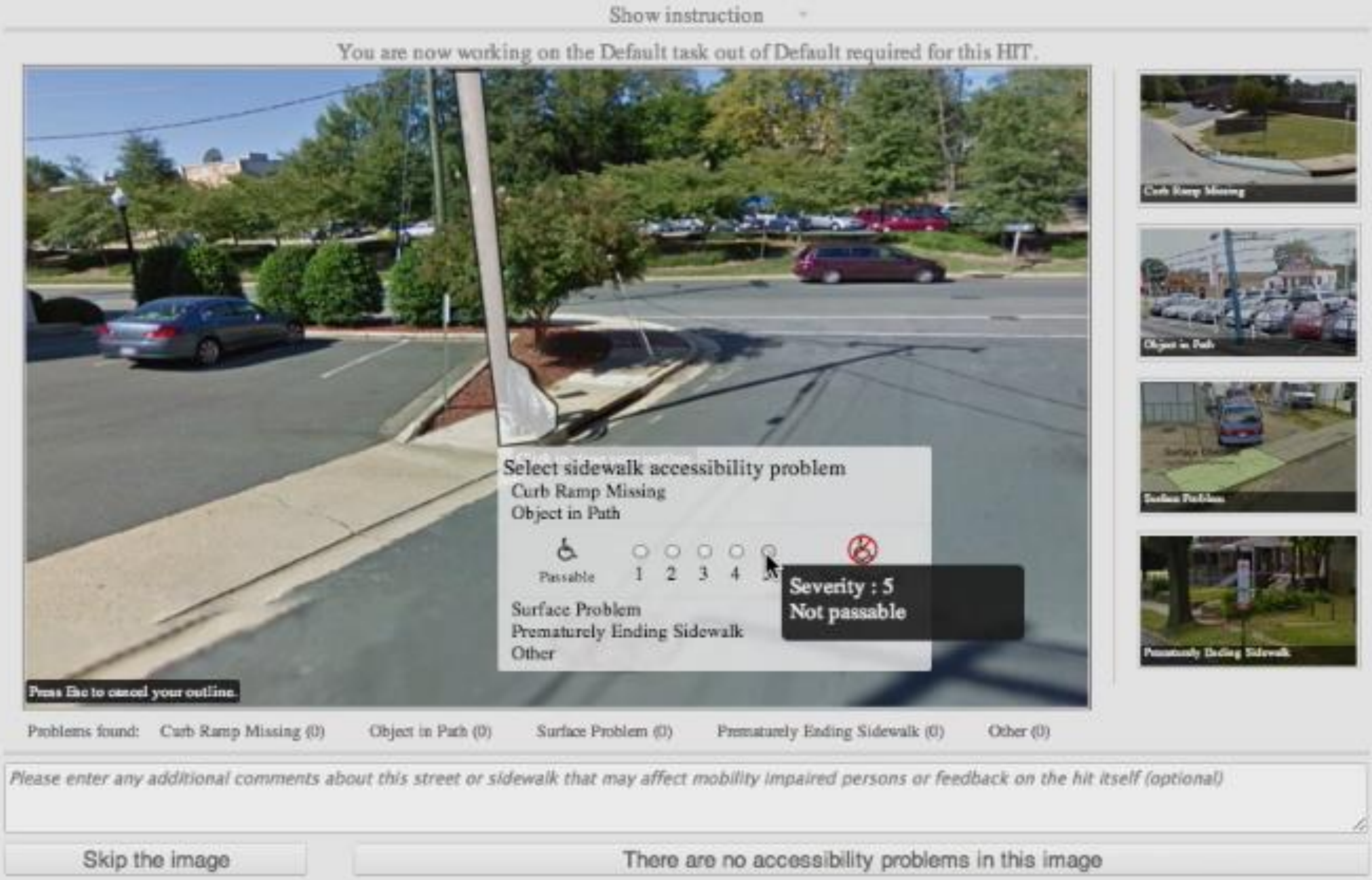
3. Rate problem severity



LABELING INTERFACE

4-STEP PROCESS

1. Find & label problem
2. Categorize problem
3. Rate problem severity
4. Submit work



LABELING INTERFACE

4-STEP PROCESS

1. Find & label problem
2. Categorize problem
3. Rate problem severity
4. Submit work

Receive another image to label & process repeats.

VERIFICATION INTERFACE

3-STEP PROCESS

1. Verify label

VERIFICATION INTERFACE

3-STEP PROCESS

1. Verify label

VERIFICATION INTERFACE

3-STEP PROCESS

1. Verify label
2. Verify rating

VERIFICATION INTERFACE

3-STEP PROCESS

1. Verify label
2. Verify rating
3. Provide details

VERIFICATION INTERFACE

3-STEP PROCESS

1. Verify label
2. Verify rating
3. Provide details

Check for false negatives

VERIFICATION INTERFACE

3-STEP PROCESS

1. Verify label
2. Verify rating
3. Provide details

Check for false negatives
Verify multiple labels/scene

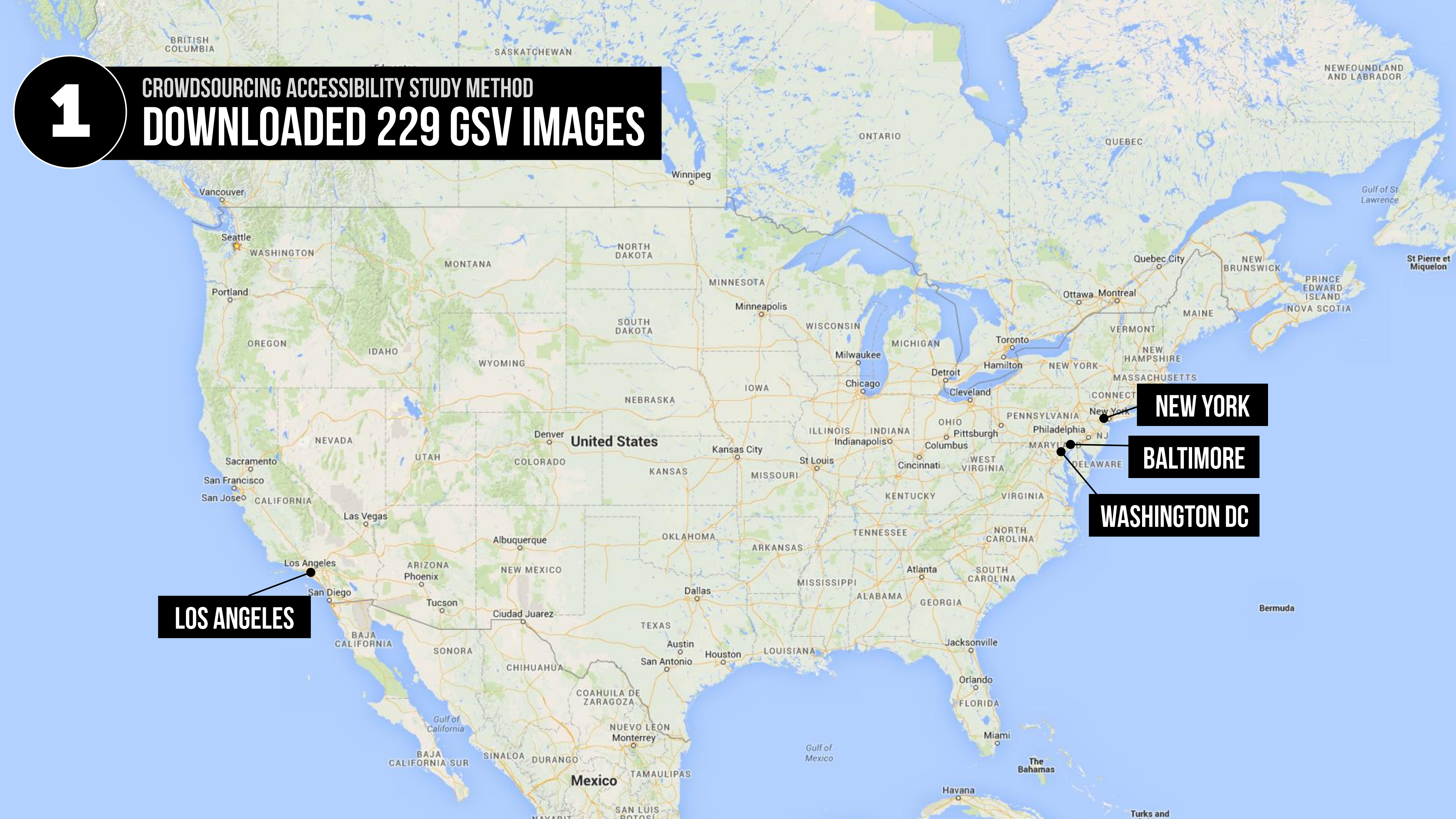
STUDY METHOD

1. Create image dataset
2. Generate ground truth labels
3. Deploy our tools to crowd
4. Compare performance to ground truth

1

CROWDSOURCING ACCESSIBILITY STUDY METHOD

DOWNLOADED 229 GSV IMAGES




SUBWAY

50 images Sidewalk Ending

66 images Object in Path

67 images Surface Problems

47 images Missing Curb Ramps

50 images No Problems

STUDY METHOD

1. Create image dataset

2. Generate ground truth labels

2 CROWDSOURCING ACCESSIBILITY STUDY METHOD

CREATE GROUND TRUTH LABELS

2

CROWDSOURCING ACCESSIBILITY STUDY METHOD

VALIDATE GROUND TRUTH LABELS

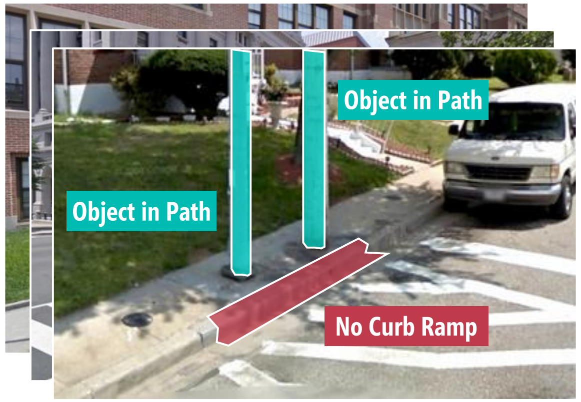
HIGH AGREEMENT BETWEEN TWO DATASETS

Bob

Sue

Alice

Majority Vote



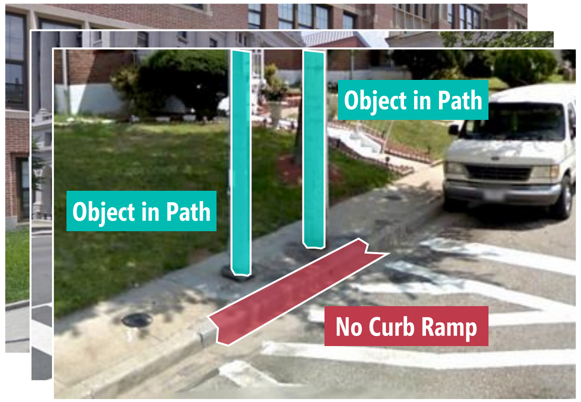
Researcher Ground Truth

Tom

Sarah

Jim

Majority Vote



Wheelchair User Ground Truth

STUDY METHOD

1. Create image dataset
2. Generate ground truth labels
3. Deploy our tools to crowd

3

CROWDSOURCING ACCESSIBILITY STUDY METHOD

DEPLOY TOOLS TO MECHANICAL TURK

amazon
mechanical turk

amazonmechanical turk
beta
Artificial Artificial Intelligence

Your Account | HITs | Qualifications

Already have an account?
Sign in as a **Worker** | **Requester**

Introduction | **Dashboard** | **Status** | **Account Settings**

Mechanical Turk is a marketplace for work.

We give businesses and developers access to an on-demand, scalable workforce.
Workers select from thousands of tasks and work whenever it's convenient.

206,470 HITs available. View them now.

Make Money
by working on HITs

HITs - *Human Intelligence Tasks* - are individual tasks that you work on. Find HITs now.

As a Mechanical Turk Worker you:

- Can work from home
- Choose your own work hours
- Get paid for doing good work

Find an interesting task | Work | Earn money

Get Results
from Mechanical Turk Workers

Ask workers to complete HITs - *Human Intelligence Tasks* - and get results using Mechanical Turk. Register Now

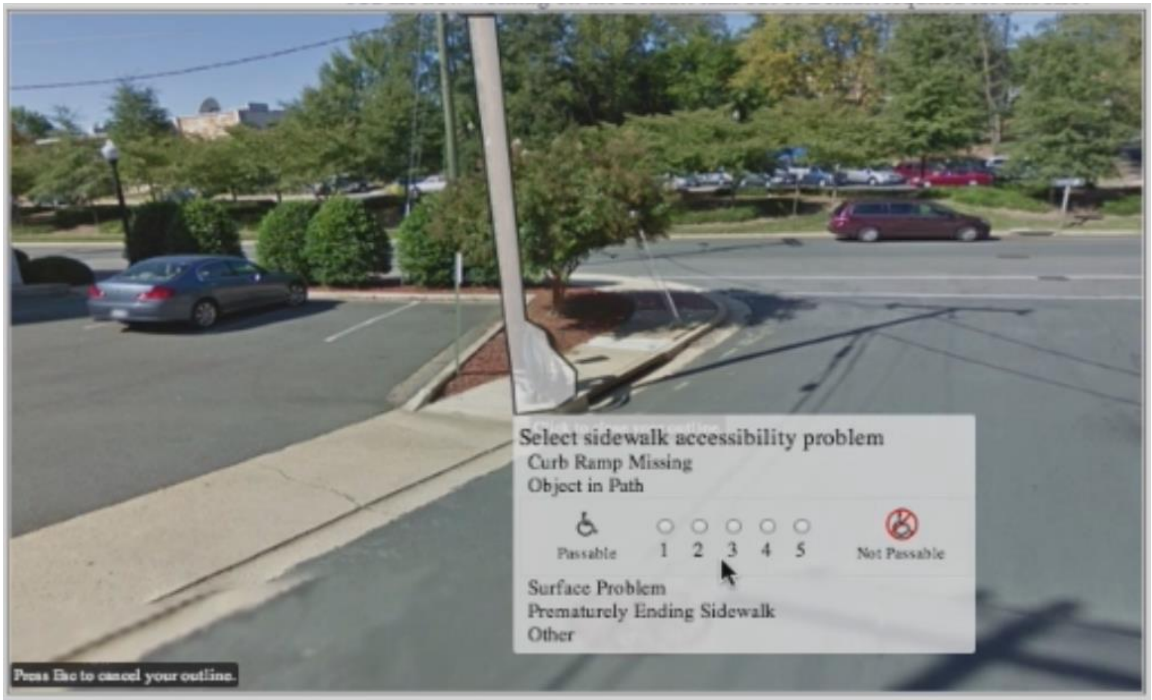
As a Mechanical Turk Requester you:

- Have access to a global, on-demand, 24 x 7 workforce
- Get thousands of HITs completed in minutes
- Pay only when you're satisfied with the results

Fund your account | Load your tasks | Get results

CROWDSOURCING ACCESSIBILITY STUDY RESULTS

MTURK STUDY STATISTICS



LABELING TASKS

185 turkers

7,517 image labeling tasks (AVG=40.6/turker)

13,379 labels (AVG=1.8/image)

VERIFICATION TASKS

273 turkers

19,189 verifications (AVG=70.2/turker)

VERIFICATIONS FASTER THAN LABELING

35.2s

LABEL AN IMAGE

10.5s

VERIFY AN IMAGE

STUDY METHOD

1. Create image dataset
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4. Compare performance to ground truth

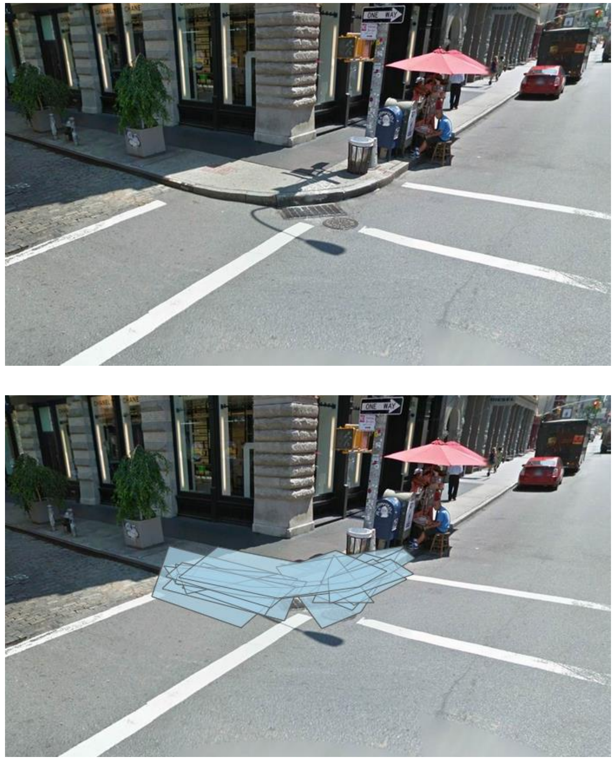
CROWDSOURCING ACCESSIBILITY STUDY RESULTS

OVERALL LABELING ACCURACY

With one labeler per image

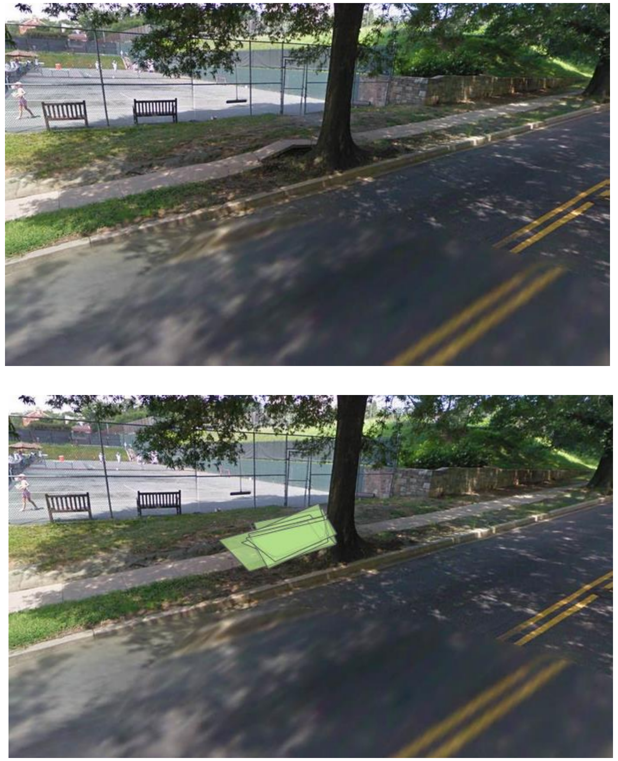
SIDEWALK ENDING

85%



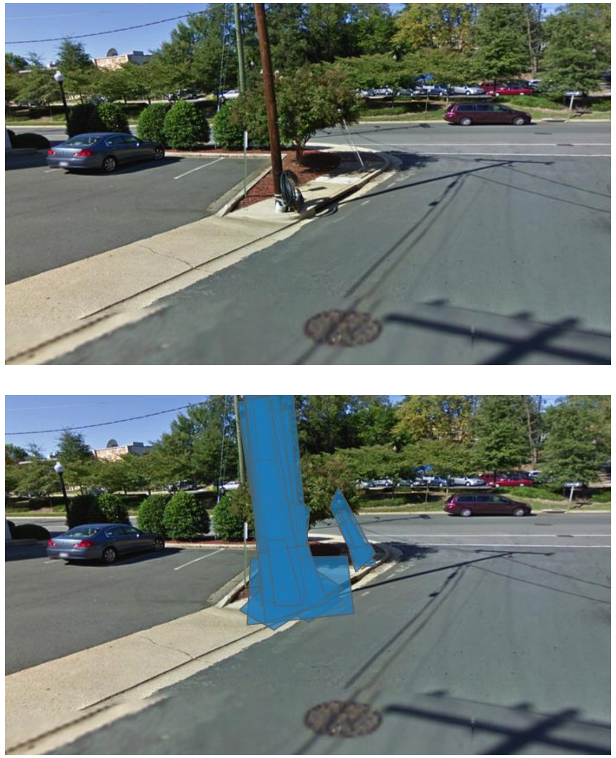
MISSING CURB RAMPS

79%



SURFACE PROBLEM

77%



OBJECT IN PATH

73%

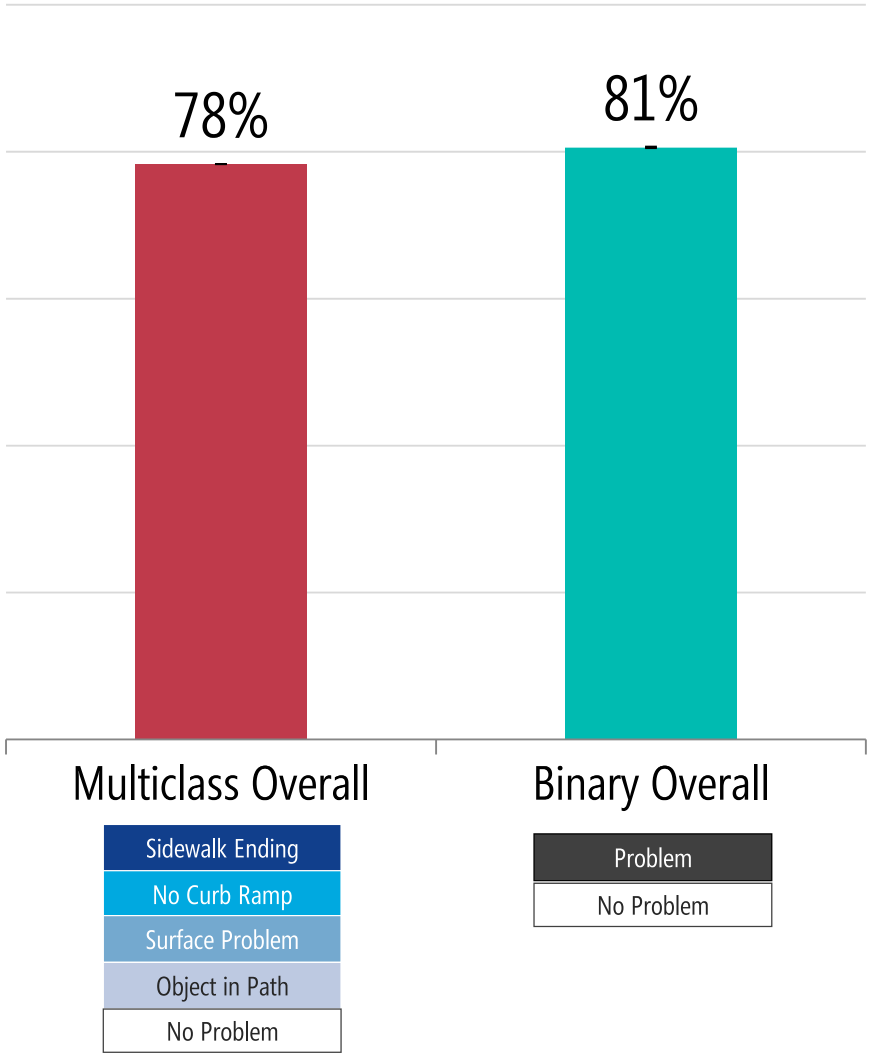
CROWDSOURCING ACCESSIBILITY STUDY RESULTS

OVERALL LABELING ACCURACY

With one labeler per image

SIDEWALK ENDING	MISSING CURB RAMPS	SURFACE PROBLEM	OBJECT IN PATH
85%	**79%**	**77%**	**73%**

AVERAGE OVERALL ACCURACY



COMMON LABELER MISTAKES

OVER LABELING

(*i.e.,* tendency towards false positives)

RANDOM LABELS

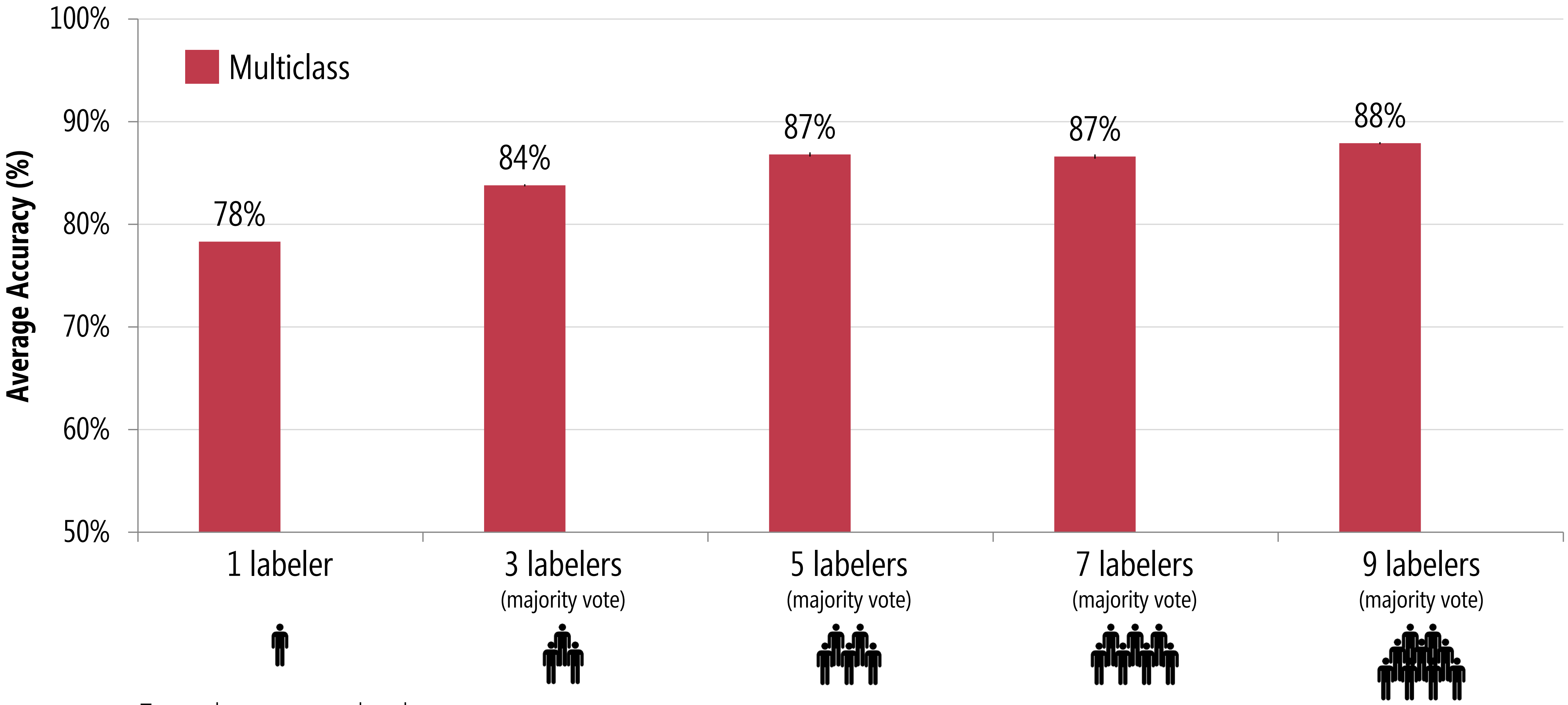
(*e.g.,* misunderstanding, malevolence)

CATEGORY ERRORS

(*i.e.,* ambiguous problem category)

CROWDSOURCING ACCESSIBILITY STUDY RESULTS

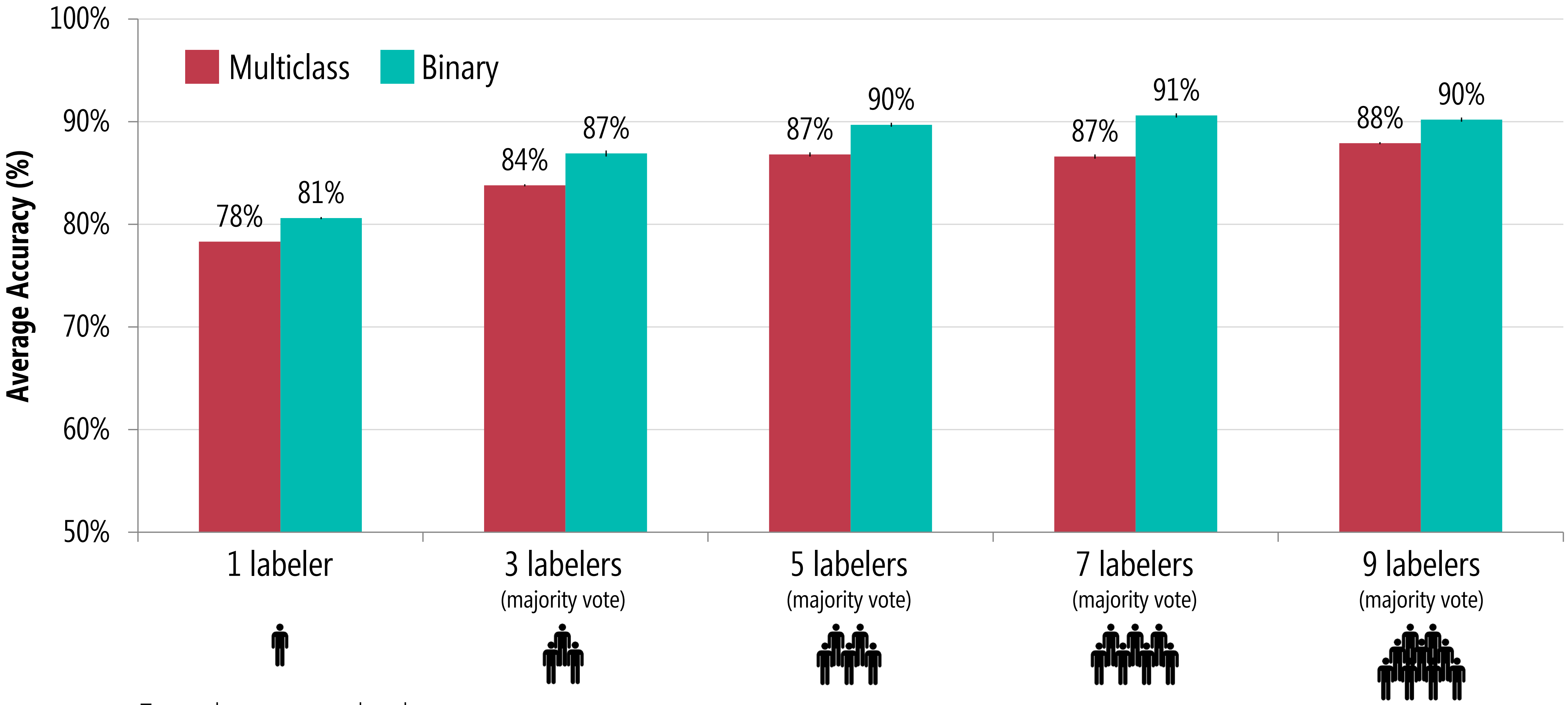
ACCURACY AS A FUNCTION OF LABELERS PER IMAGE



Error bars: standard error

CROWDSOURCING ACCESSIBILITY STUDY RESULTS

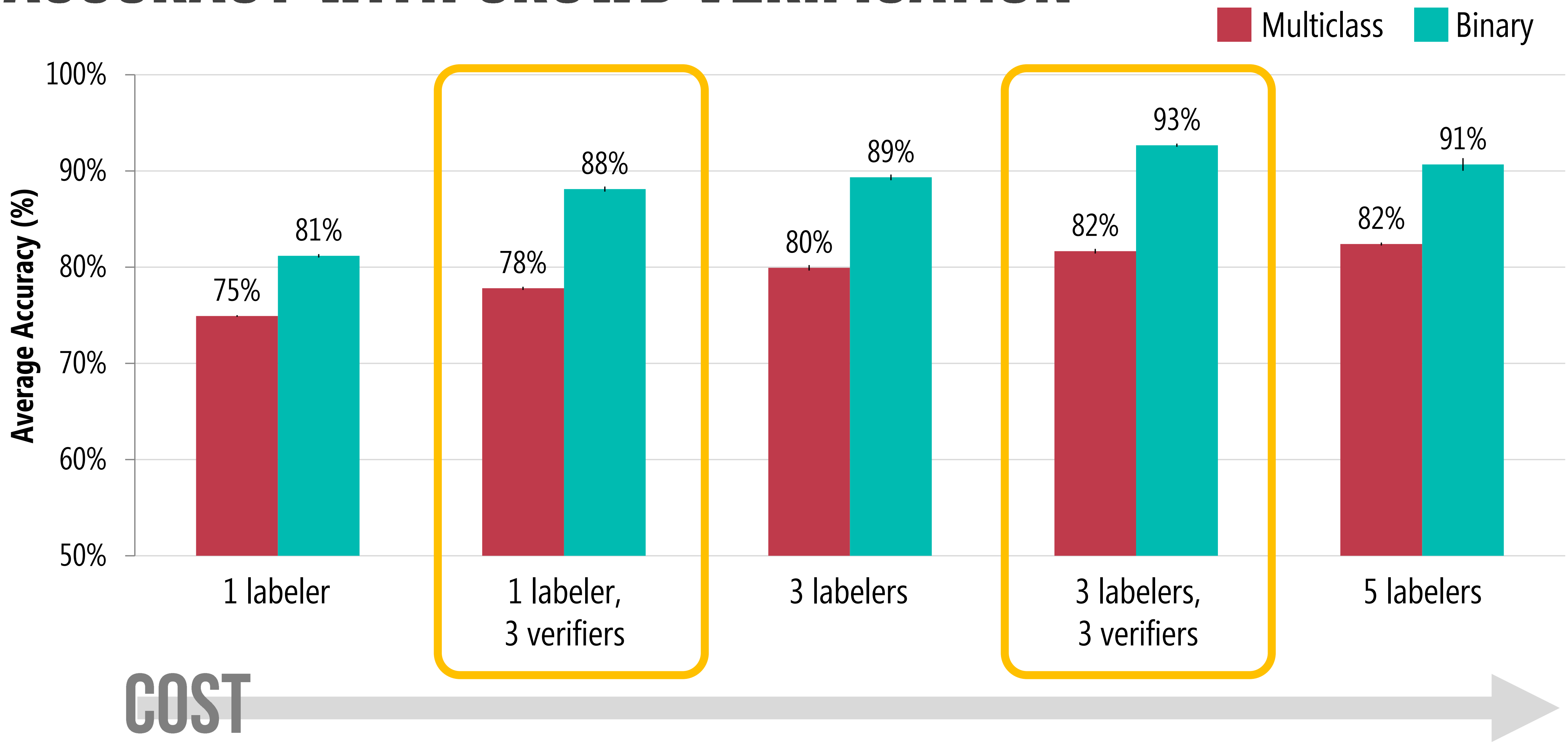
ACCURACY AS A FUNCTION OF LABELERS PER IMAGE



Error bars: standard error

CROWDSOURCING ACCESSIBILITY STUDY RESULTS

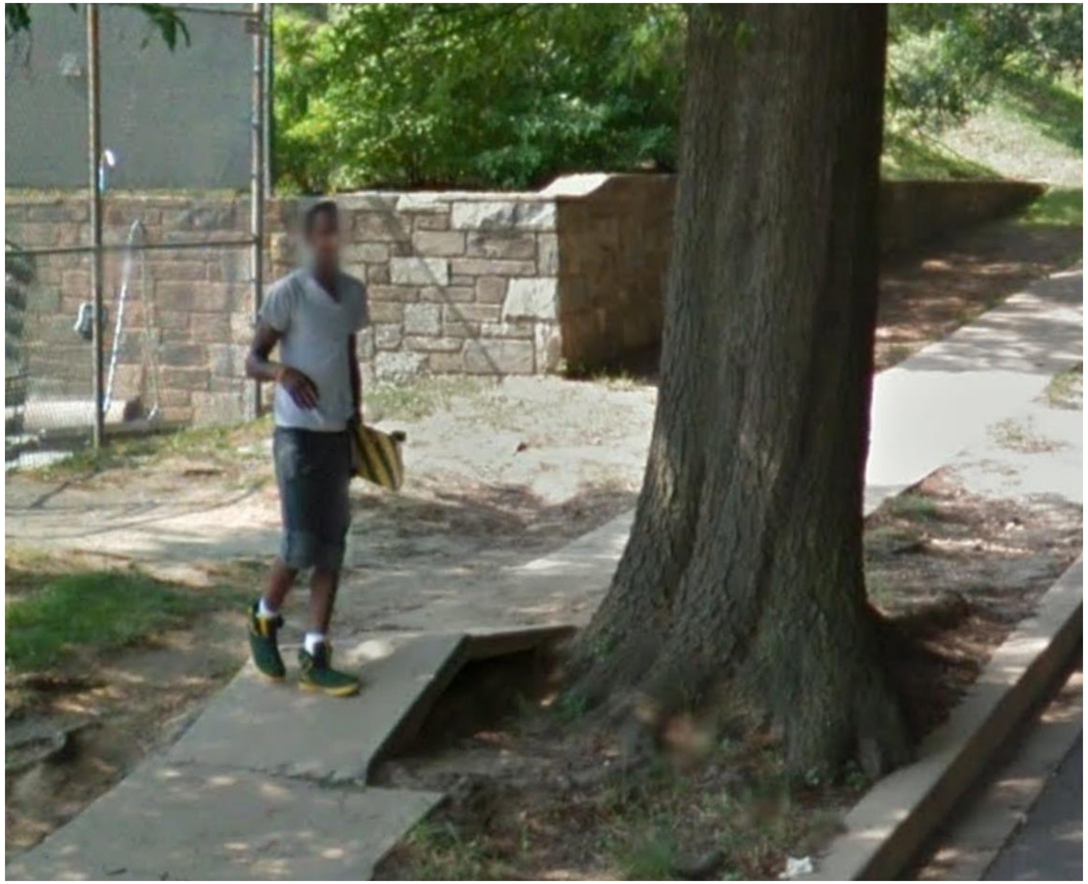
ACCURACY WITH CROWD VERIFICATION



Error bars: standard error

But this approach relied **purely manual labor**.
Can we do better?

KEY RESEARCH QUESTIONS



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Tohme

遠目 ·*Remote Eye*

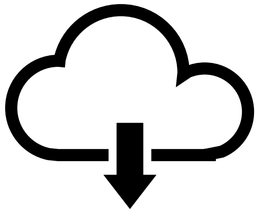
TOHME

遠目 Remote Eye

1

svCrawl

Web Scraper

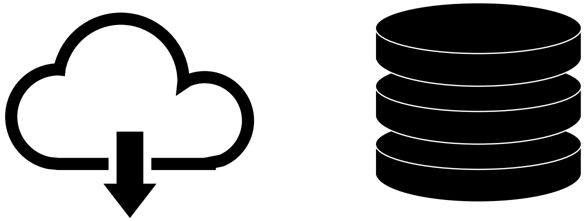


TOHME

遠目 Remote Eye

1 svCrawl

Web Scraper



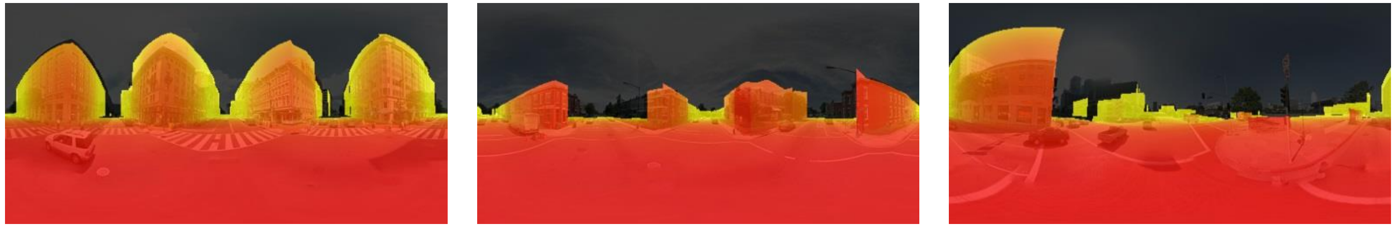
Street View images
3D-depth maps
Top-down map images
GIS metadata

2

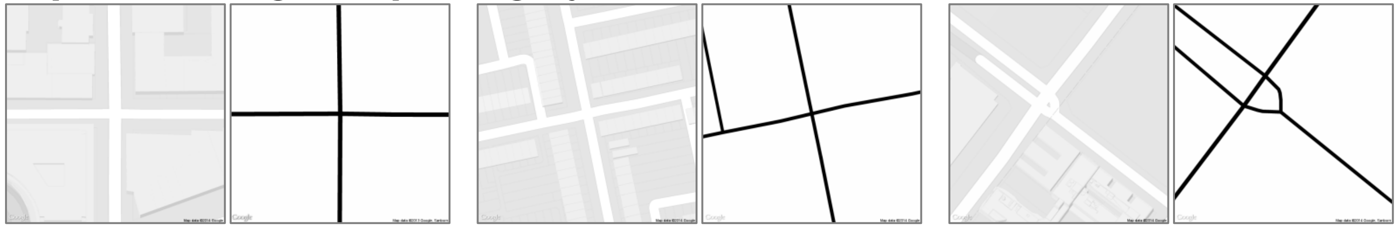
Street Dataset

Google Street View Panoramas

3D Point-cloud Data



Top-down Google Maps Imagery

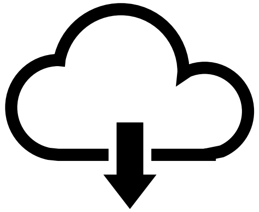


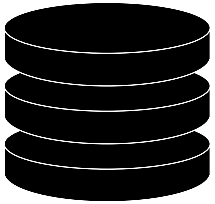
GIS Metadata

<Latitude & longitude/>
<GSV image age/>
<Street & city names/>
<Intersection topology/>

TOHME
遠目 Remote Eye

1 svCrawl
Web Scraper





Street View images
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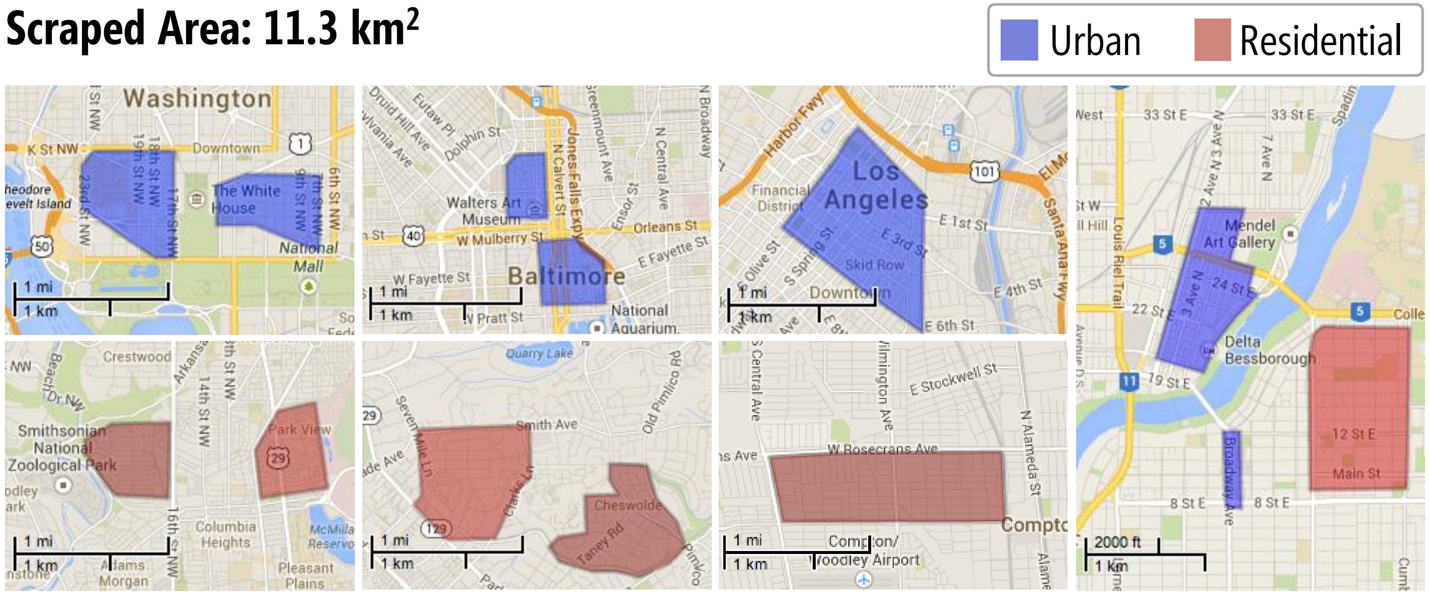
2 **Street Dataset**

Scraped Area: 11.3 km^2



D.C. | Baltimore | Los Angeles | Saskatoon

Dataset Statistics

1,086
intersections

2,877
curb ramps

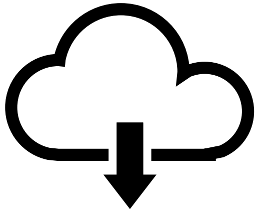
647
missing
curb ramps

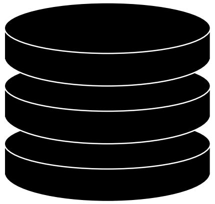
2.2 yrs (SD=1.3)
average GSV image age

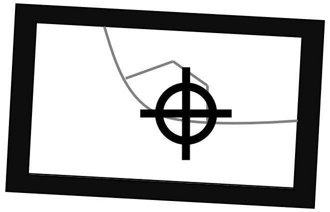
TOHME
遠目 Remote Eye

1 svCrawl
Web Scraper

3 svDetect
Automatic Curb Ramp Detection







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2 **Street Dataset**

TOHME
遠目 Remote Eye

1 svCrawl
Web Scraper

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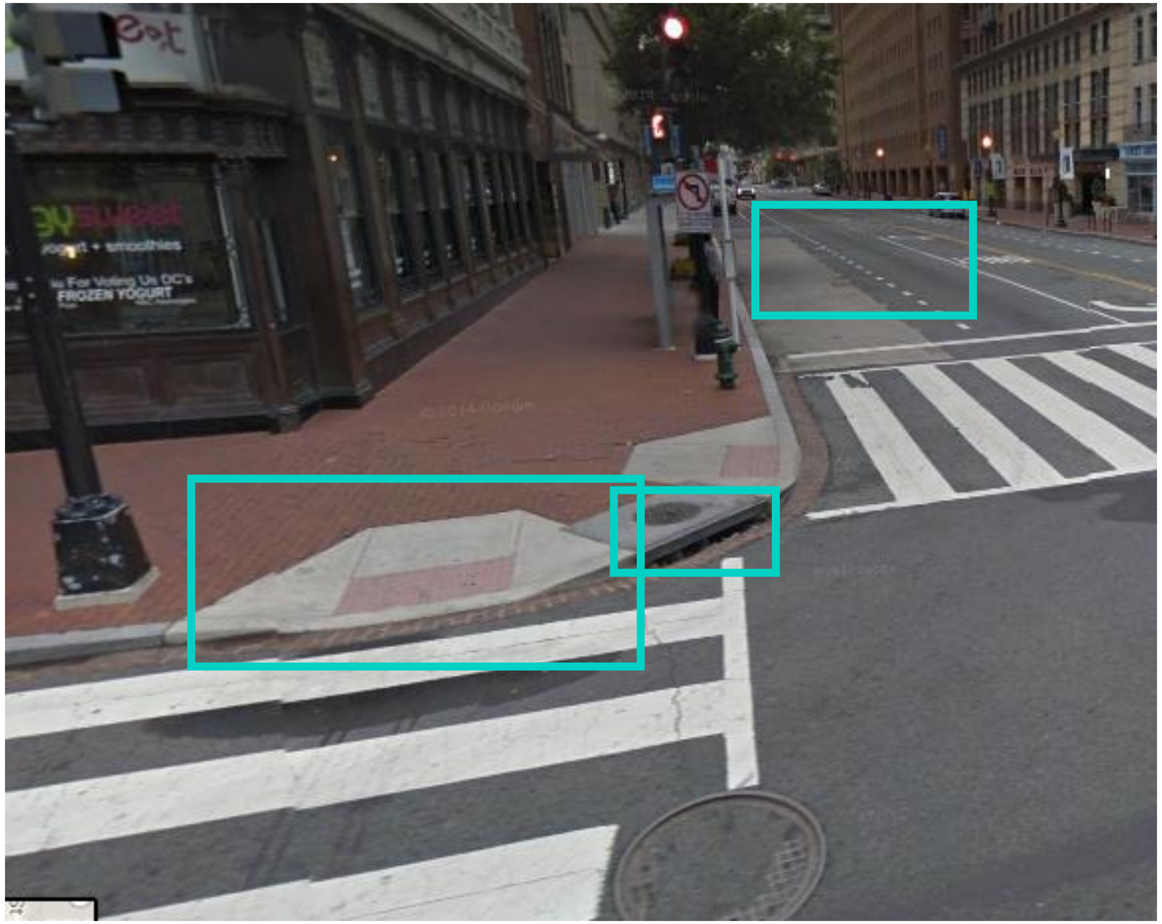
Automatic Curb Ramp Detection



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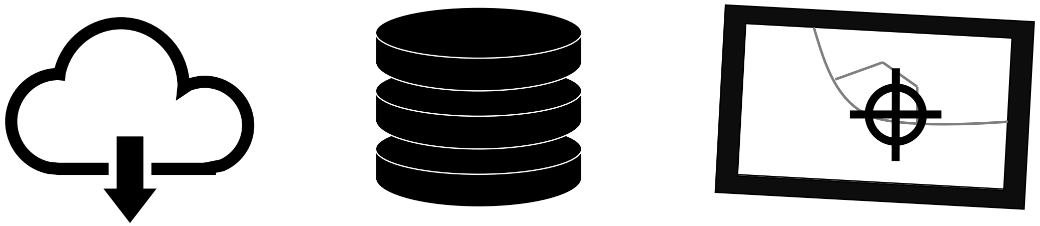

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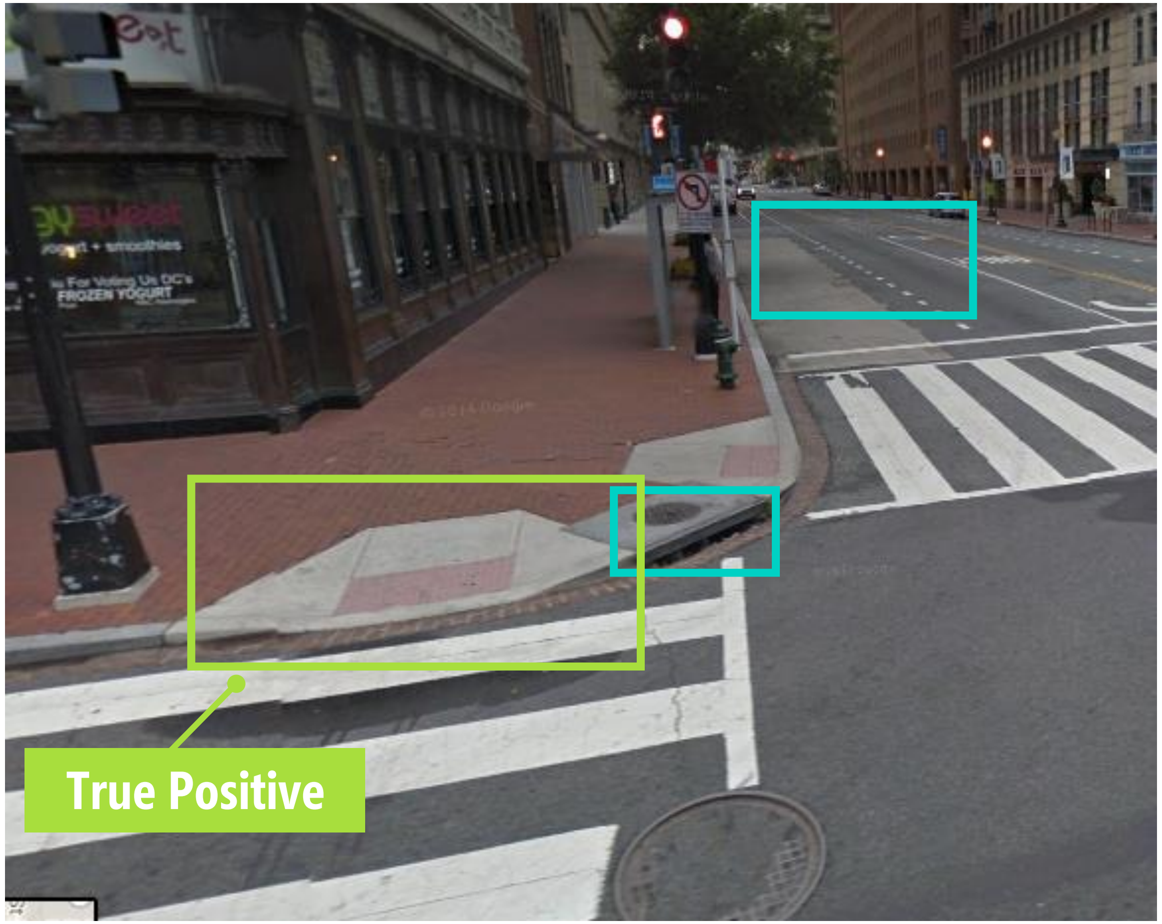

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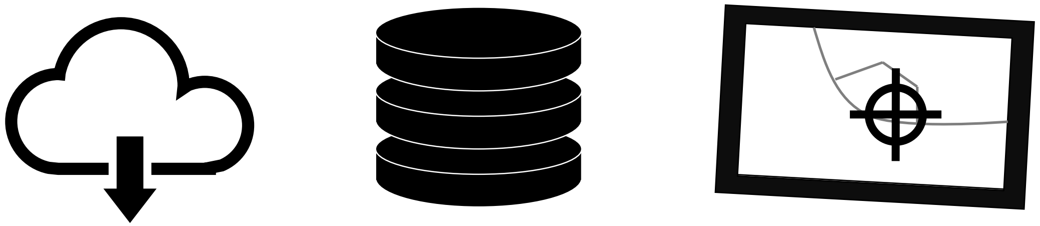

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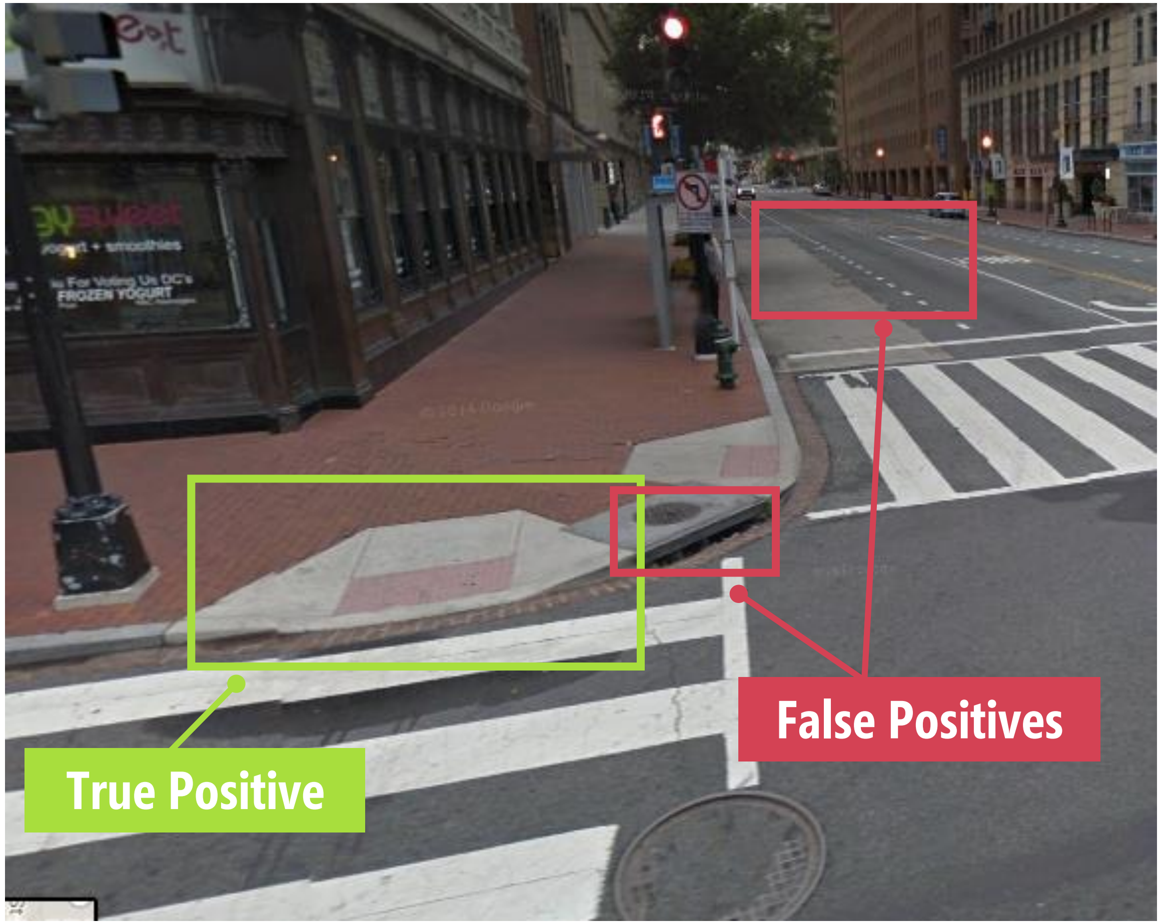

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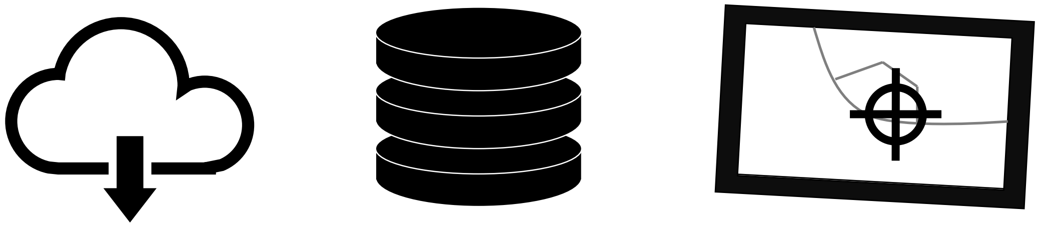

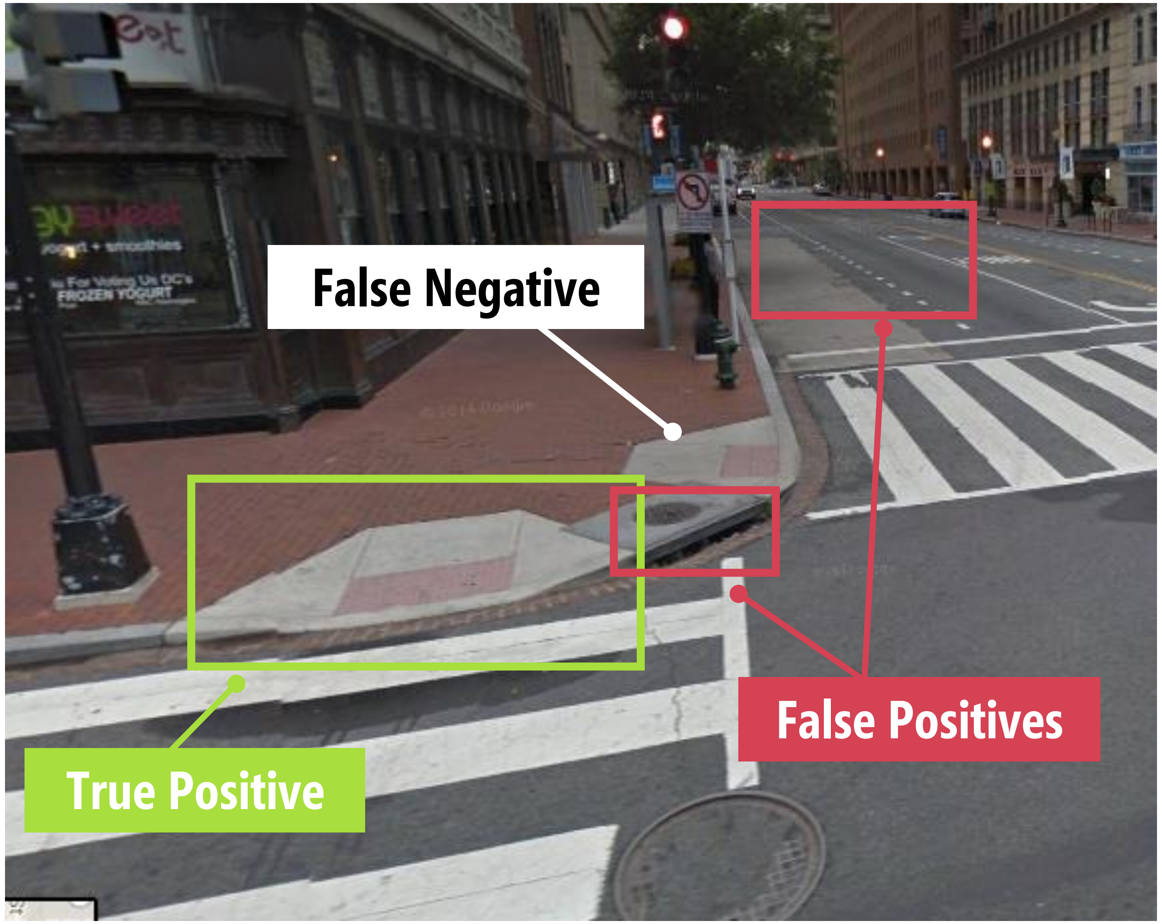

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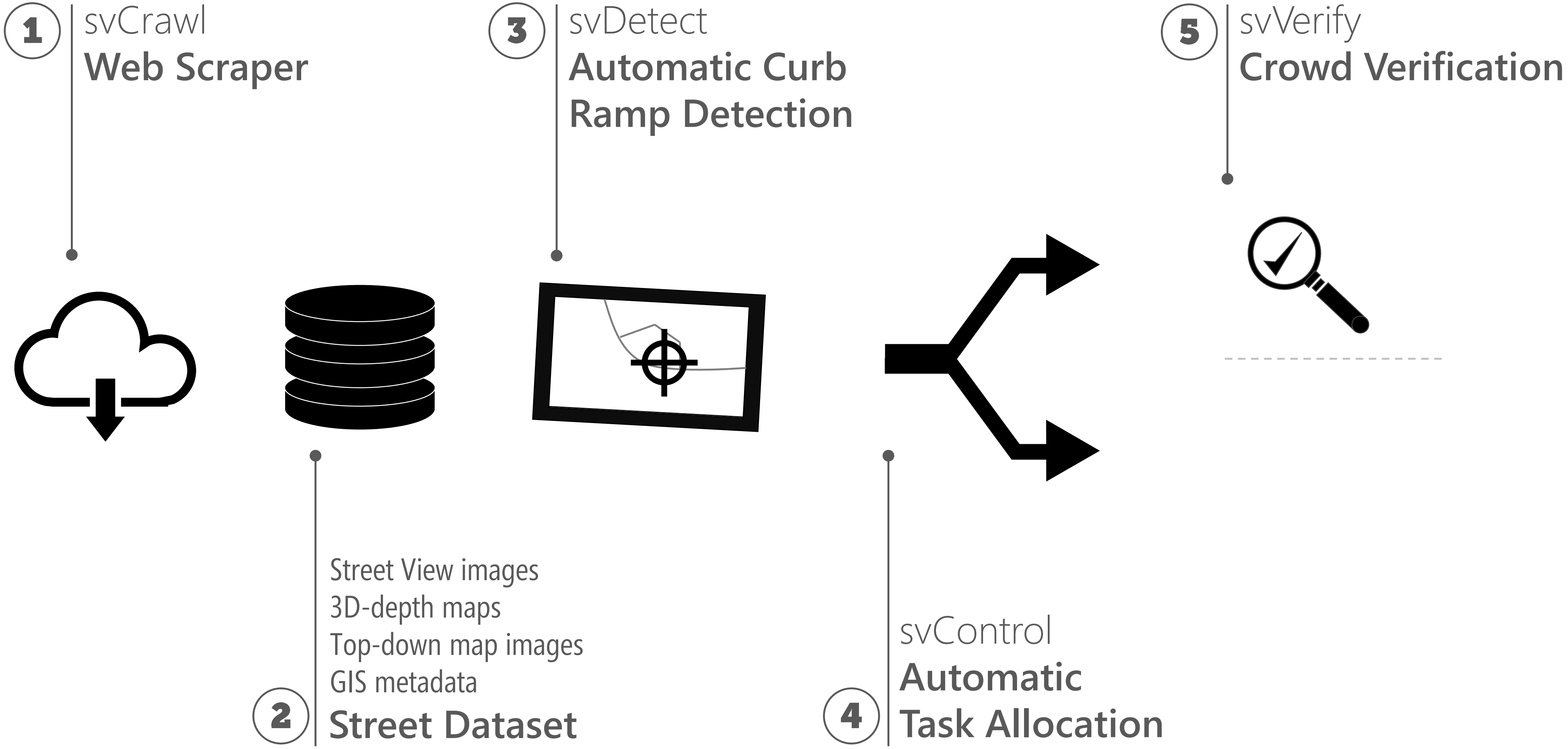
TOHME
遠目 Remote Eye



TOHME
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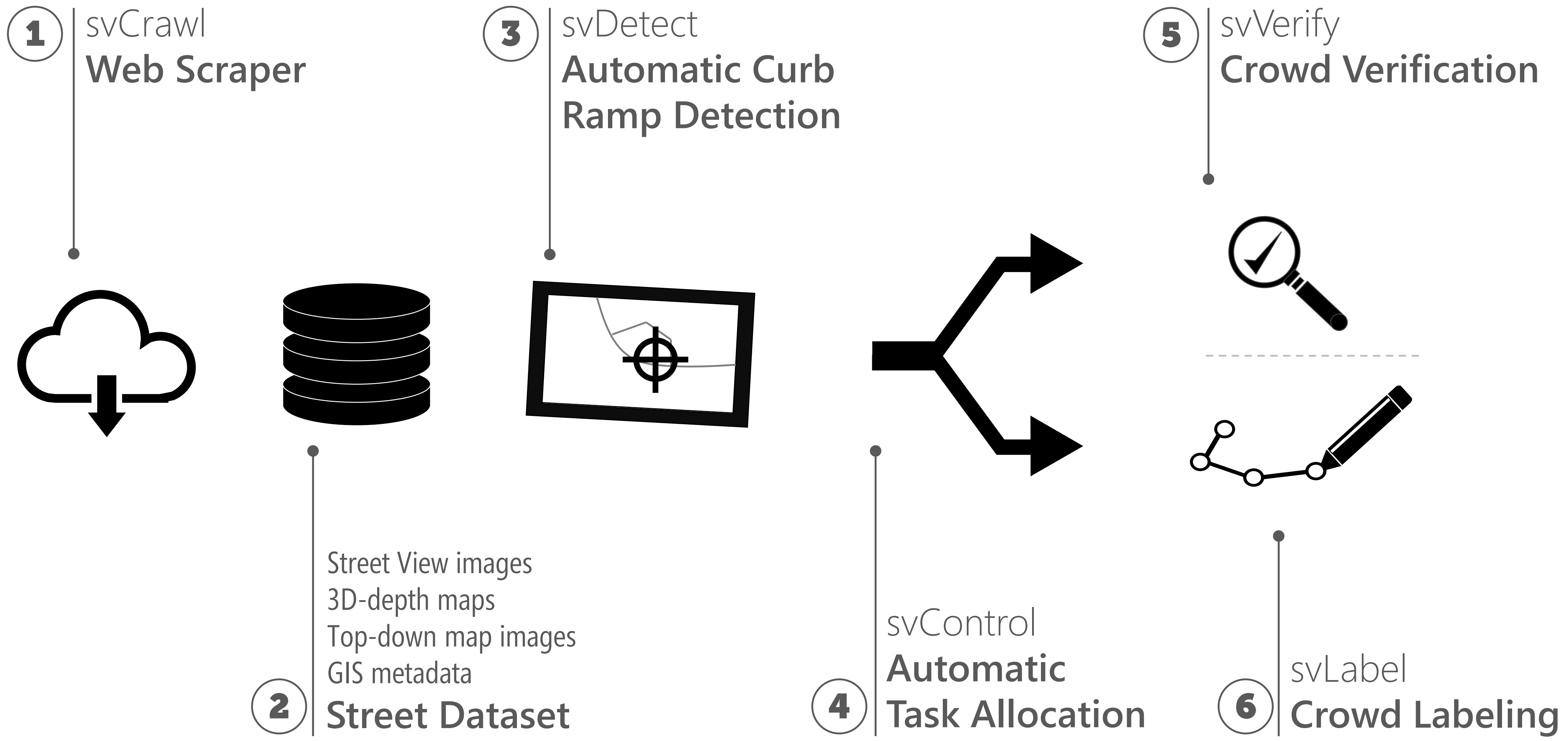

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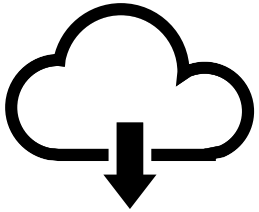
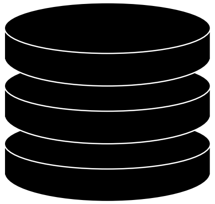
Web Scraper

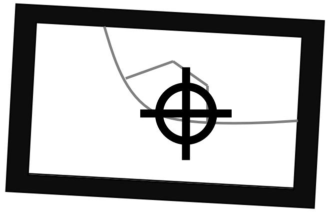


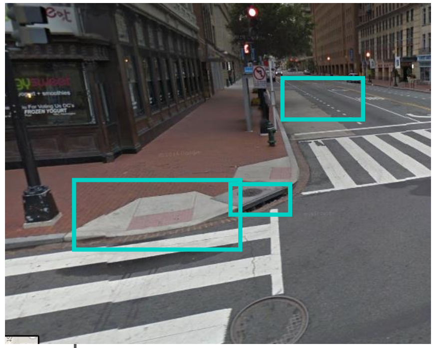


Street View images
3D-depth maps
Top-down map images
GIS metadata

2 **Street Dataset**

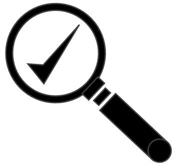
3 svDetect
Automatic Curb Ramp Detection





4 svControl
Automatic Task Allocation

5 svVerify
Crowd Verification



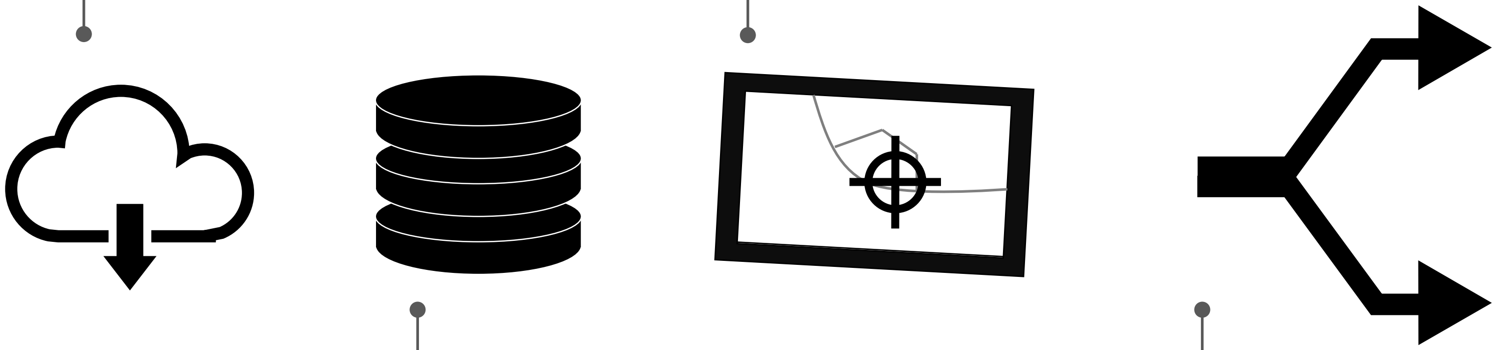
TOHME

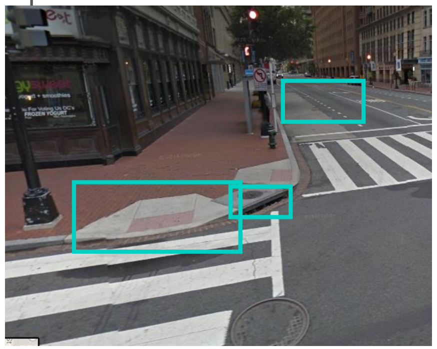
遠目 Remote Eye

1 svCrawl
Web Scraper

3 svDetect
Automatic Curb Ramp Detection

5 svVerify
Crowd Verification





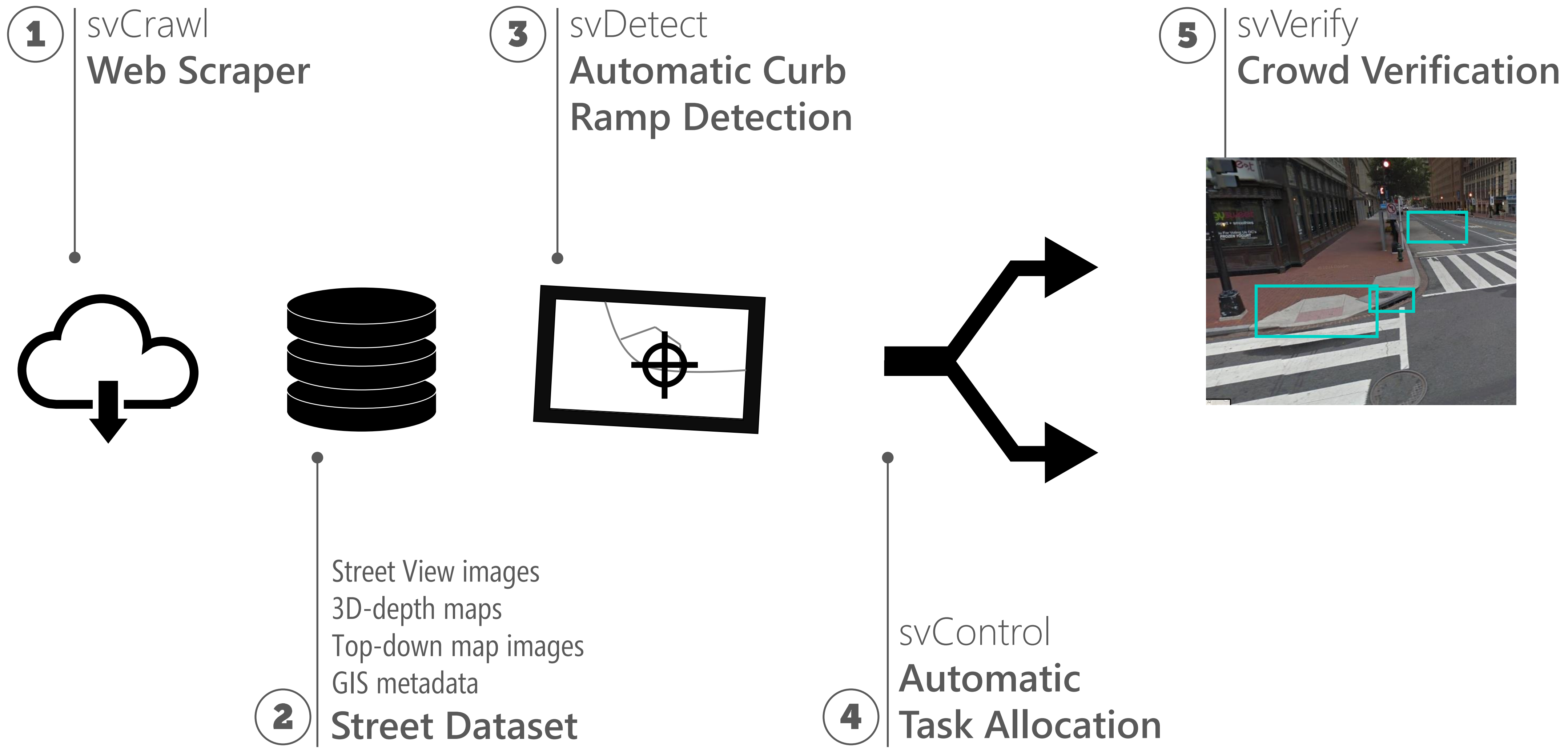
Street View images
3D-depth maps
Top-down map images
GIS metadata

2 **Street Dataset**

4 svControl
Automatic Task Allocation

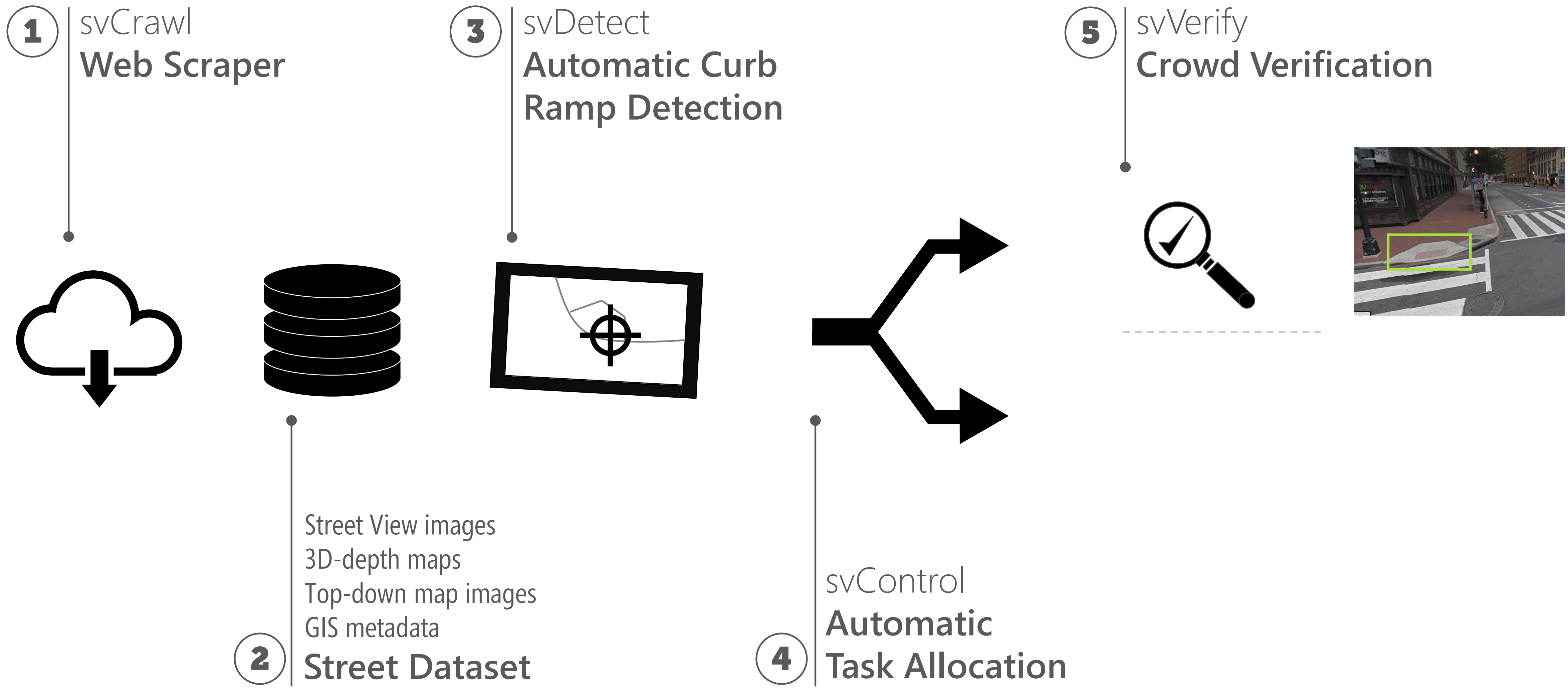
TOHME

遠目 Remote Eye

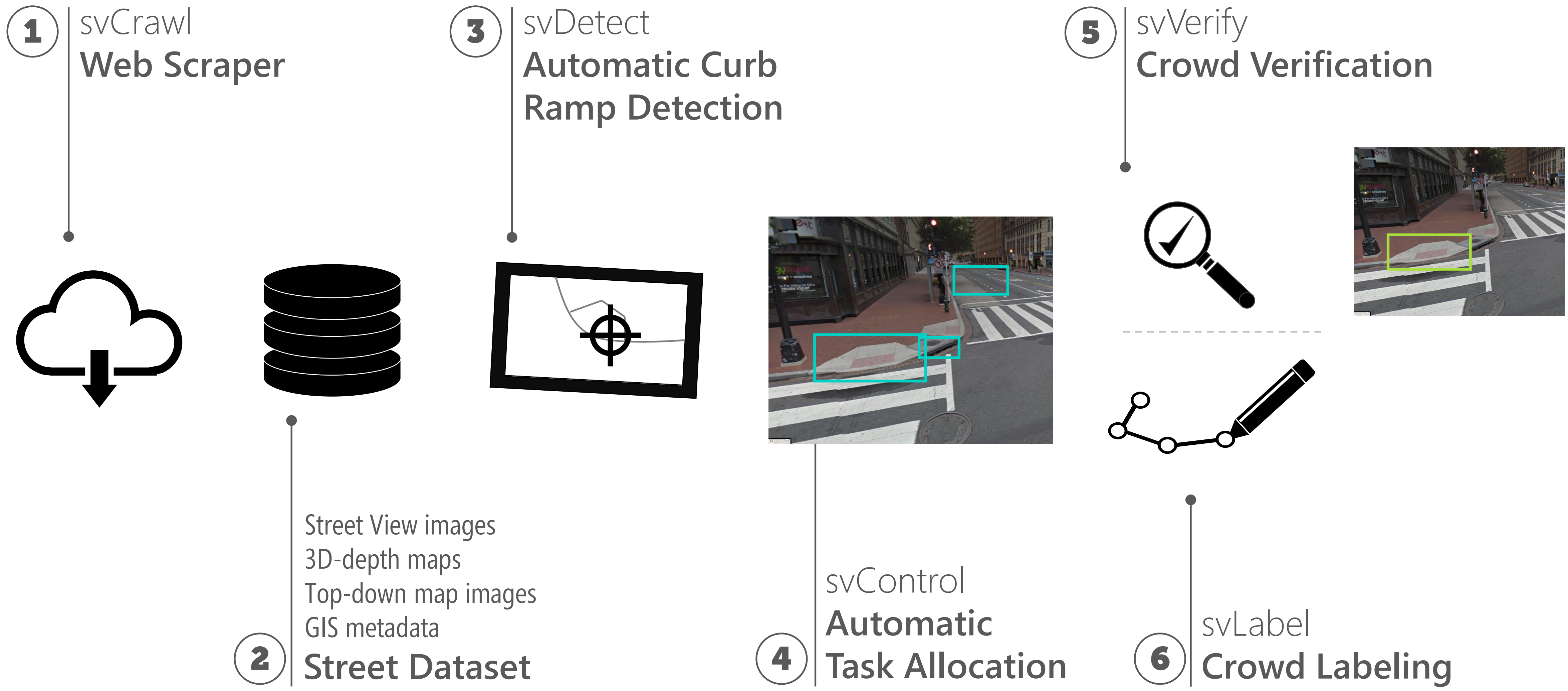


TOHME

遠目 Remote Eye

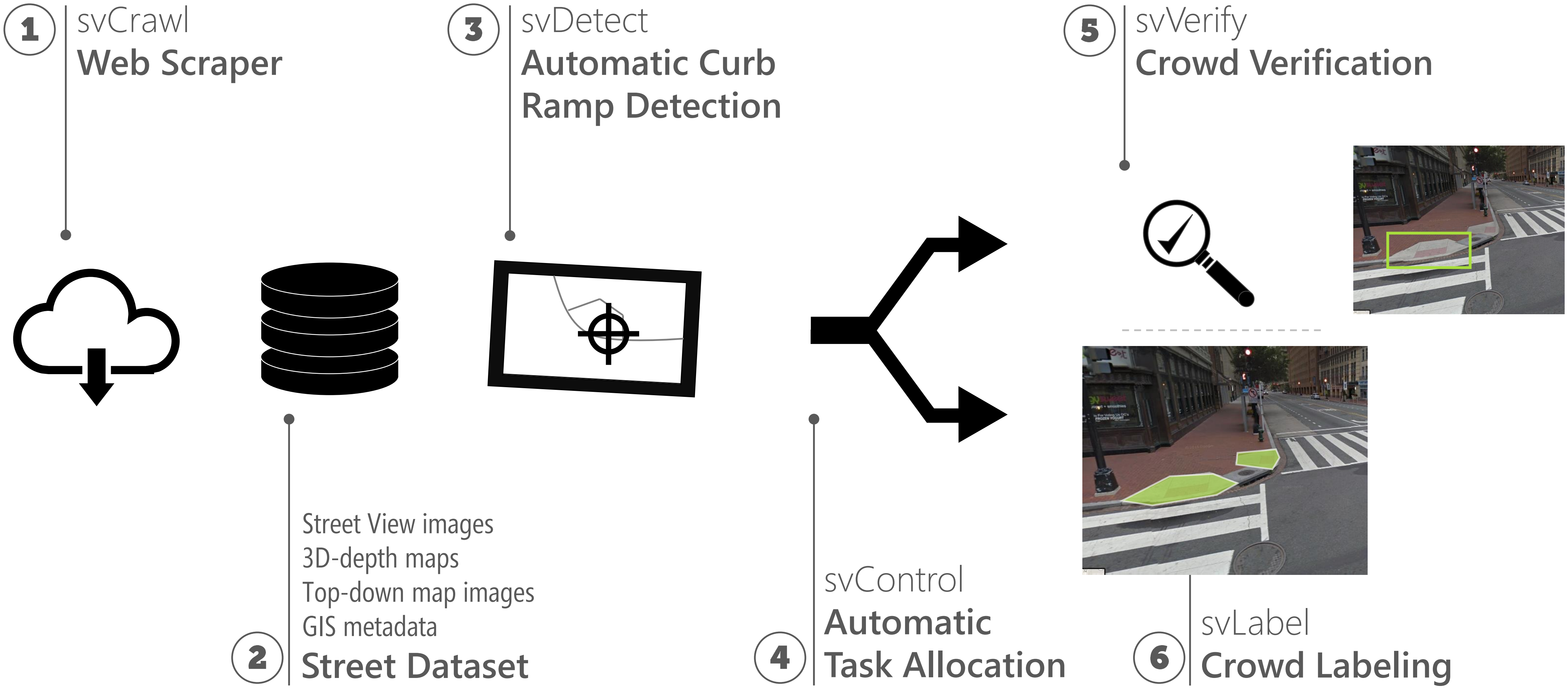


TOHME
遠目 Remote Eye

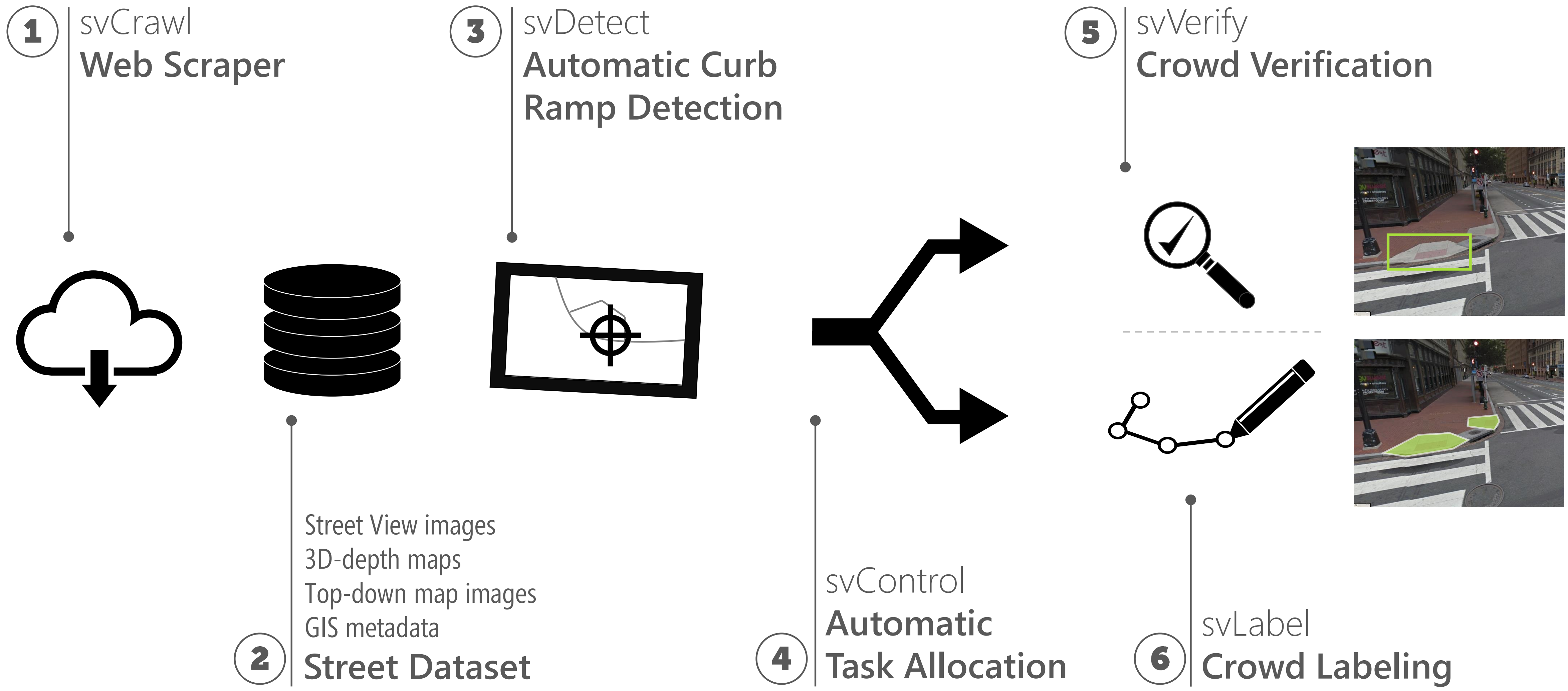


TOHME

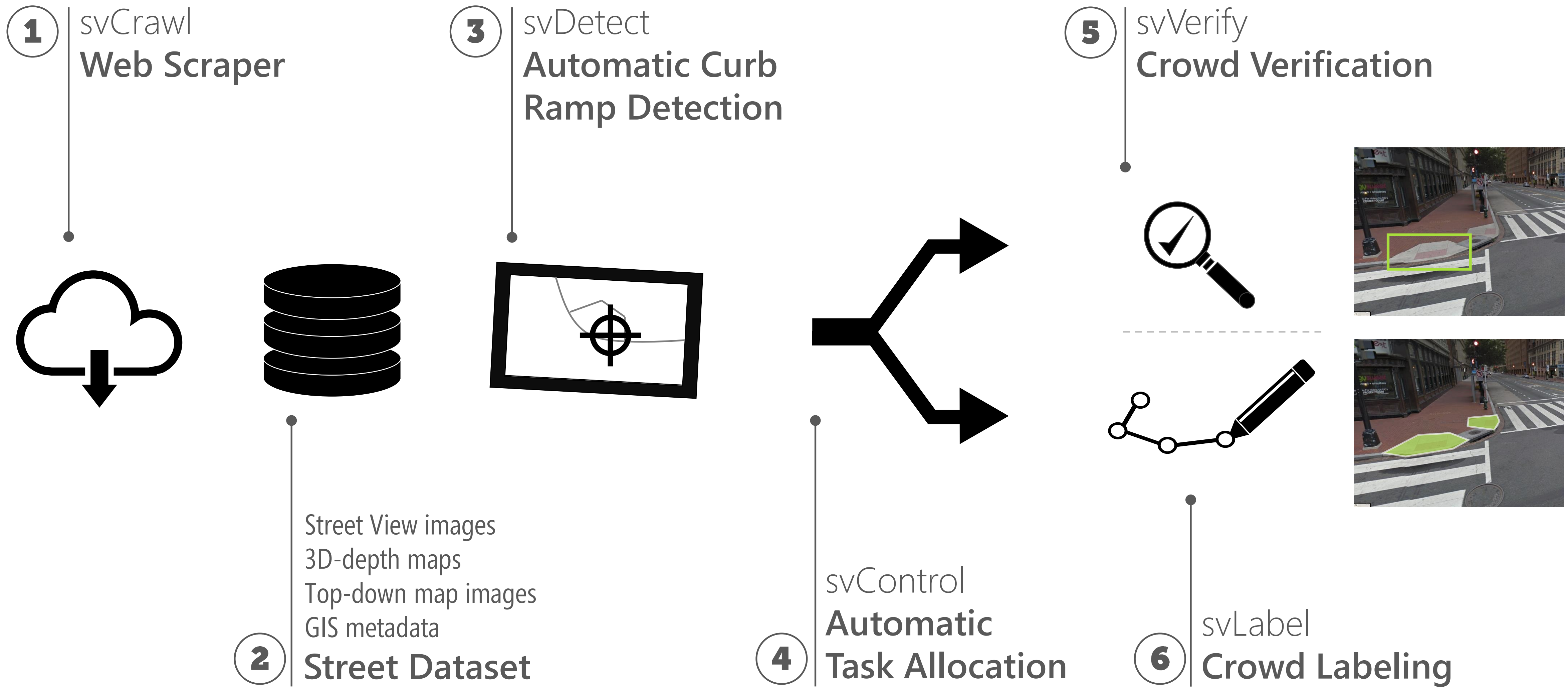
遠目 Remote Eye

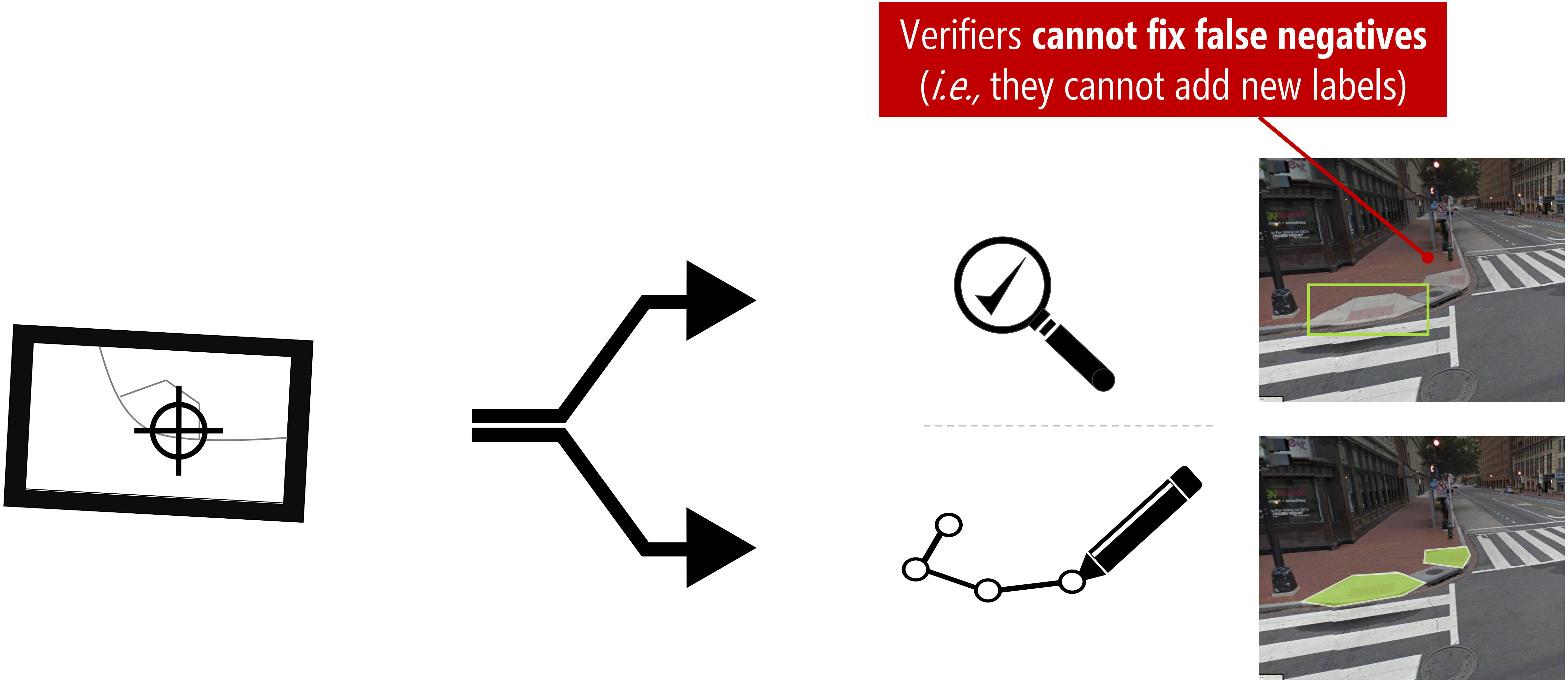


TOHME
遠目 Remote Eye

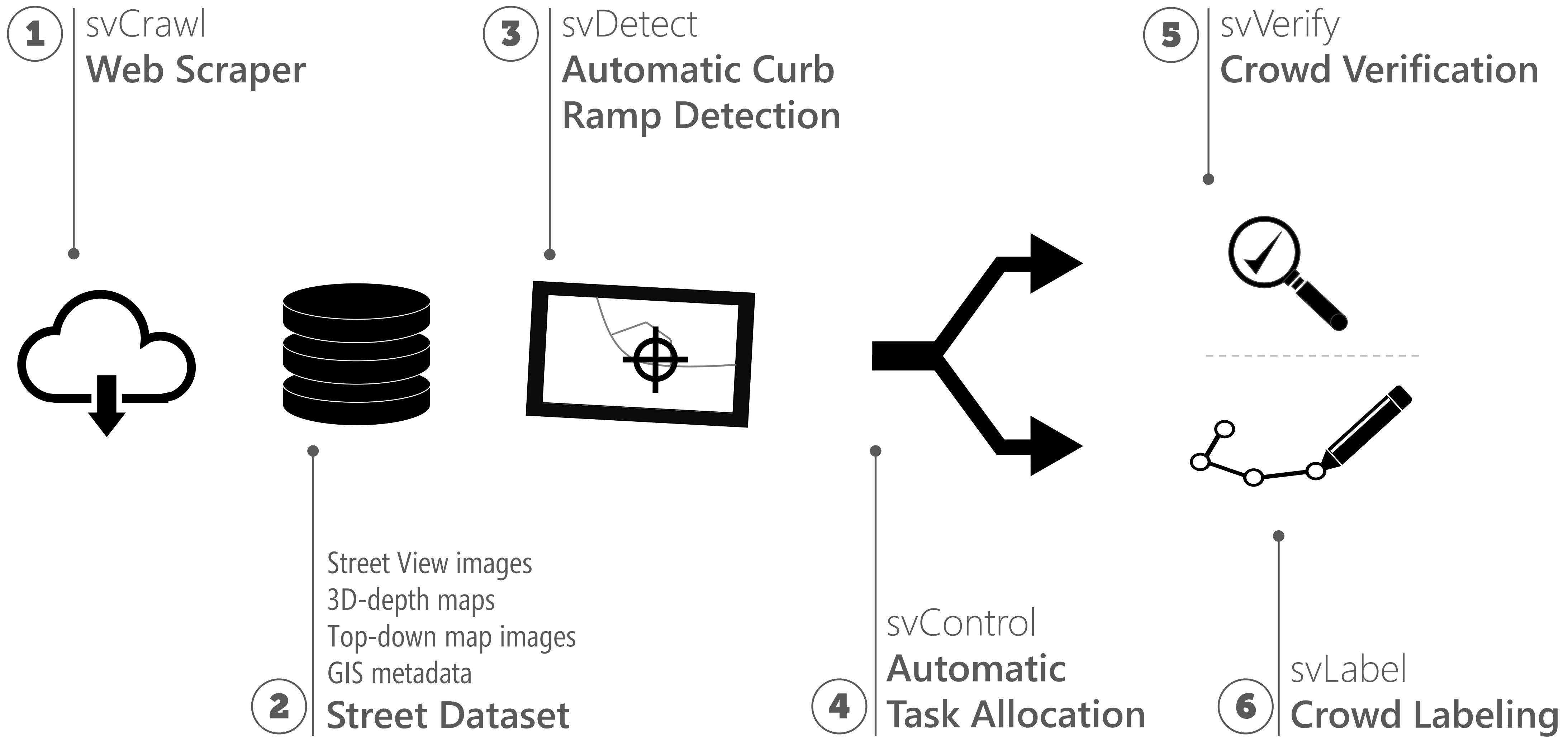


TOHME
遠目 Remote Eye



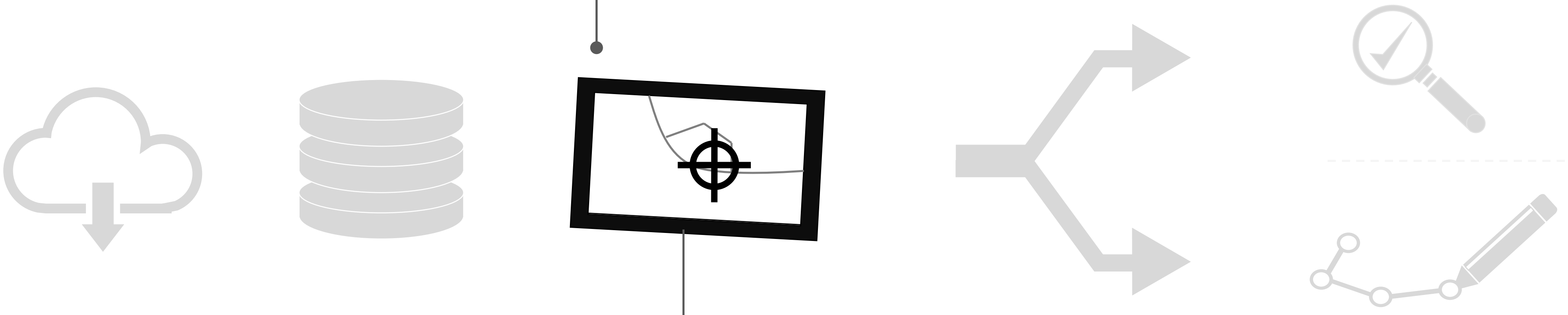

Verifiers **cannot fix false negatives**
(*i.e.,* they cannot add new labels)

TOHME
遠目 Remote Eye



TOHME
遠目 Remote Eye

3 svDetect
Automatic Curb Ramp Detection

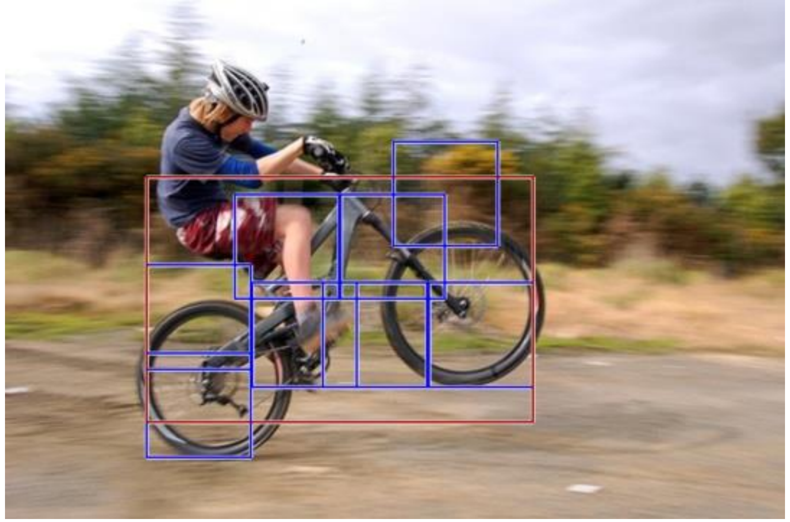


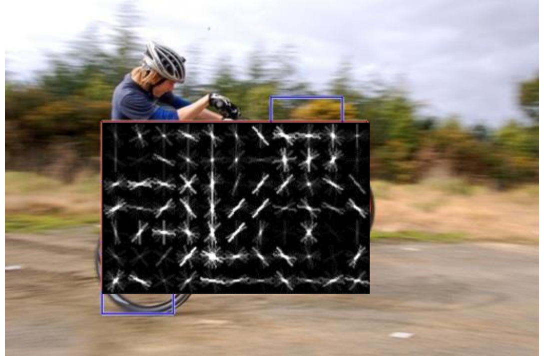
1. Deformable part model (DPM)
2. Post-processing DPM
3. SVM-based classifier

1

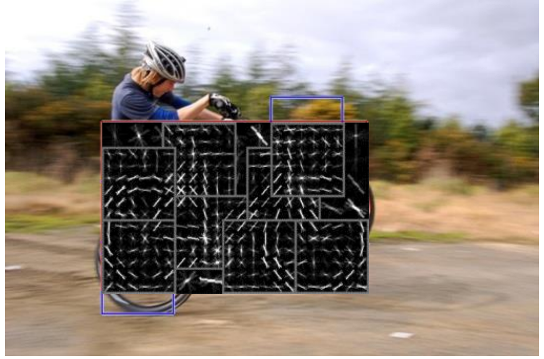
AUTOMATIC CURB RAMP DETECTOR

DEFORMABLE PART MODEL

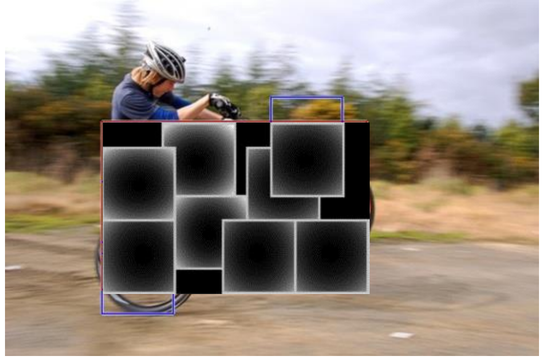




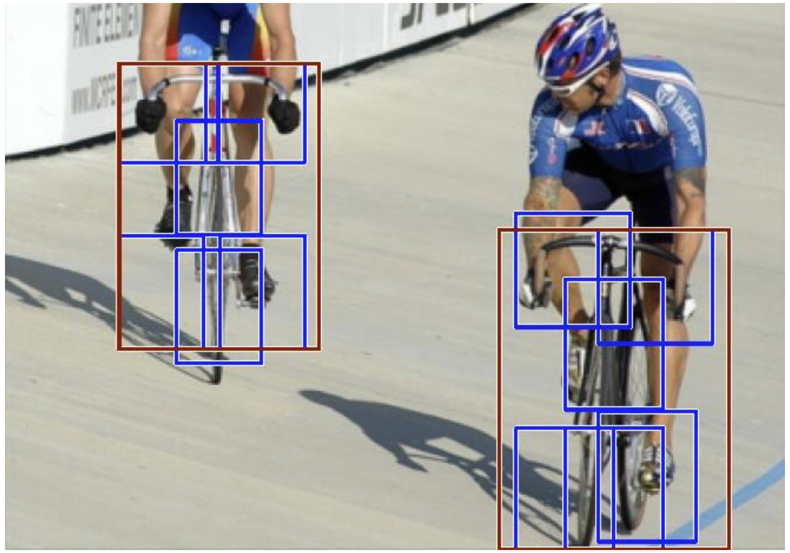
Root filter

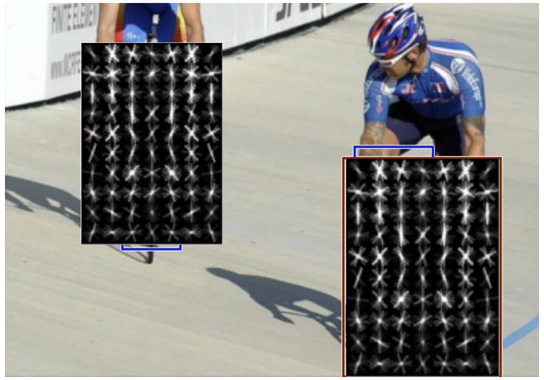


Parts filter

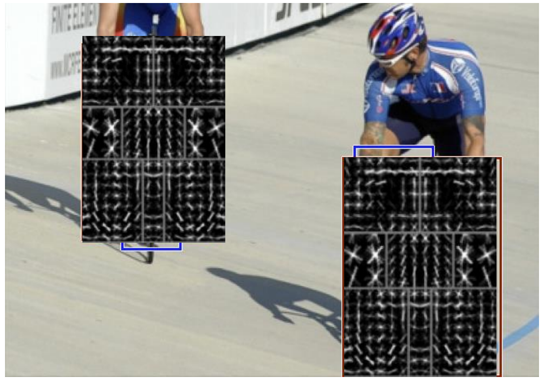


Displacement cost

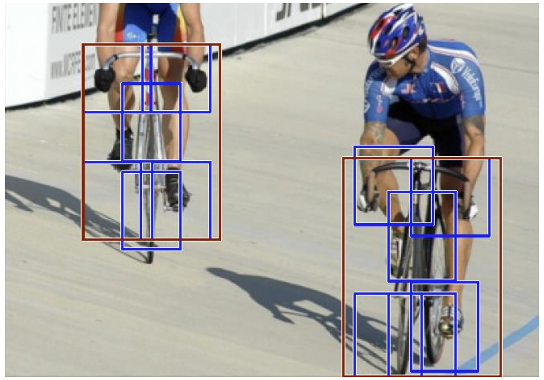




Root filter



Parts filter



Displacement cost

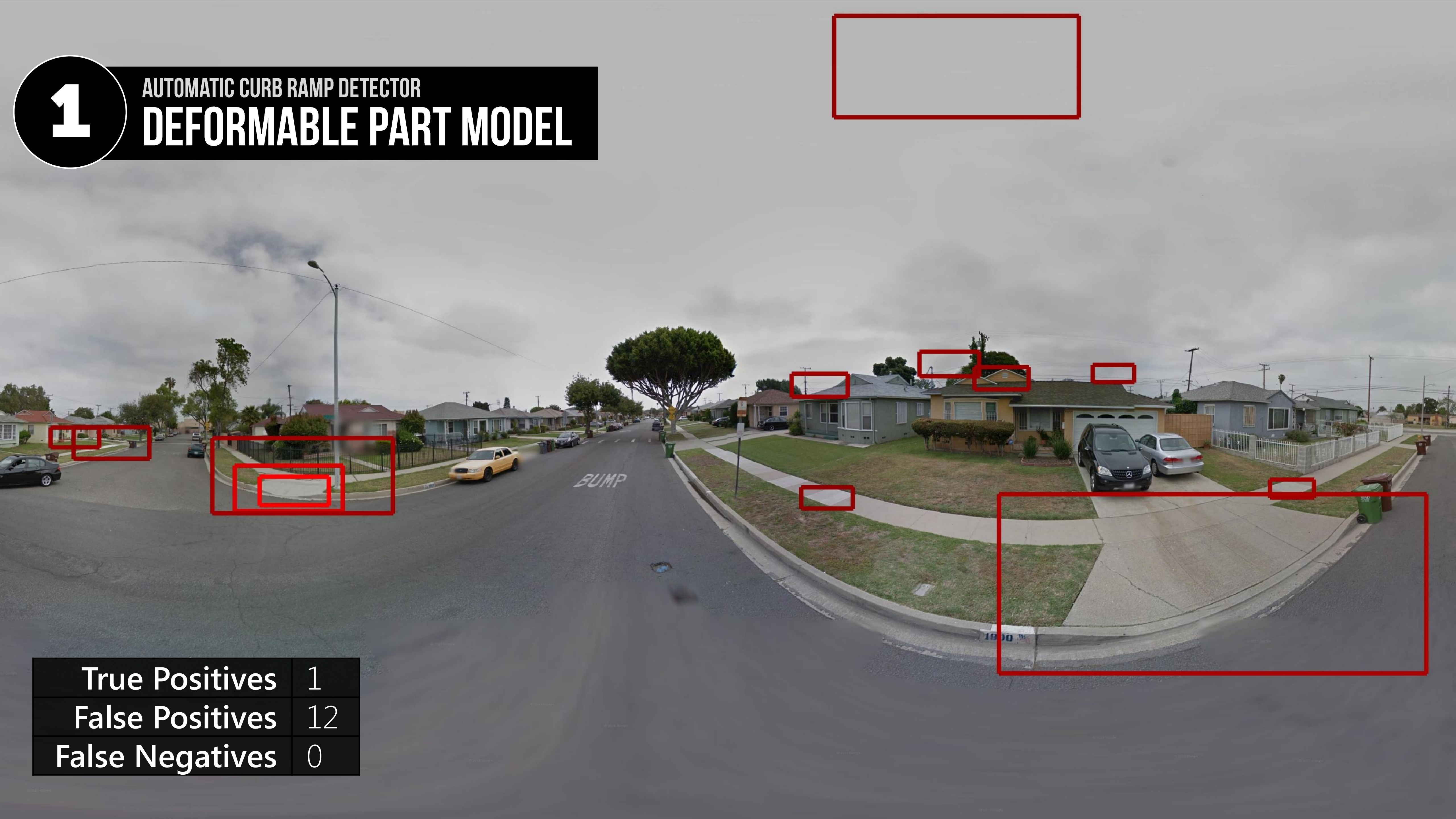
Felzenszwalb *et al.*, CVPR'08, CVPR'10

1

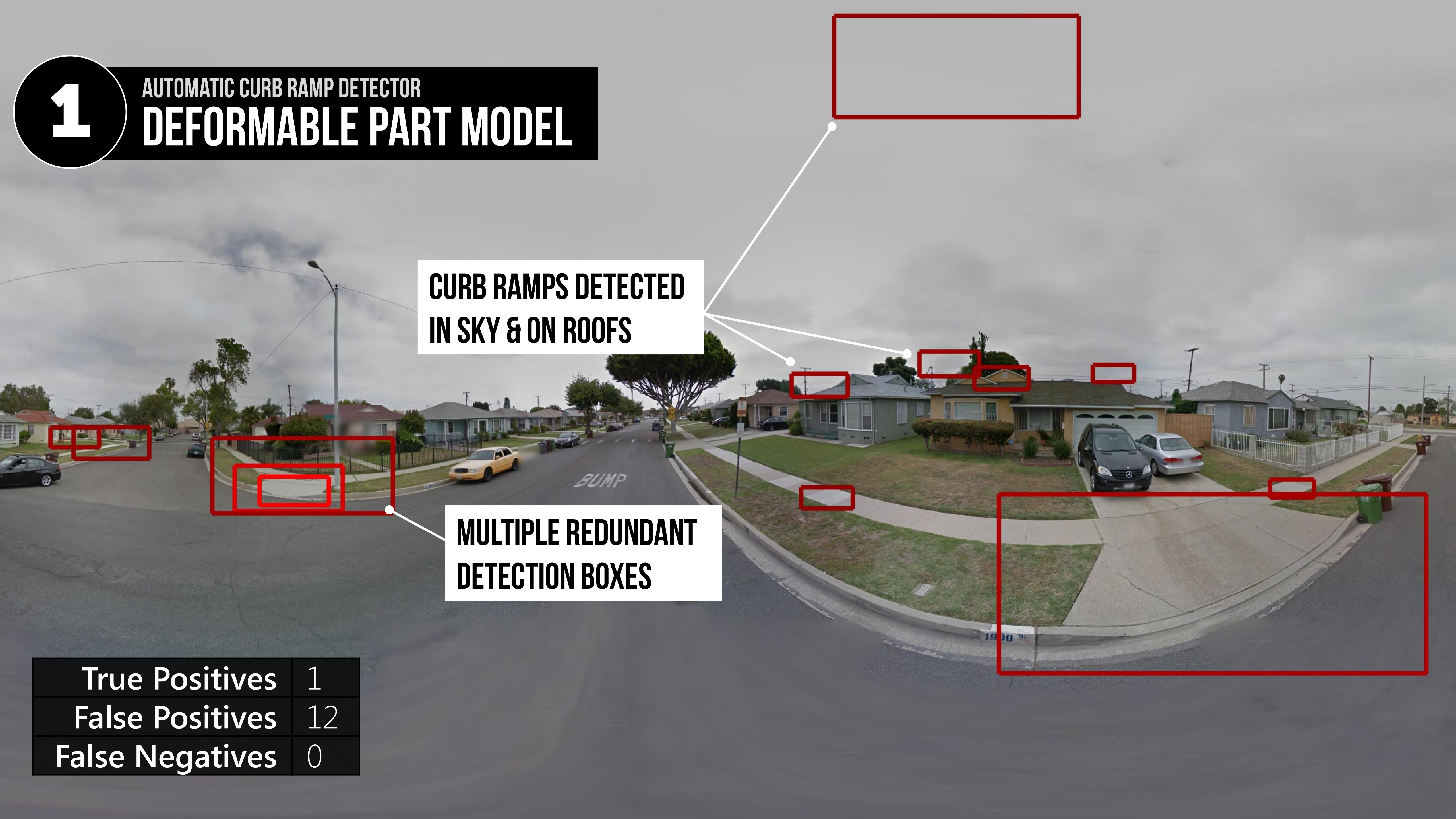
AUTOMATIC CURB RAMP DETECTOR

DEFORMABLE PART MODEL

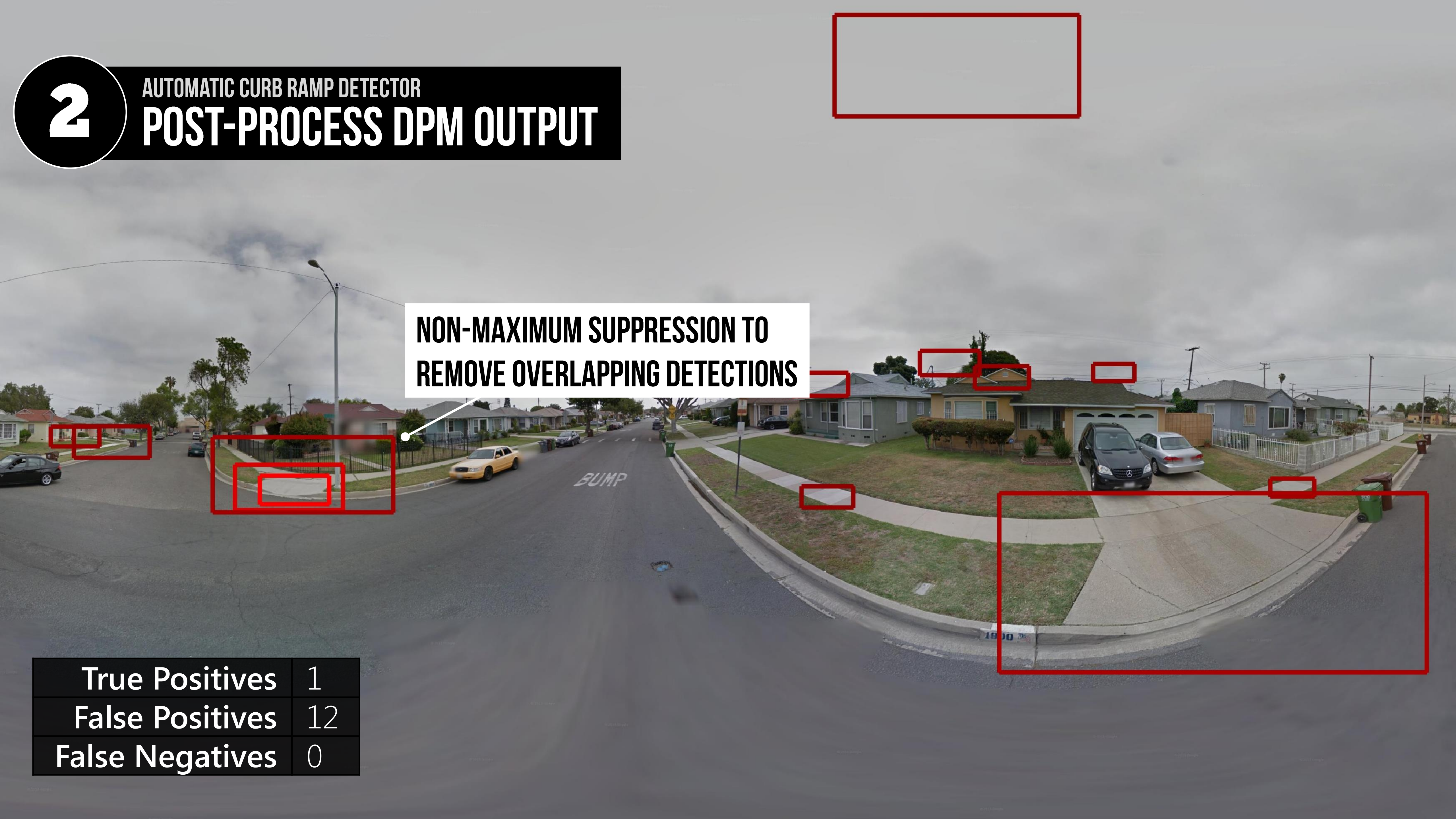
1 AUTOMATIC CURB RAMP DETECTOR
DEFORMABLE PART MODEL



True Positives	1
False Positives	12
False Negatives	0


1
AUTOMATIC CURB RAMP DETECTOR
DEFORMABLE PART MODEL
CURB RAMPS DETECTED
IN SKY & ON ROOFS
MULTIPLE REDUNDANT
DETECTION BOXES
BUMP
True Positives 1
False Positives 12
False Negatives 0

2 AUTOMATIC CURB RAMP DETECTOR
POST-PROCESS DPM OUTPUT

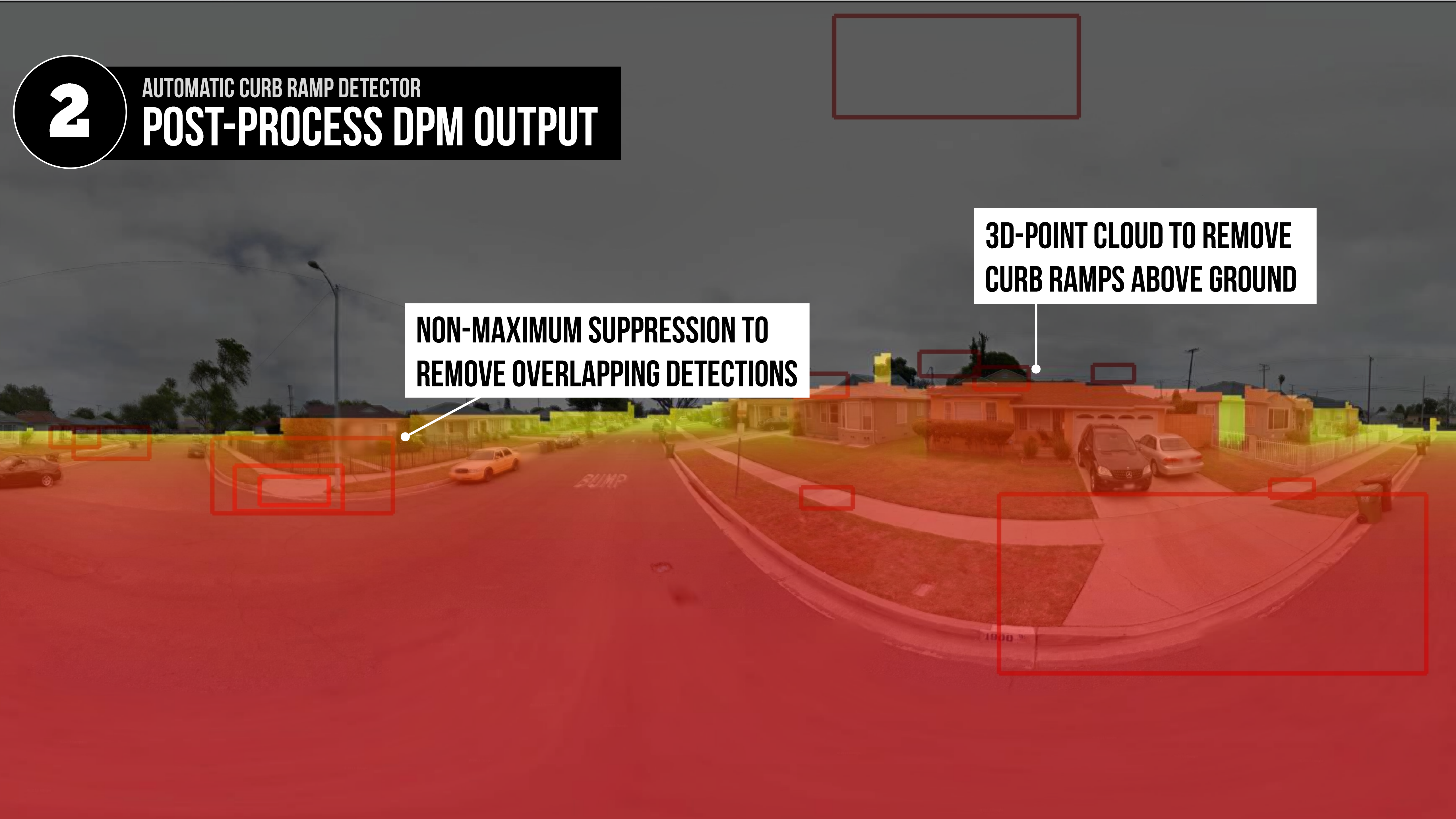


True Positives	1
False Positives	12
False Negatives	0

2

AUTOMATIC CURB RAMP DETECTOR

POST-PROCESS DPM OUTPUT



2 AUTOMATIC CURB RAMP DETECTOR
POST-PROCESS DPM OUTPUT

True Positives	1
False Positives	5
False Negatives	0

3 AUTOMATIC CURB RAMP DETECTOR
SVM-BASED REFINEMENT

True Positives	1
False Positives	5
False Negatives	0

3

AUTOMATIC CURB RAMP DETECTOR

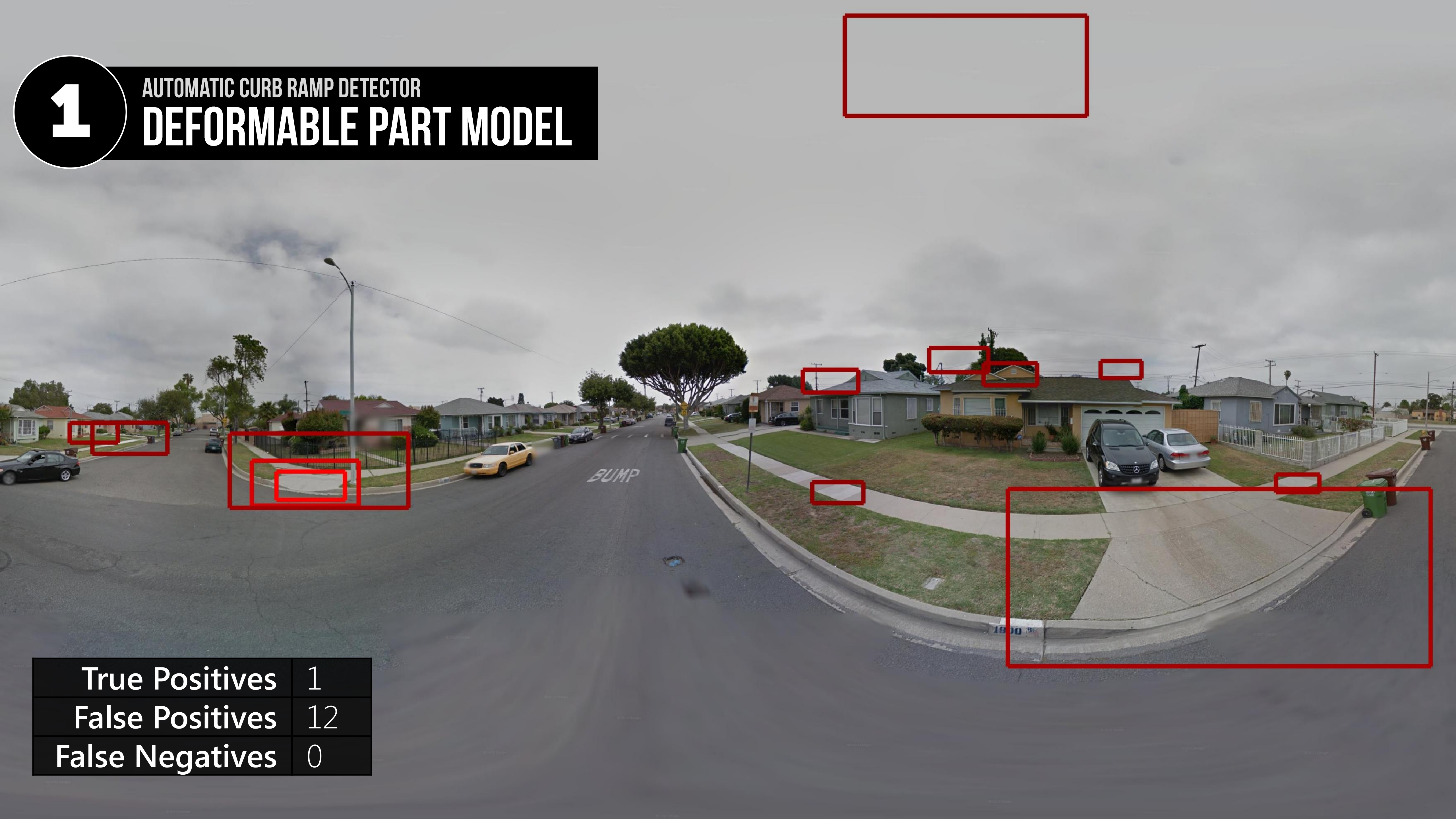
FINAL OUTPUT

True Positives	1
False Positives	3
False Negatives	0

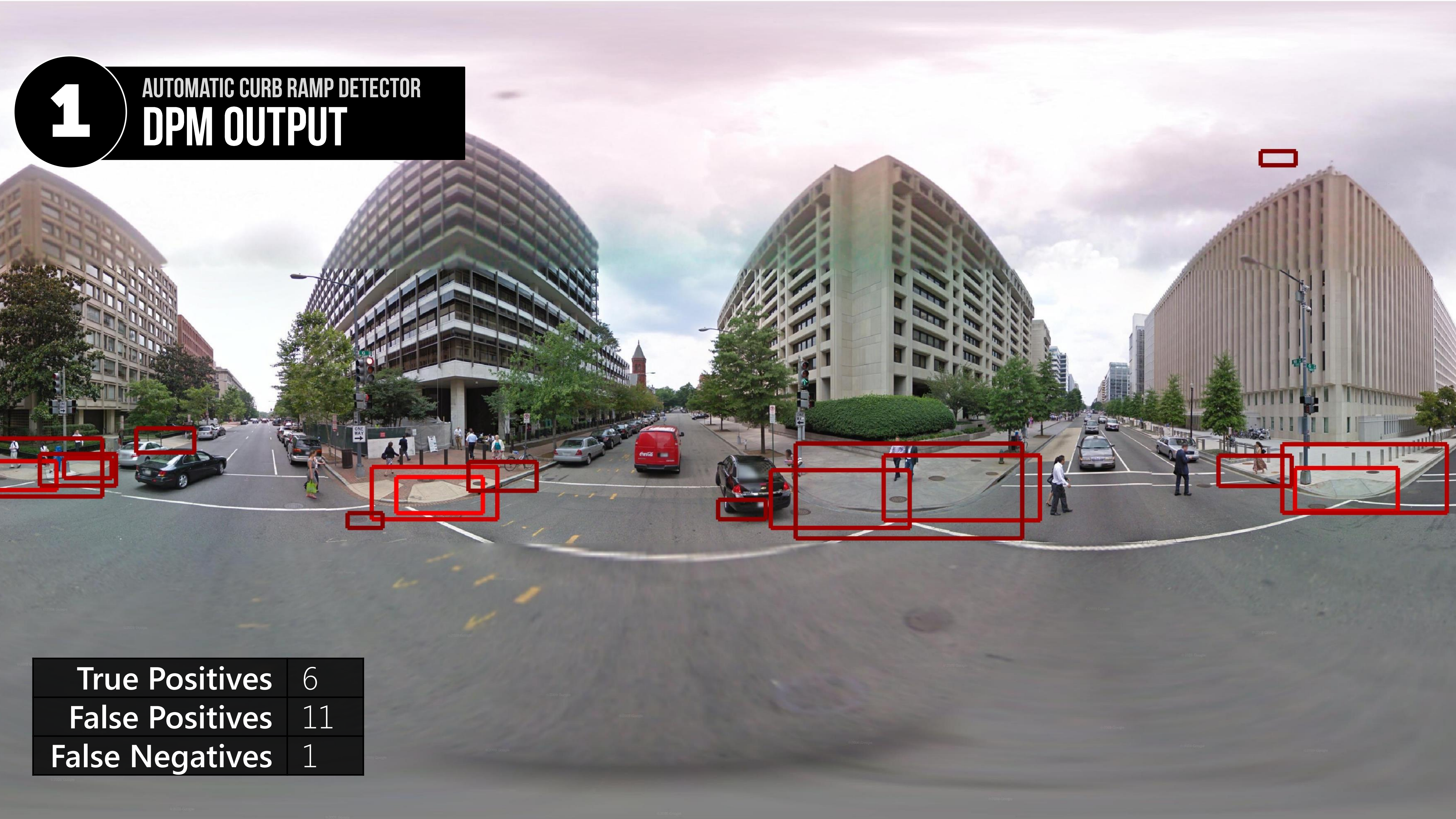
1

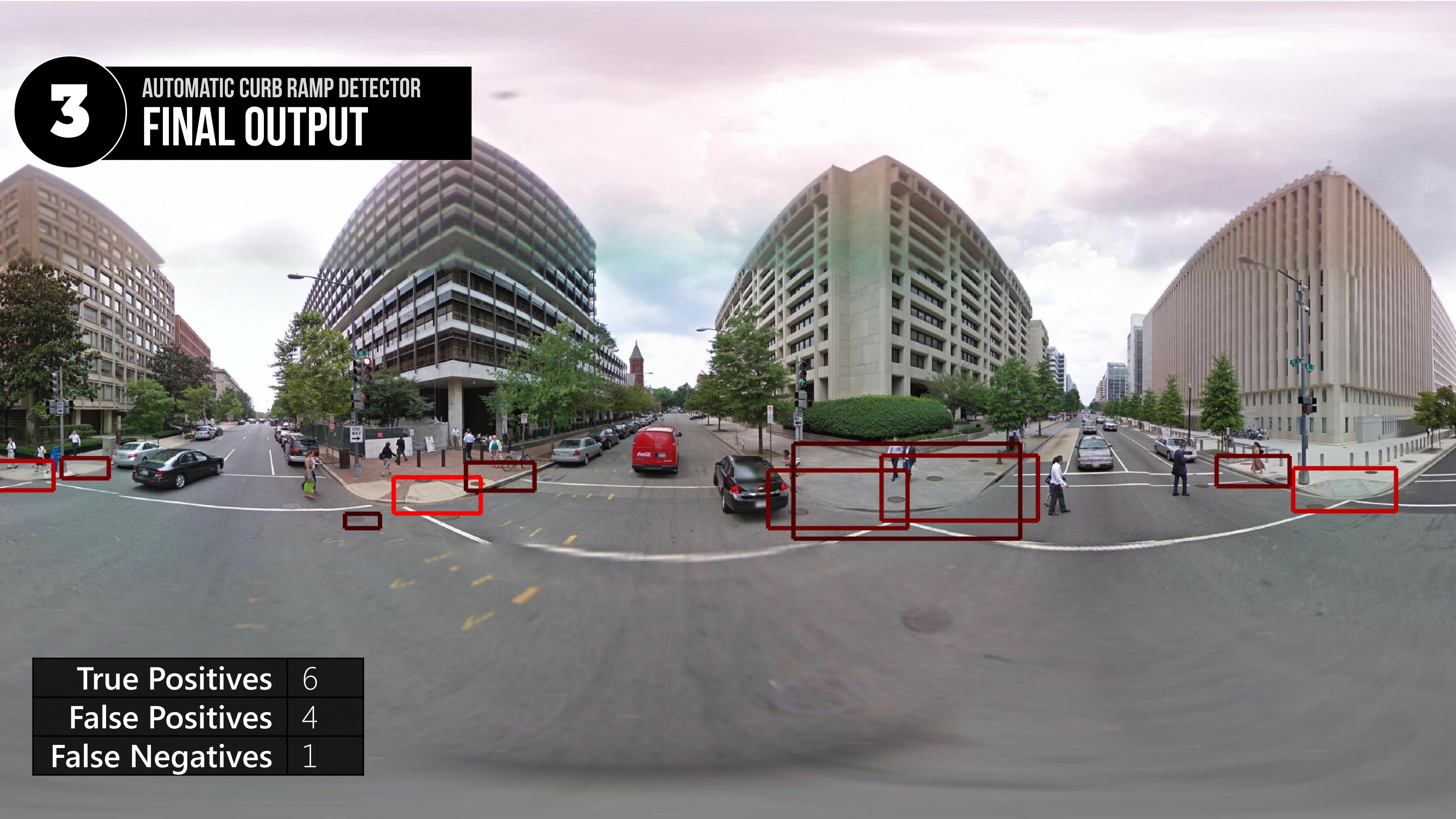
AUTOMATIC CURB RAMP DETECTOR

DEFORMABLE PART MODEL



True Positives	1
False Positives	12
False Negatives	0

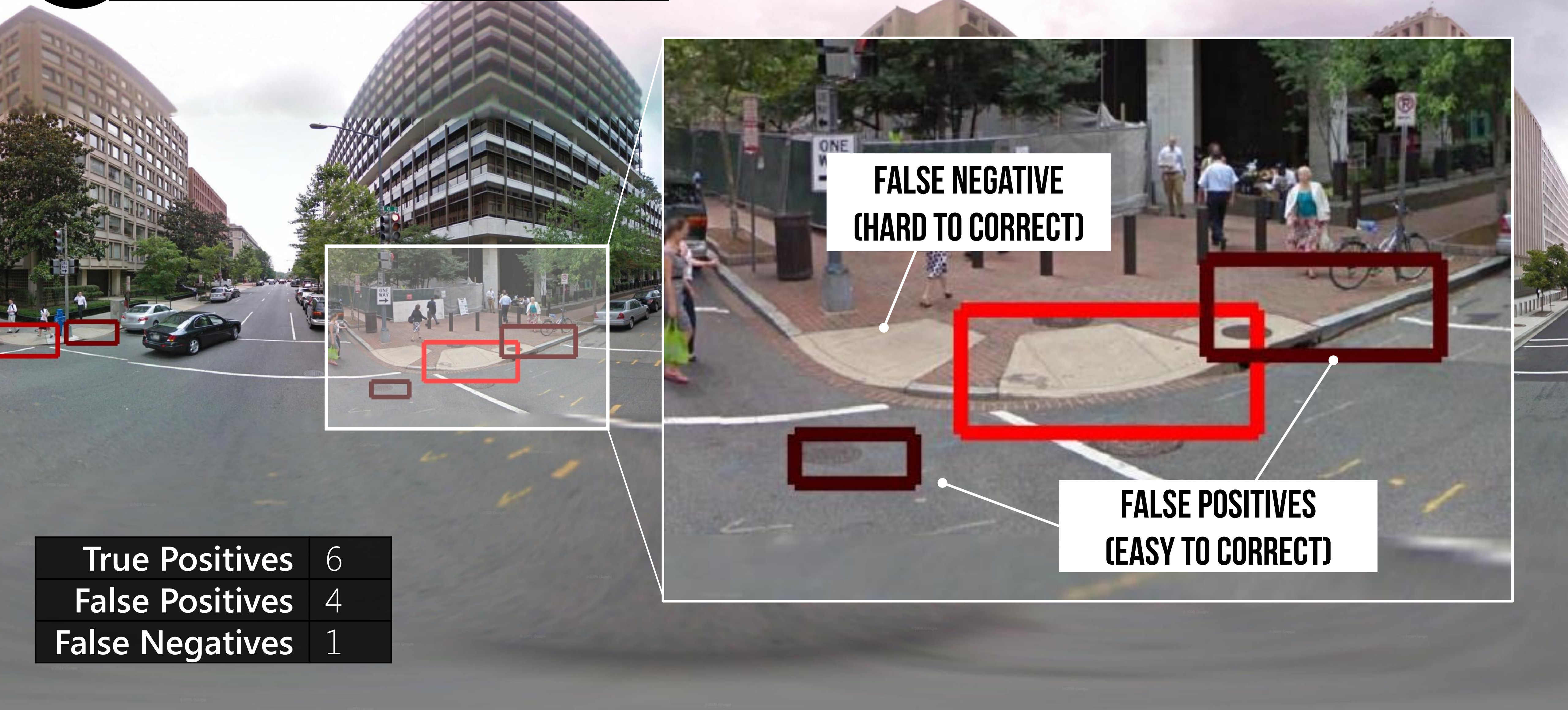

1
AUTOMATIC CURB RAMP DETECTOR
DPM OUTPUT
True Positives 6
False Positives 11
False Negatives 1



3 AUTOMATIC CURB RAMP DETECTOR
FINAL OUTPUT

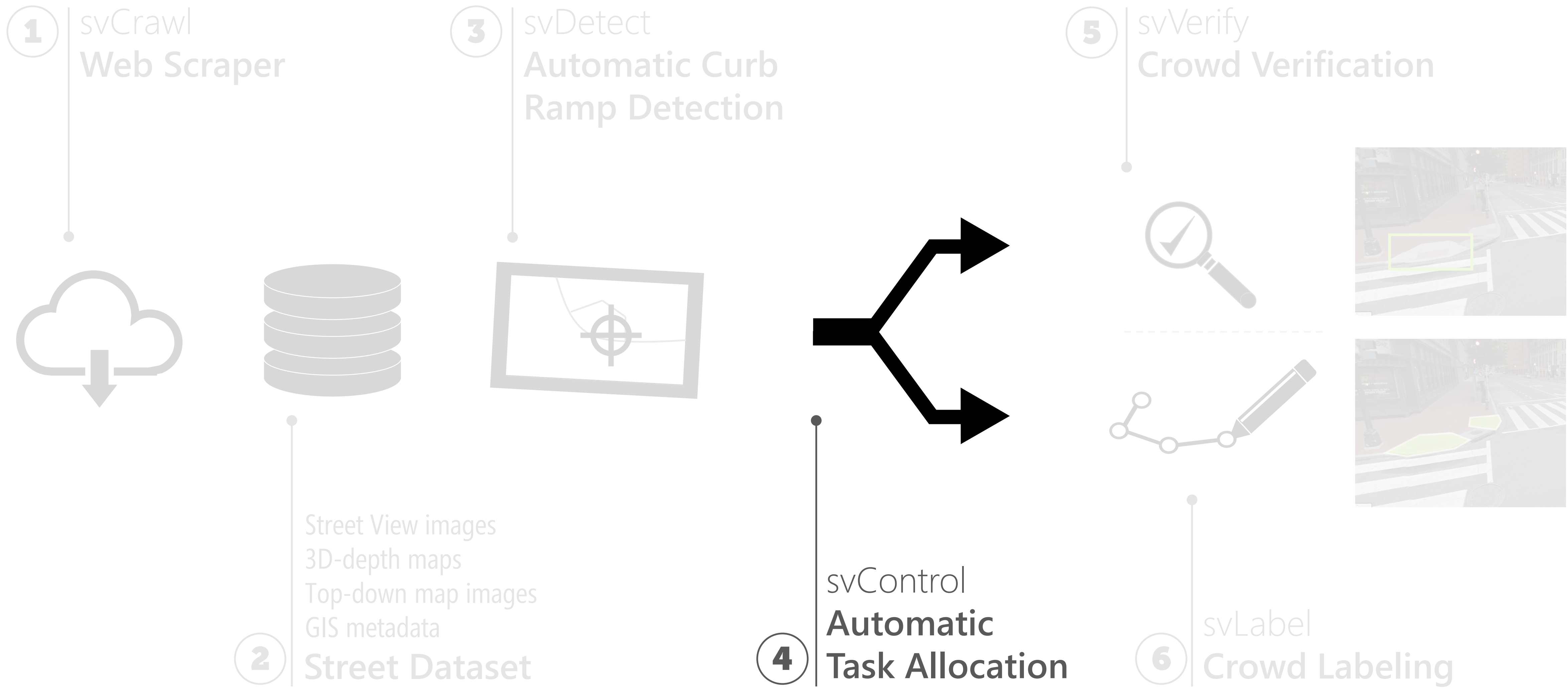
True Positives	6
False Positives	4
False Negatives	1

3 AUTOMATIC CURB RAMP DETECTOR
FINAL OUTPUT



True Positives	6
False Positives	4
False Negatives	1

TOHME
遠目 Remote Eye



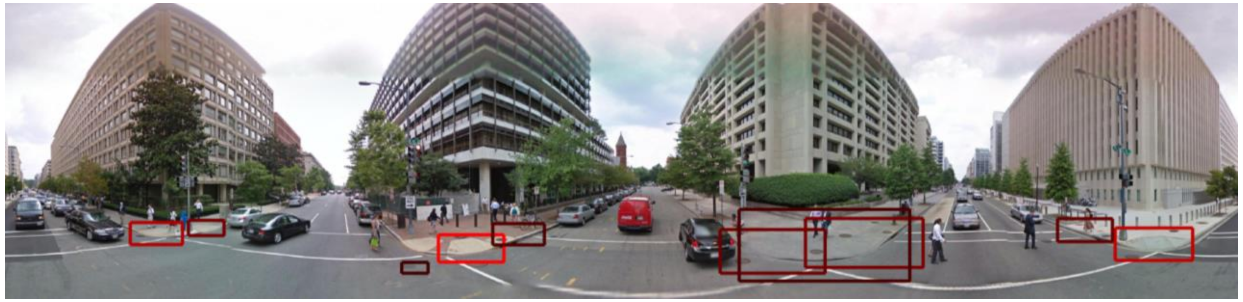
SMART TASK ALLOCATOR

SVM TRAINED WITH 23 INPUT FEATURES

Binary classifier trained to predict occurrence of false negatives from svDetect stage

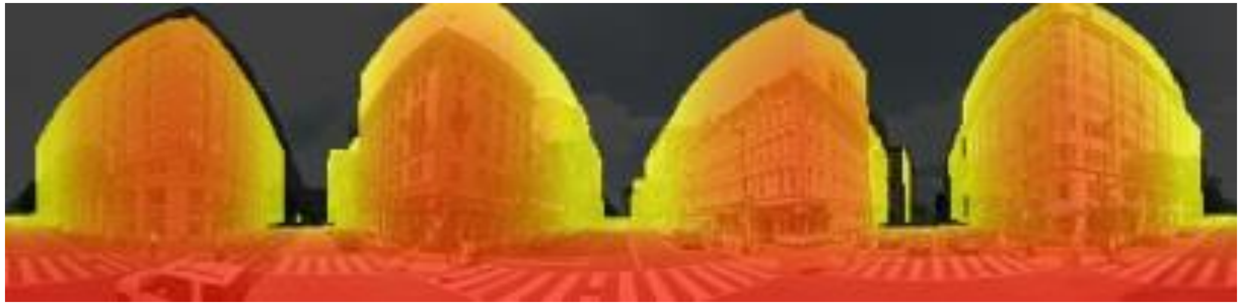
svControl
Automatic Task Allocation
4

Curb Ramp Detector Output (16 Features)



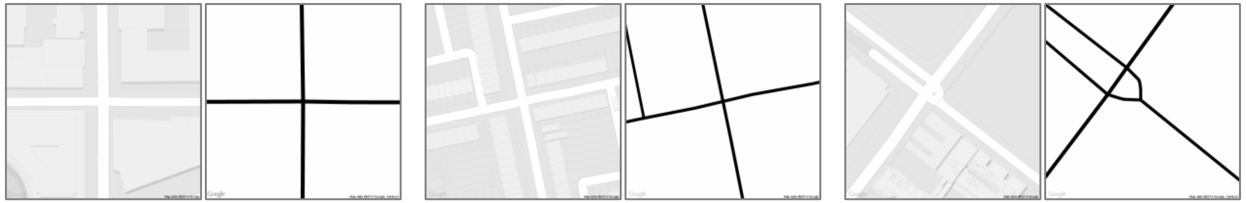
Raw # of bounding boxes
Descriptive stats of confidence scores
Descriptive stats of XY-coordinates

3D-Point Cloud Data (5 Features)



Descriptive stats of depth information (*e.g.,* average, median, variance) of pixel depth

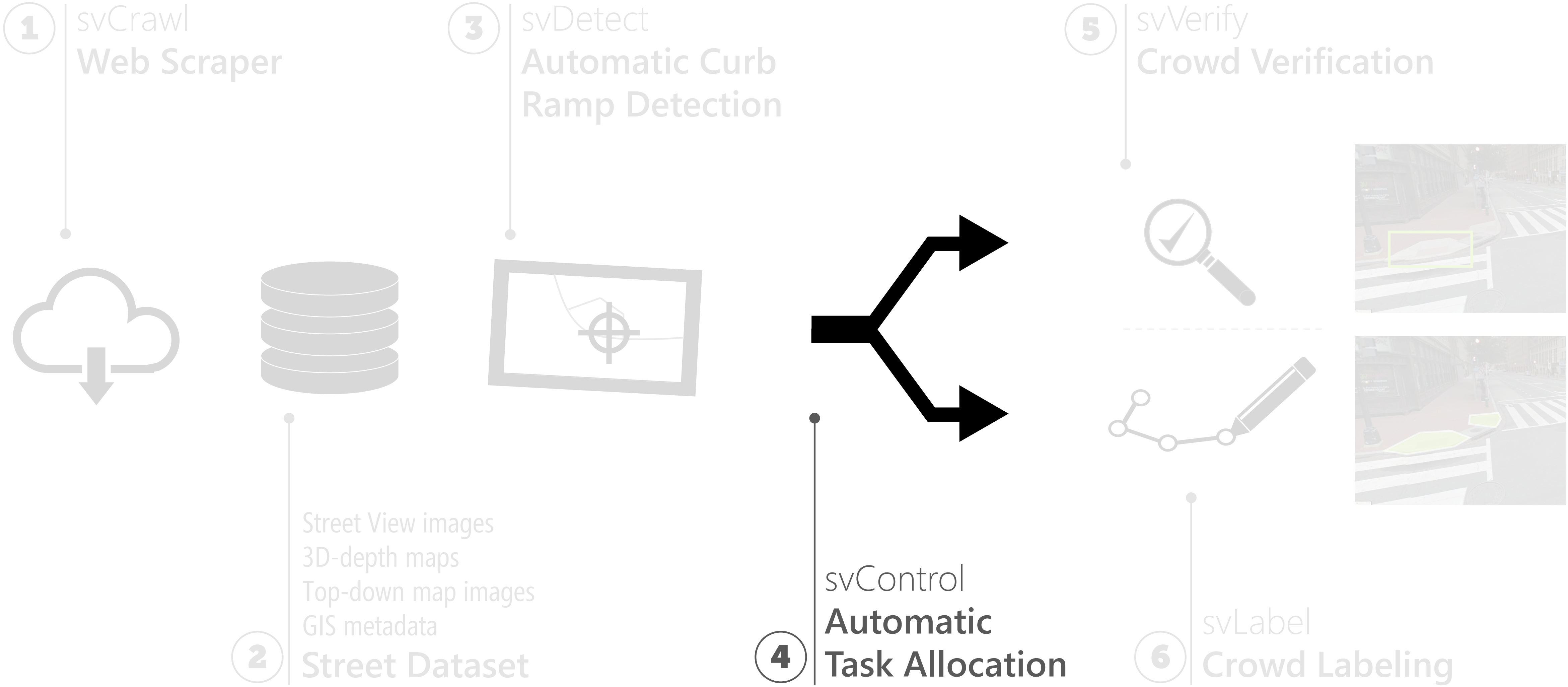
Intersection Complexity (2 Features)



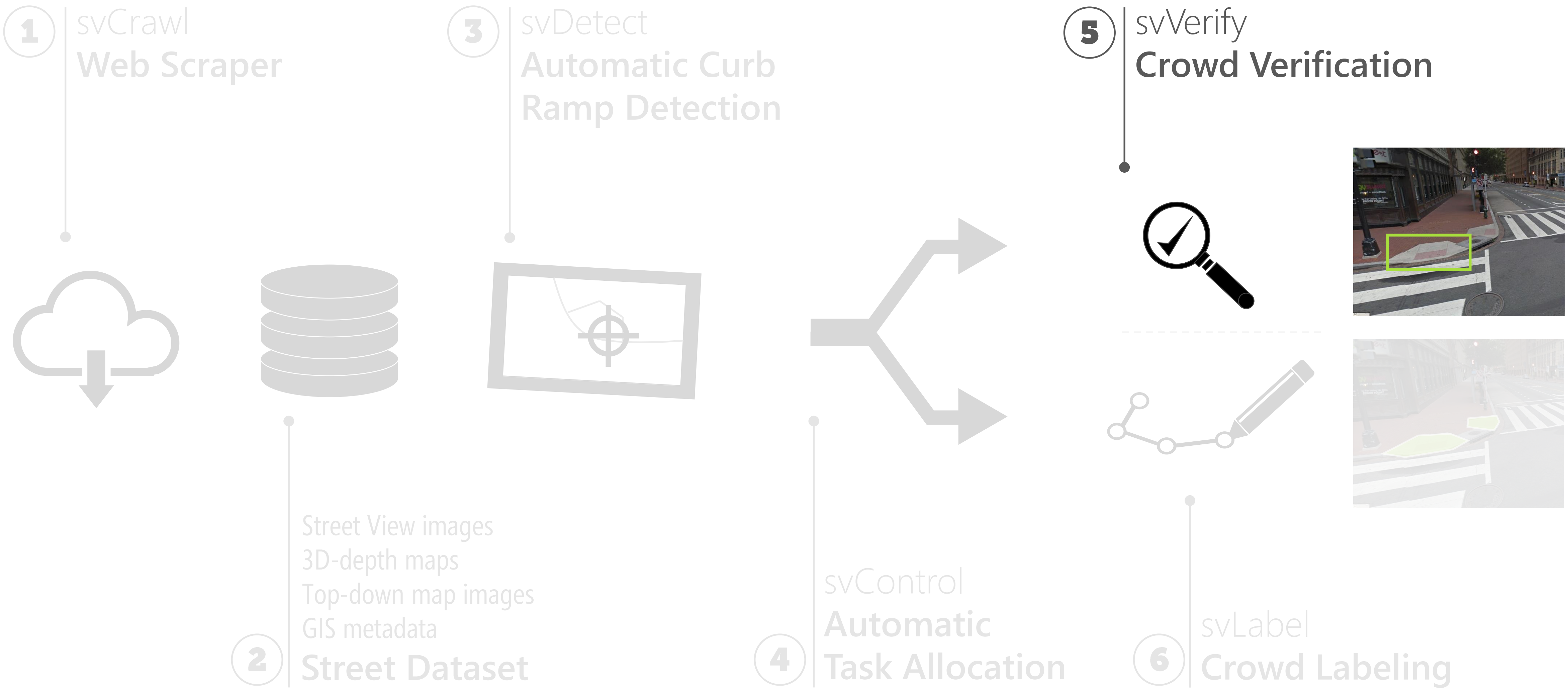
Cardinality (# of connected streets)
Amount of road

TOHME

遠目 Remote Eye

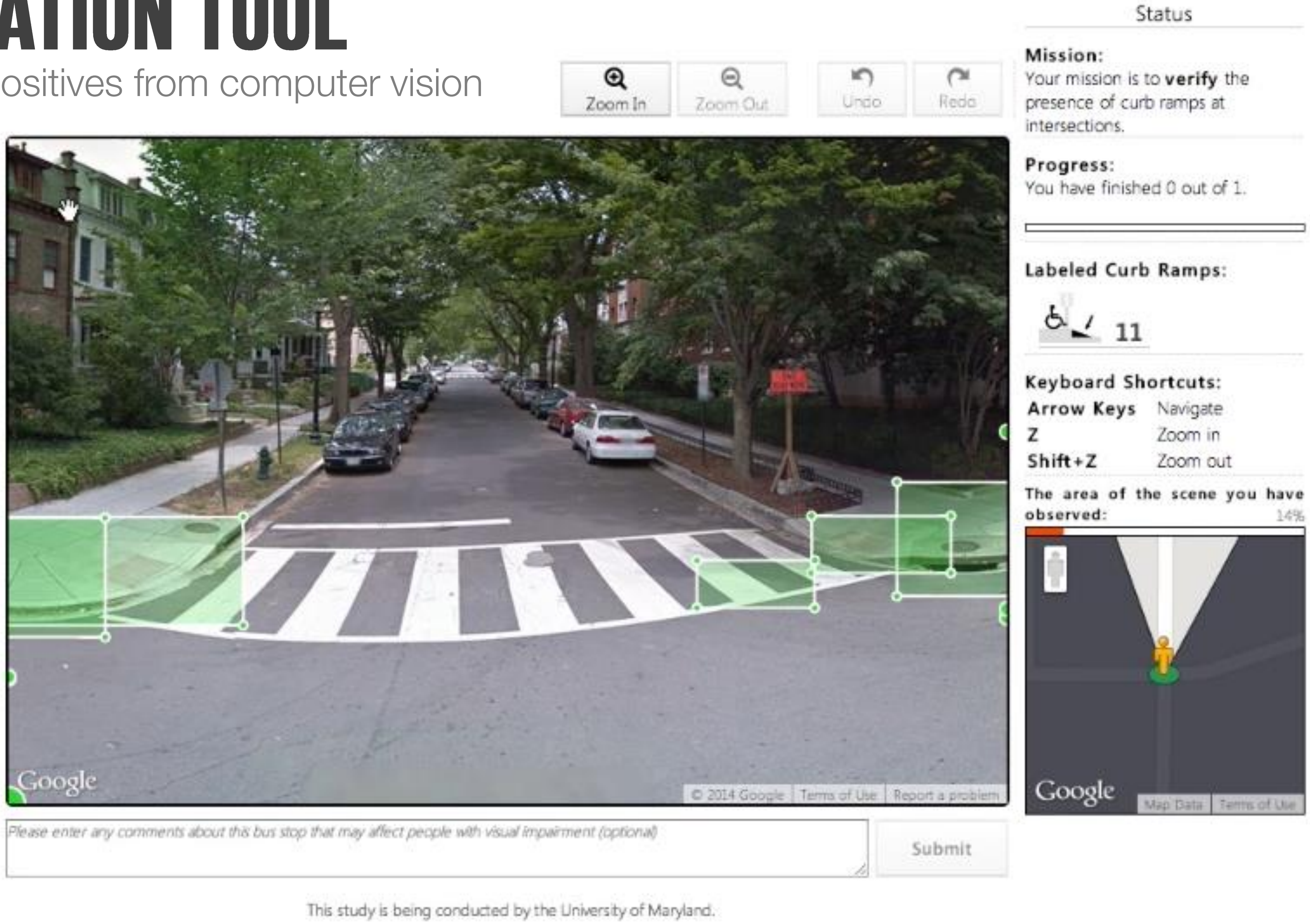


TOHME
遠目 Remote Eye



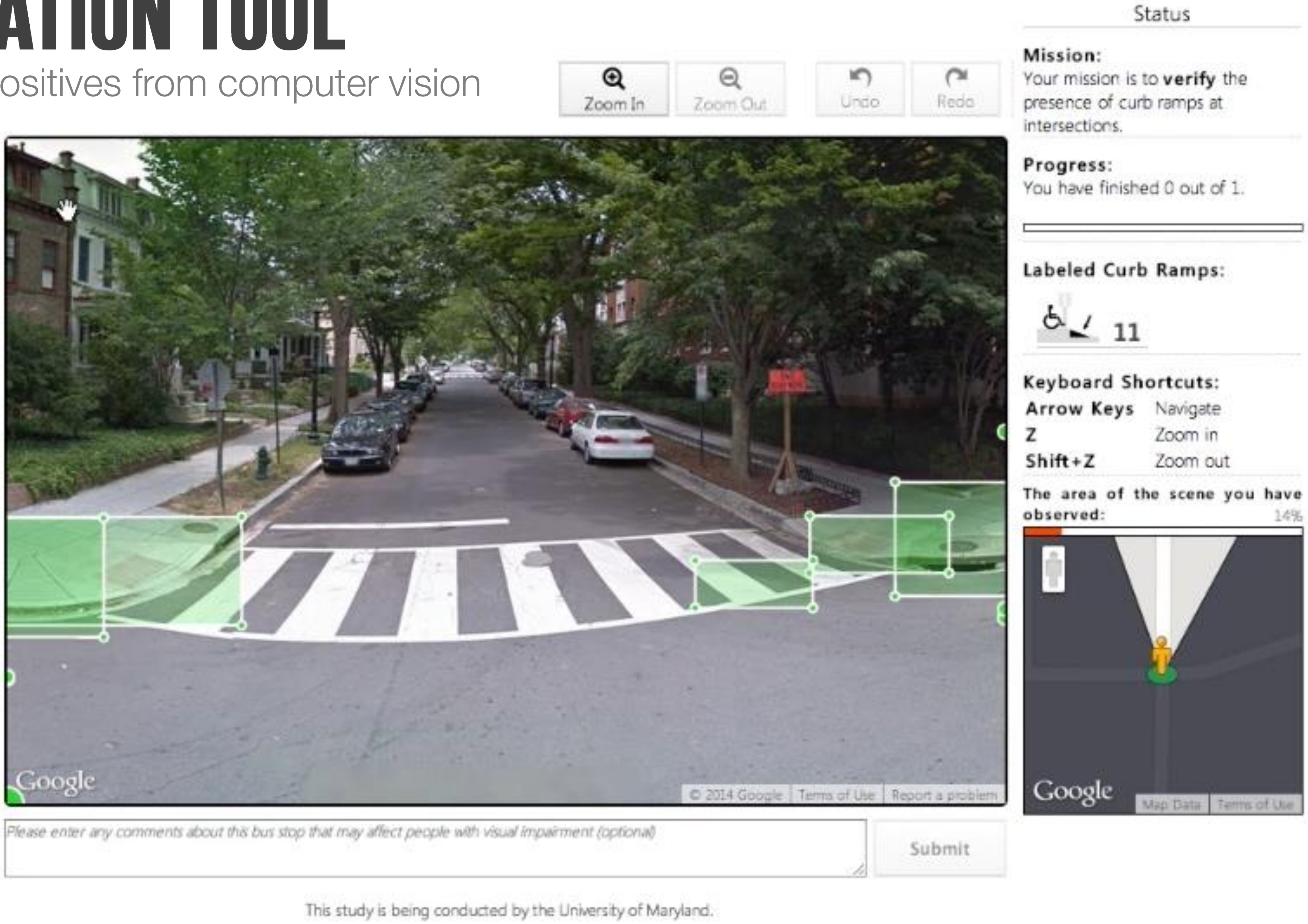
VERIFICATION TOOL

Correct false positives from computer vision

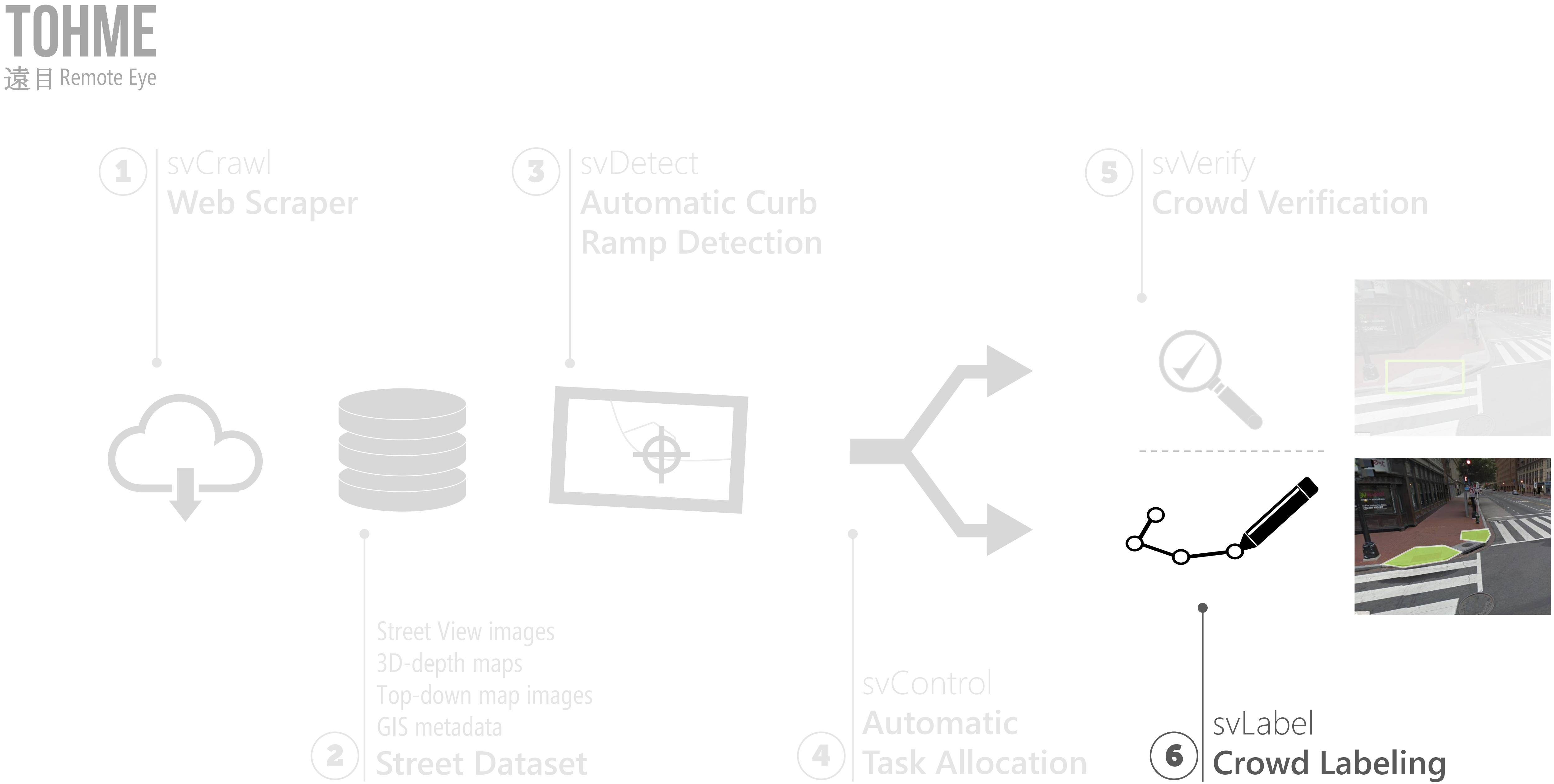


VERIFICATION TOOL

Correct false positives from computer vision

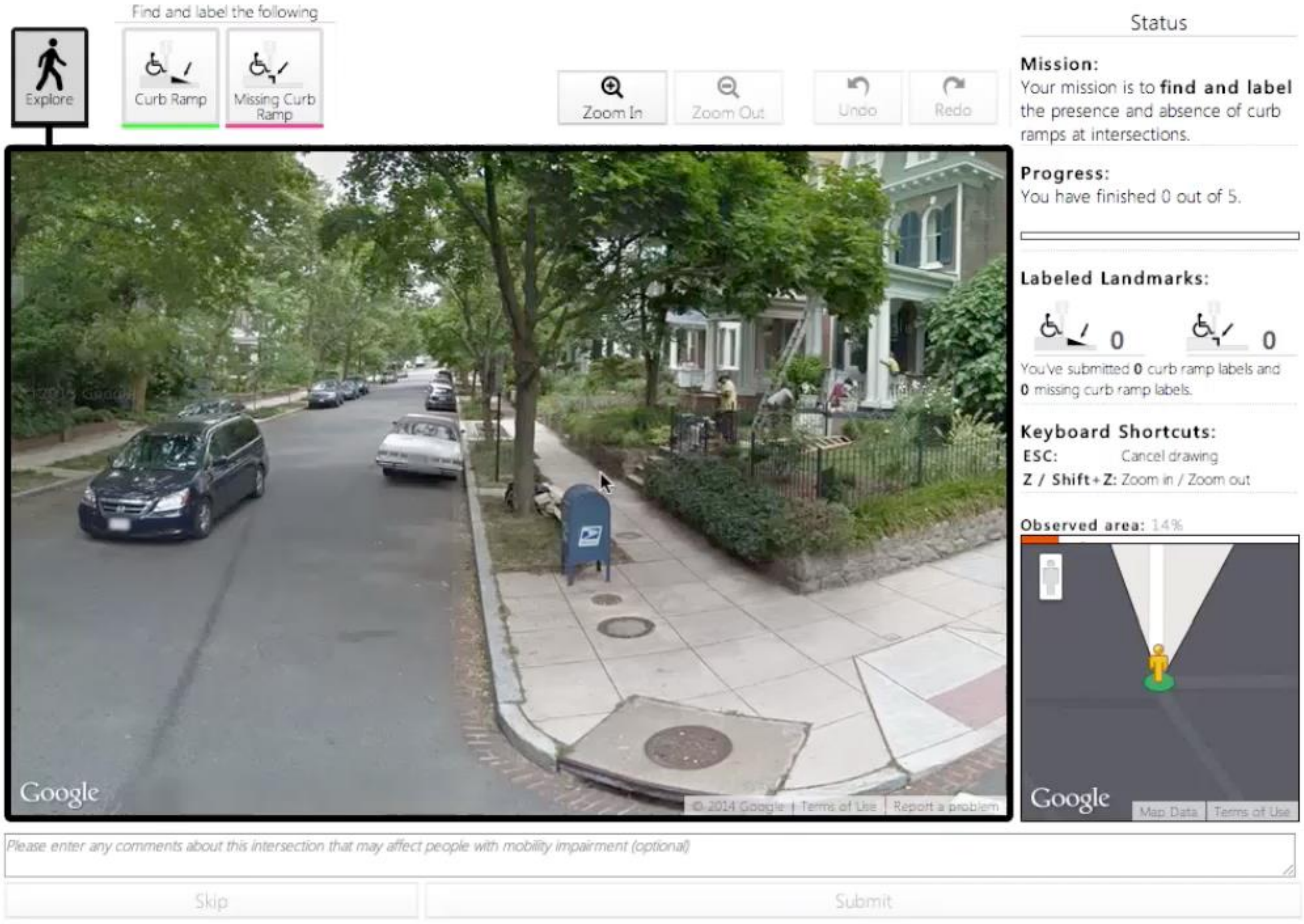


Playback Speed: **2x**


TOHME
遠目 Remote Eye
1
svCrawl
Web Scraper
2
Street View images
3D-depth maps
Top-down map images
GIS metadata
Street Dataset
3
svDetect
Automatic Curb
Ramp Detection
4
svControl
Automatic
Task Allocation
5
svVerify
Crowd Verification
6
svLabel
Crowd Labeling

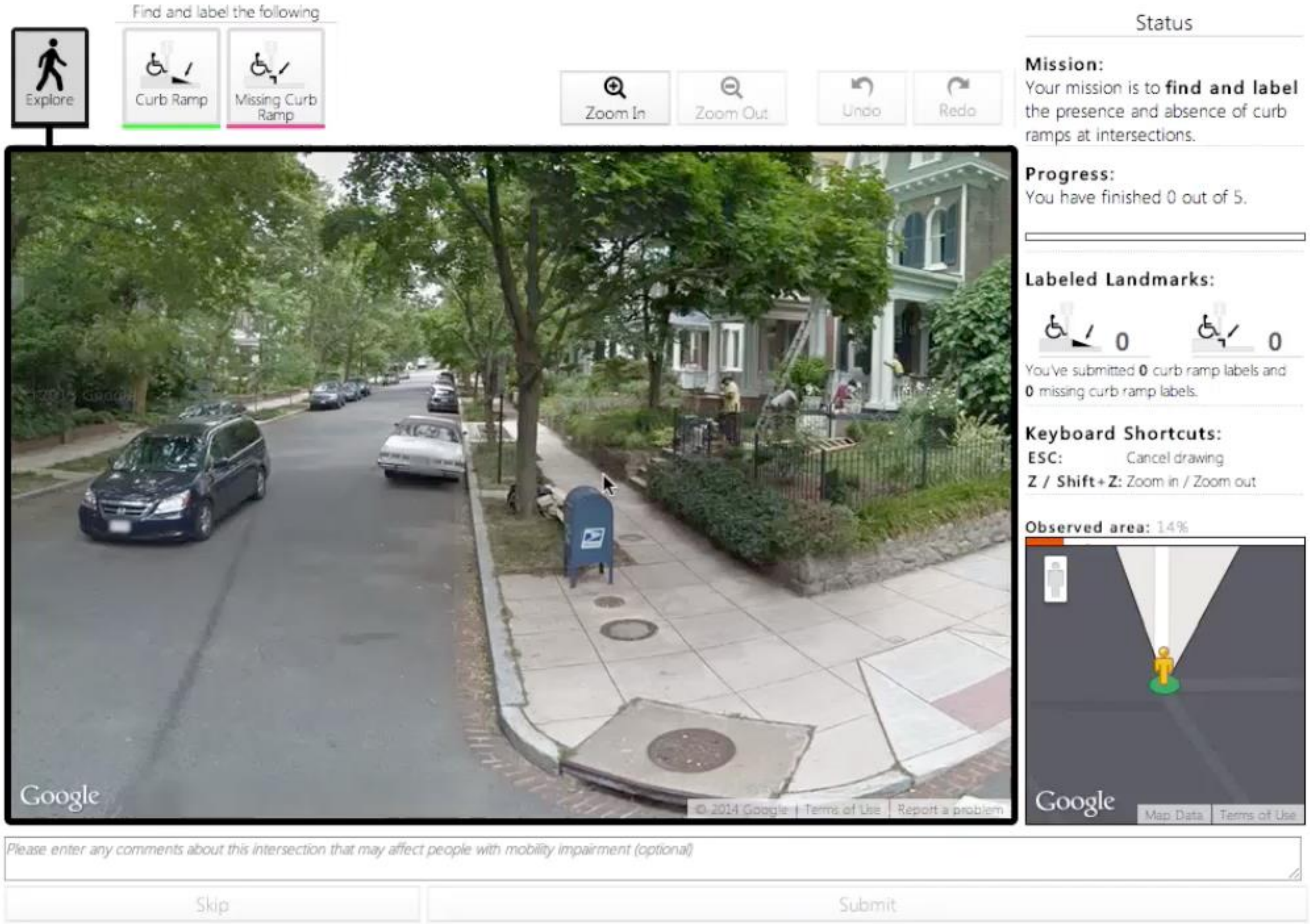
CROWD INTERFACES

LABELING TOOL



CROWD INTERFACES

LABELING TOOL



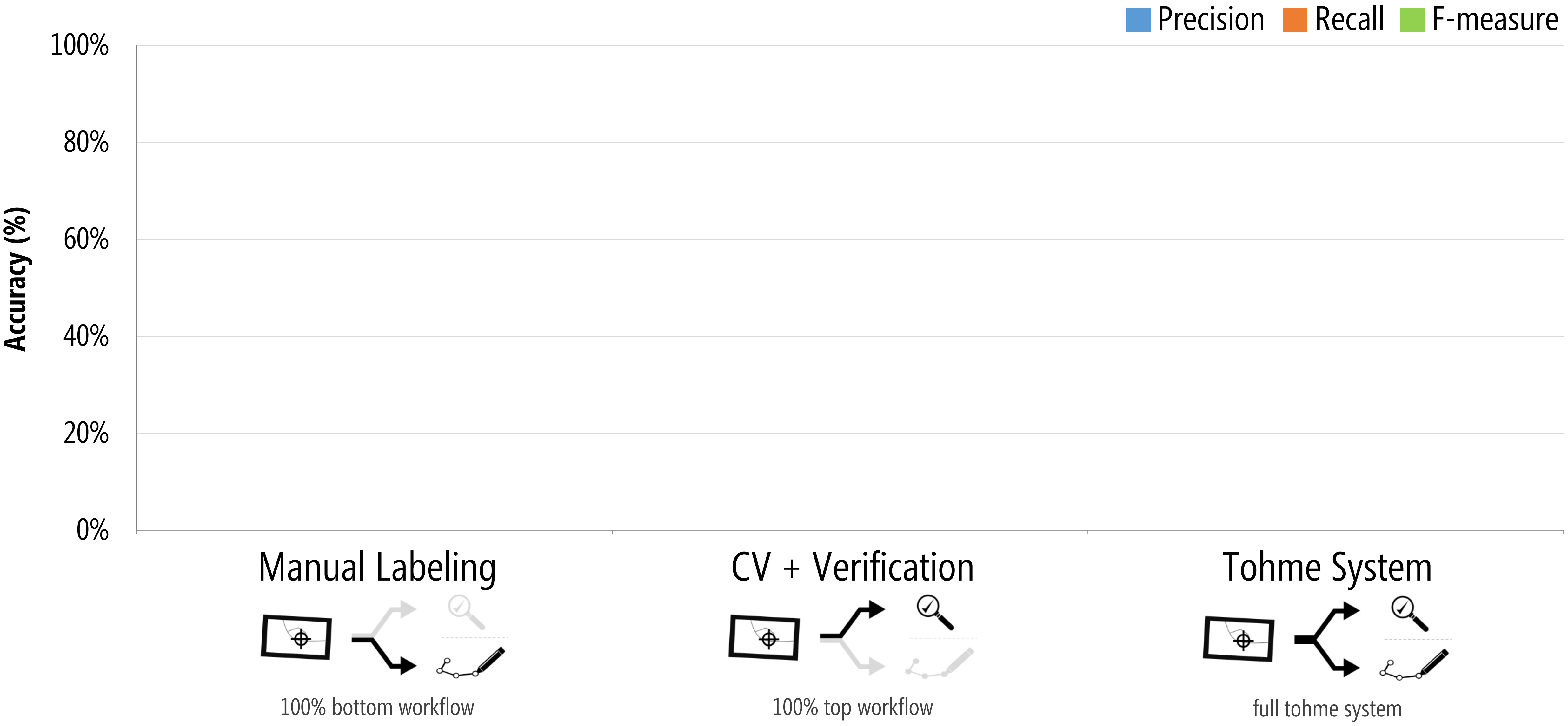
Playback Speed: **2x**

STUDY METHOD

1. Generate ground truth labels
2. Train computer vision & task controller
3. Deploy Tohme to crowd
4. Compare Tohme to baseline

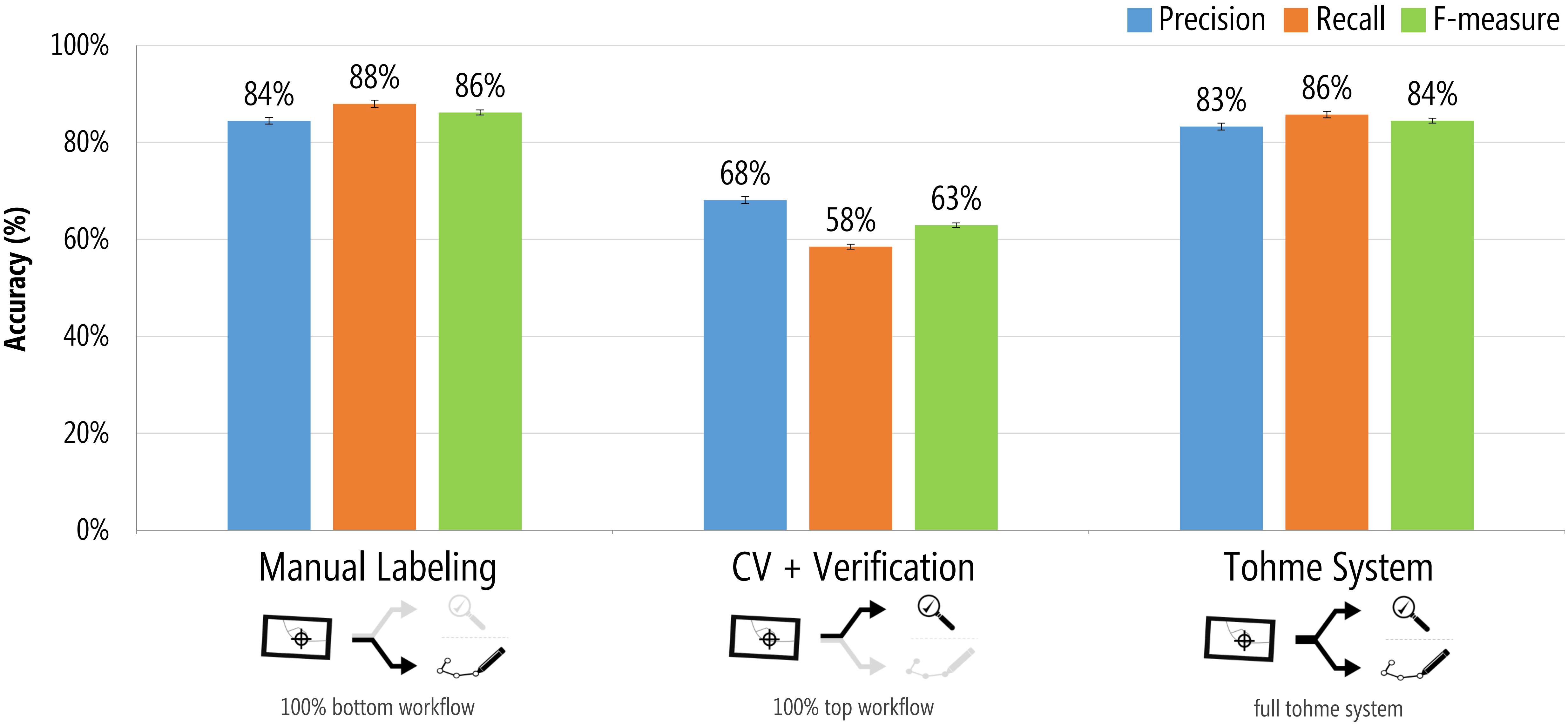
TOHME EVALUATION

OVERALL RESULTS



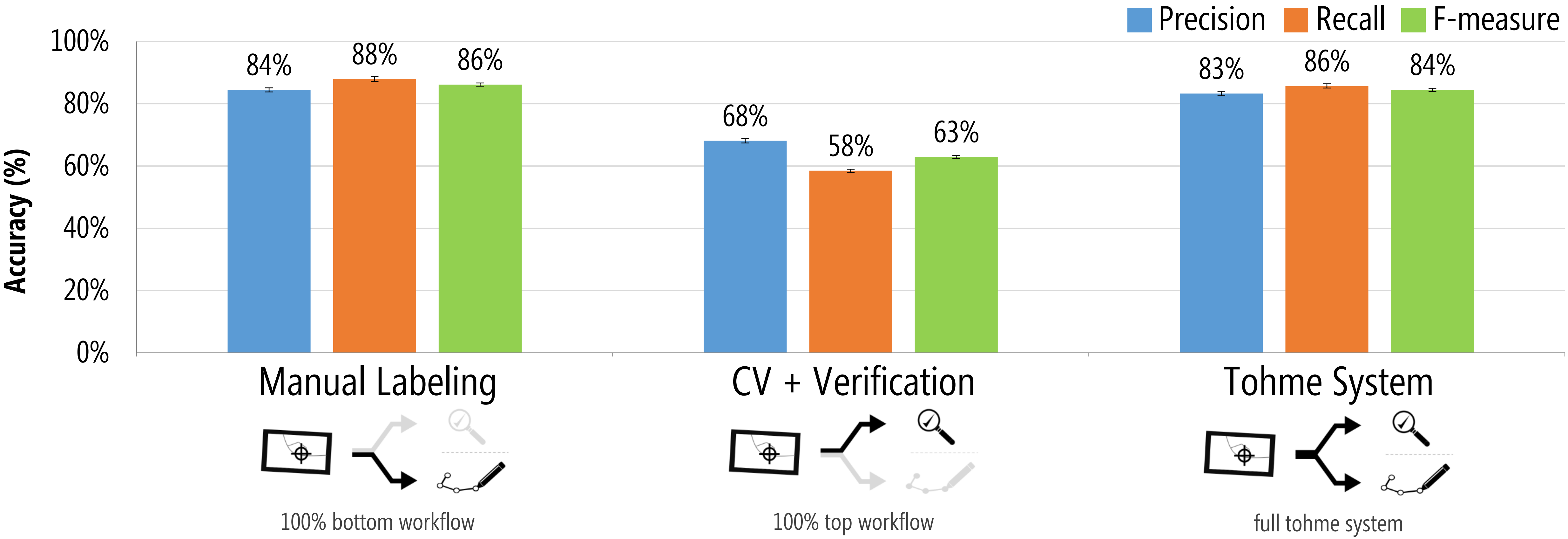
TOHME EVALUATION

OVERALL RESULTS



TOHME EVALUATION

OVERALL RESULTS



94s PER SCENE

42s PER SCENE

81s PER SCENE

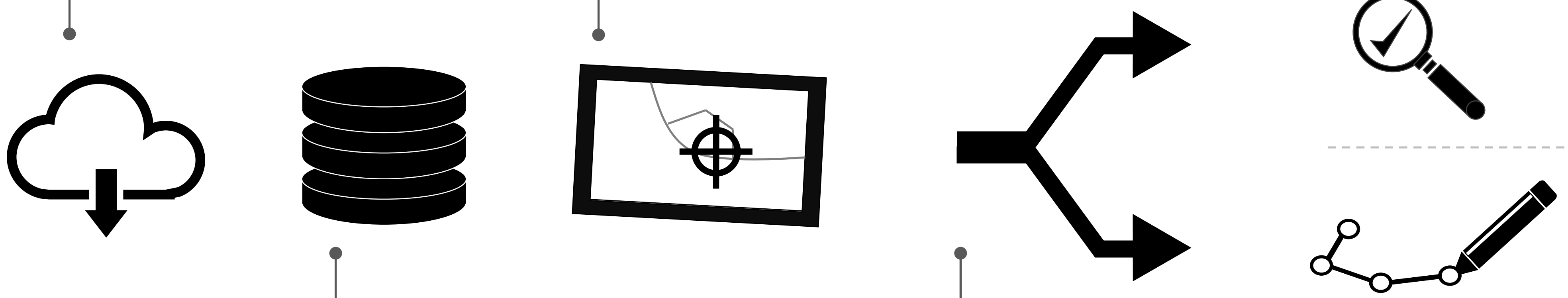
TOHME EVALUATION

TASK CONTROLLER PERFORMANCE

1 svCrawl
Web Scraper

3 svDetect
Automatic Curb Ramp Detection

5 svVerify
Crowd Verification



80%
SCENES CORRECTLY ROUTED

50%
SCENES CORRECTLY ROUTED

Street View images
3D-depth maps
Top-down map images
GIS metadata

2 **Street Dataset**

4 svControl
Automatic Task Allocation

6 svLabel
Crowd Labeling

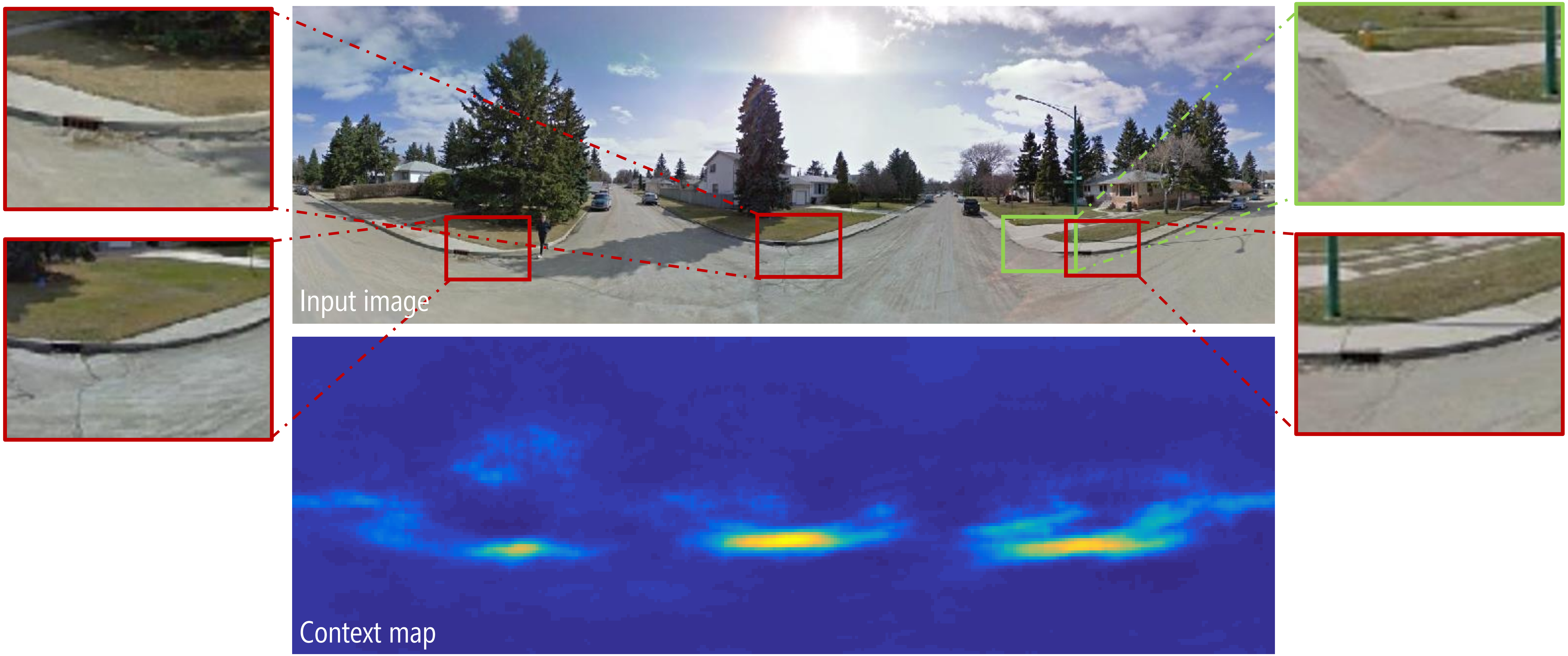
CURRENT & FUTURE WORK

1. Improving detection algorithms
2. Project Sidewalk
3. New workflows & interfaces
4. Developing new assistive technologies

CURRENT & FUTURE WORK

APPLYING CONVOLUTIONAL NEURAL NETWORKS

Recently accepted to CVPR'17



PROJECT
SIDEWALK
HTTP://PROJECTSIDEWALK.IO

PROJECT SIDEWALK

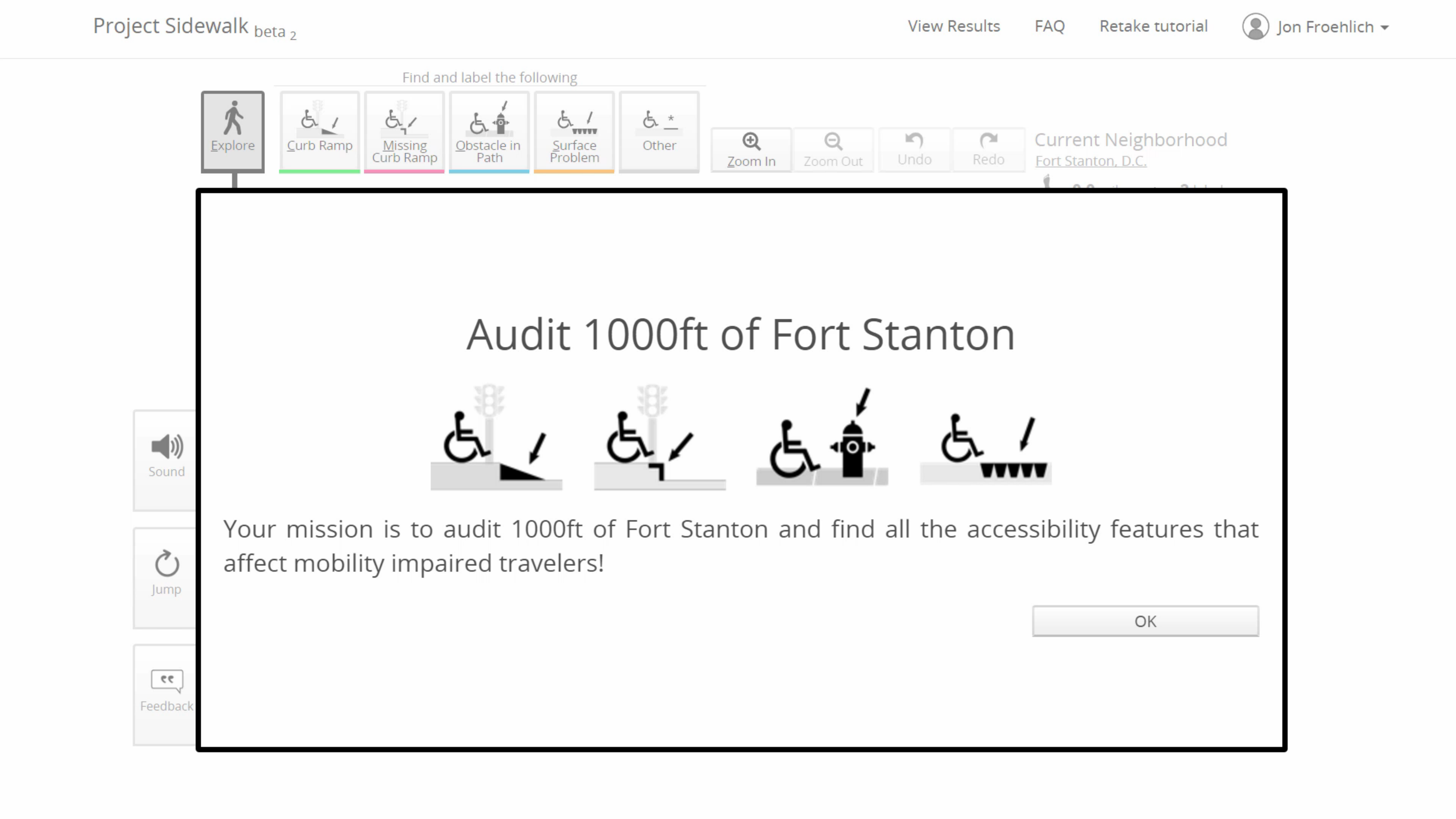
Start Mapping Login

Let's create a path for everyone.

Start Mapping

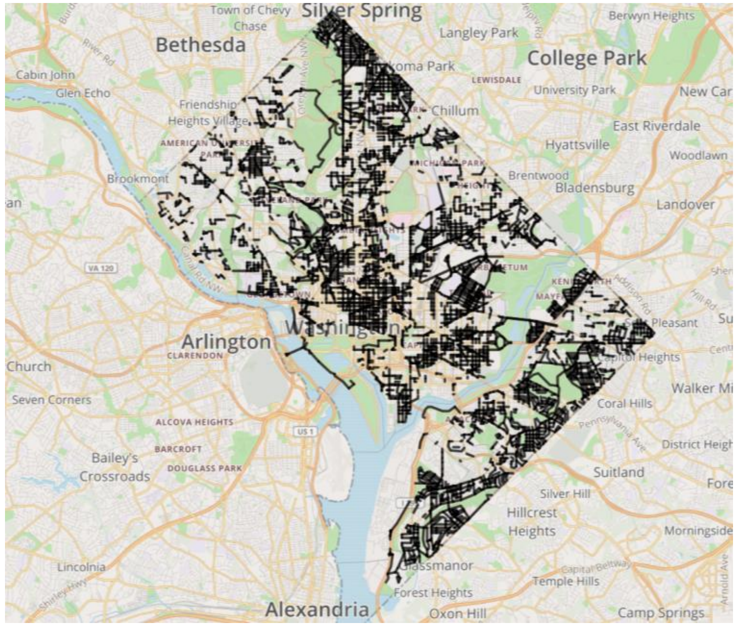
Using our tool

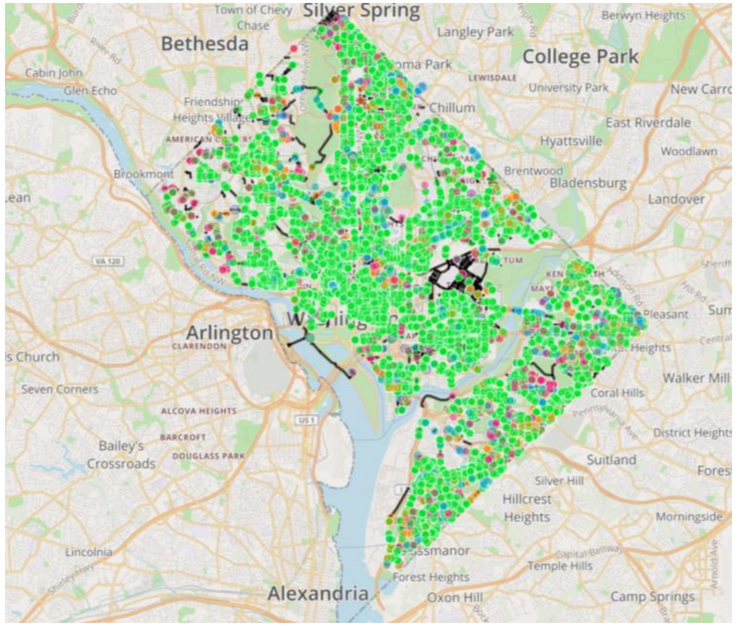
Through Project Sidewalk, you can virtually walk through a neighborhood in Washington D.C. and help identify accessibility issues in 3 easy steps.


Project Sidewalk beta 2
View Results
FAQ
Retake tutorial
Jon Froehlich
Find and label the following
Explore
Curb Ramp
Missing Curb Ramp
Obstacle in Path
Surface Problem
Other
Zoom In
Zoom Out
Undo
Redo
Current Neighborhood
Fort Stanton, D.C.
Sound
Jump
Feedback
Audit 1000ft of Fort Stanton
Your mission is to audit 1000ft of Fort Stanton and find all the accessibility features that affect mobility impaired travelers!
OK

CURRENT & FUTURE WORK

PROJECT SIDEWALK CONTRIBUTIONS





500

USERS

470

MILES

66,000

LABELS

19393.jpg 7915.jpg 19395.jpg 19394.jpg 19392.jpg 19390.jpg 19387.jpg 19383.jpg 19388.jpg 19384.jpg 19386.jpg 19389.jpg 19385.jpg 19382.jpg 19381.jpg 19379.jpg 19380.jpg 19377.jpg 19375.jpg 19374.jpg 19372.jpg 19373.jpg
19371.jpg 19376.jpg 19370.jpg 19368.jpg 19369.jpg 19367.jpg 19358.jpg 19359.jpg 19365.jpg 19362.jpg 19361.jpg 19363.jpg 19357.jpg 19350.jpg 19354.jpg 19351.jpg 19349.jpg 19346.jpg 19345.jpg 19341.jpg 19348.jpg 19342.jpg
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19307.jpg 19312.jpg 19310.jpg 19306.jpg 19311.jpg 19305.jpg 19302.jpg 19301.jpg 19300.jpg 19299.jpg 19292.jpg 19289.jpg 19297.jpg 19290.jpg 19291.jpg 19298.jpg 19294.jpg 19295.jpg 19288.jpg 19283.jpg 19285.jpg 19287.jpg
19281.jpg 19284.jpg 19280.jpg 19282.jpg 19279.jpg 19278.jpg 19277.jpg 19275.jpg 19269.jpg 19271.jpg 19264.jpg 19265.jpg 19262.jpg 19260.jpg 19261.jpg 19254.jpg 19259.jpg 19255.jpg 19258.jpg 19257.jpg 19253.jpg 19256.jpg
19252.jpg 19247.jpg 19248.jpg 19246.jpg 19237.jpg 19238.jpg 19236.jpg 19239.jpg 19235.jpg 19240.jpg 19234.jpg 19232.jpg 19222.jpg 19221.jpg 19223.jpg 19228.jpg 19224.jpg 19231.jpg 19229.jpg 19230.jpg 19220.jpg 19219.jpg
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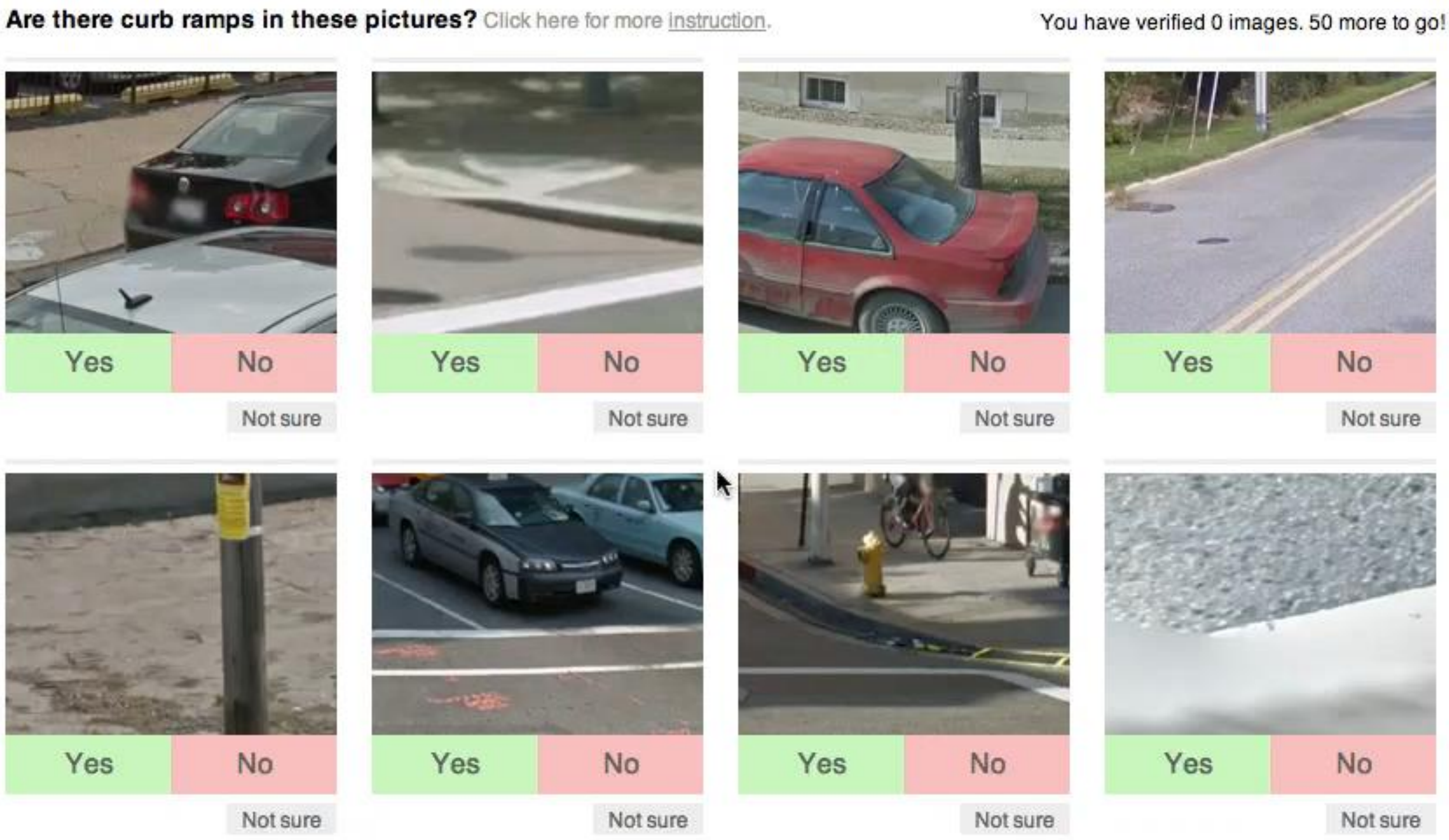
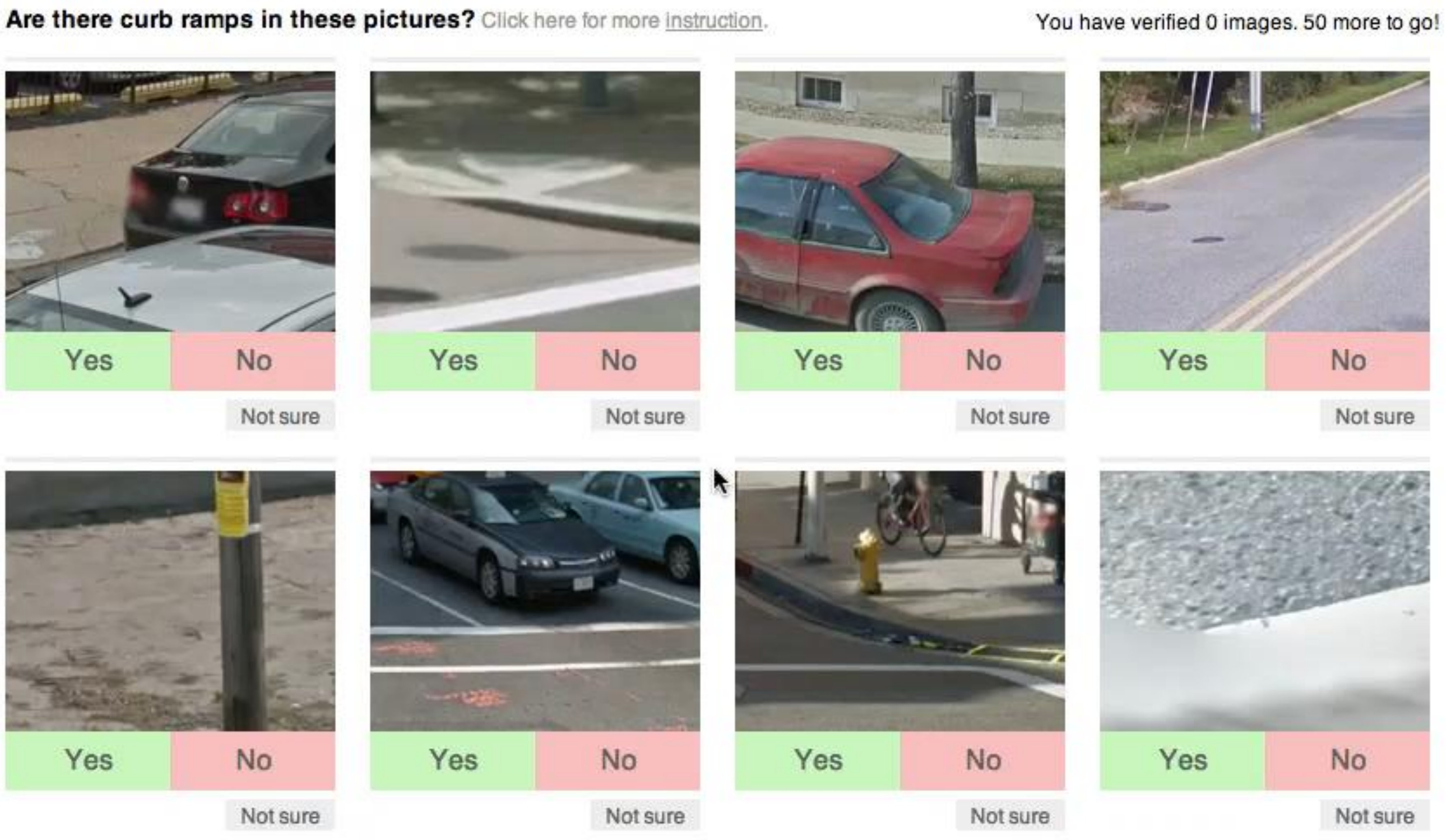
19183.jpg 19176.jpg 19170.jpg 19164.jpg 19163.jpg 19165.jpg 19162.jpg 19160.jpg 19166.jpg 19169.jpg 19159.jpg 19158.jpg 19157.jpg 19151.jpg 19137.jpg 19152.jpg 19156.jpg 19155.jpg 19142.jpg 19144.jpg 19143.jpg 19135.jpg
19134.jpg 19126.jpg 19132.jpg 19123.jpg 19128.jpg 19130.jpg 19129.jpg 19125.jpg 19133.jpg 19131.jpg 19124.jpg 19121.jpg 19122.jpg 19120.jpg 19113.jpg 19109.jpg 19116.jpg 19112.jpg 19111.jpg 19117.jpg 19108.jpg 19095.jpg
19089.jpg 19090.jpg 19084.jpg 19082.jpg 19078.jpg 19074.jpg 19075.jpg 19081.jpg 19077.jpg 19076.jpg 19083.jpg 19070.jpg 19067.jpg 19066.jpg 19065.jpg 19043.jpg 19041.jpg 19051.jpg 19040.jpg 19050.jpg 19045.jpg 19042.jpg
19036.jpg 19031.jpg 19032.jpg 19027.jpg 19028.jpg 19023.jpg 19029.jpg 19030.jpg 19033.jpg 19024.jpg 19022.jpg 19020.jpg 19017.jpg 19018.jpg 19012.jpg 19014.jpg 19013.jpg 19015.jpg 19016.jpg 19019.jpg 19011.jpg 19001.jpg
18999.jpg 19000.jpg 18996.jpg 18991.jpg 18971.jpg 18985.jpg 18984.jpg 18973.jpg 18967.jpg 18964.jpg 18963.jpg 18961.jpg 18962.jpg 18958.jpg 18957.jpg 18960.jpg 18959.jpg 18953.jpg 18952.jpg 18951.jpg 18942.jpg 18944.jpg

CURRENT & FUTURE WORK

NEW HYBRID WORKFLOWS & INTERFACES

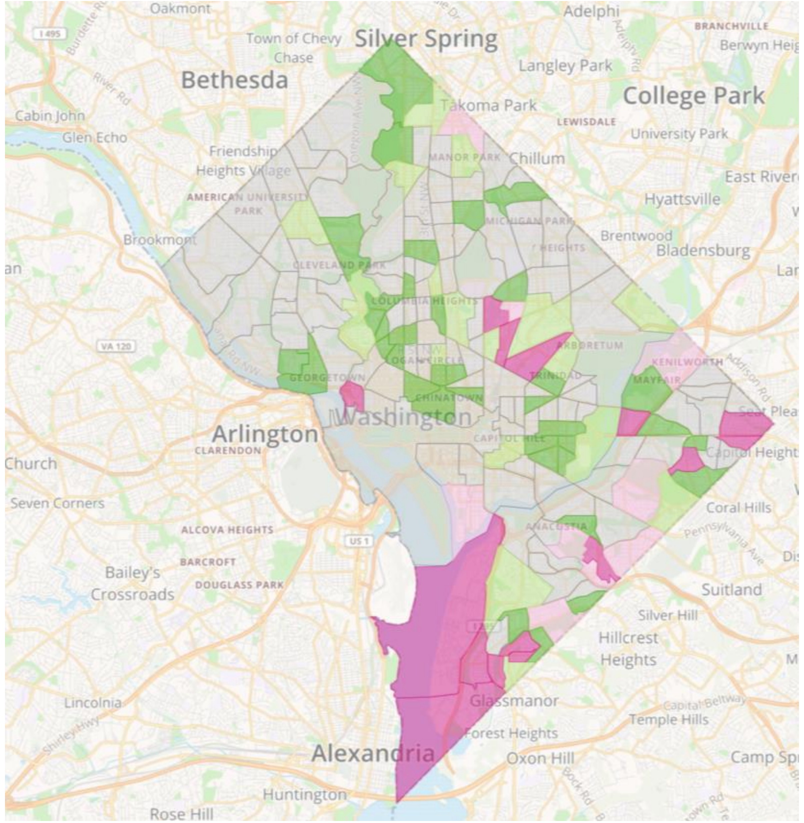


NEW HYBRID WORKFLOWS & INTERFACES




2906 34th St NW
Washington, District of Columbia
Street View - Sep 2007
Garfield St NW
Back to Map
Google
Image capture: Sep 2007
© 2014 Google
Terms
Privacy
Report a problem

NOVEL ASSISTIVE TECHNOLOGY APPLICATIONS



Build new models & visualizations of city accessibility

Smart routing for people with mobility impairments

MAKEABILITY LAB

FOUR FOCUS AREAS

ENVIRONMENTAL SUSTAINABILITY

HEALTH & WELLNESS

ACCESSIBILITY

STEM EDUCATION

MAKEABILITY LAB

FOUR FOCUS AREAS

ENVIRONMENTAL SUSTAINABILITY

HEALTH & WELLNESS

ACCESSIBILITY

STEM EDUCATION

See: Barton, *et al.,* 2008; Naiser & Hand, 2008; Kafai, *et al.,* 2014;


RONJA
Kirjojen
tapahtuma
paikkoja

Complex Problems

Wearables: an engaging vehicle for building science skills?

Unprecedented data
Inherently personalized
Life relevant
Actively engage body in learning

THREAD 2: STEM EDUCATION

ENABLING NEW STEM LEARNING EXPERIENCES WITH WEARABLES

BODYVIS
[IDC'13, CHI'15, ICLS'16, CHI'17]

SHAREDPHYS
[IDC'16, ICLS'16, CHI'17]

MAKERWEAR
[IDC'15, CHI'16, CHI'17]

THREAD 2: STEM EDUCATION

ENABLING NEW STEM LEARNING EXPERIENCES WITH WEARABLES

BODYVIS

SHAREDPHYS

How can we...

use the human body and physical activity as an engaging platform for scientific inquiry?

"Does my heart beat faster when running vs. reading a book? Why?"

"How does my breathing rate compare to my classmate's and why may this be?"

"How does food travel through my body?"

ADVANCING SCIENCE LEARNING & INQUIRY EXPERIENCES THROUGH WEARABLES

BODYVIS & SHAREDPHYS TEAM

PROFESSORS

Jon Froehlich

Tamara Clegg

GRAD STUDENTS

Leyla Norooz

Seokbin Kang

Virginia Byrne

Rafael Velez

Amy Green

UNDERGRADUATE STUDENTS

Monica Katzen

Angelisa Plane

Vanessa Oguamanam

Thomas Outing

Anita Jorgensen

HIGH SCHOOL STUDENT

Sage Chen

ENGAGING YOUNG CHILDREN IN WEARABLE DESIGN

MAKERWEAR TEAM

PROFESSORS

Jon Froehlich

Tamara Clegg

GRAD STUDENTS

Majeed Kazemitabaar

Liang He

UNDERGRADUATE STUDENTS

Jason McPeak

Katie Wang

Alex Jiao

Thomas Outing

Tony Cheng

HIGH SCHOOL STUDENT

Chloe Aloimonos

WHAT IF OUR CLOTHES REVEALED HOW OUR BODIES FUNCTIONED?

HOW COULD THIS CHANGE THE WAY CHILDREN LEARN ABOUT AND UNDERSTAND THEIR BODIES?

COULD A T-SHIRT BE A PLATFORM FOR EXPERIMENTATION AND INQUIRY

Norooz & Froehlich, IDC'13; Norooz *et al.*, CHI'15; Norooz *et al.*, ICLS'16; Clegg *et al.*, CHI'17

BODYVIS: FOUR GENERATIONS

PROTOTYPE 1

Stuffed fabric organs
Heartrate Only
LEDs, EL-Wire
Arduino Uno

PROTOTYPE 2

Improved Anatomy
Heartrate, Breathing
LEDs
Lilypad Arduino

PROTOTYPE 3

Labeled, Removable Anatomy
Heartrate, Breathing, Digestion
LEDs, Sound, Touchscreen
Arduino Uno, Smartphone

PROTOTYPE 4

Added Organs (*e.g.*, Bladder)
Heartrate, Breathing, Digestion
LEDs, Sound, Haptics, Touchscreen
Arduino BLE Mini, Smartphone

BODYVIS: FOUR GENERATIONS

PROTOTYPE 1

Stuffed fabric organs
Heartrate Only
LEDs, EL-Wire
Arduino Uno

PROTOTYPE 2

Improved Anatomy
Heartrate, Breathing
LEDs
Lilypad Arduino

PROTOTYPE 3

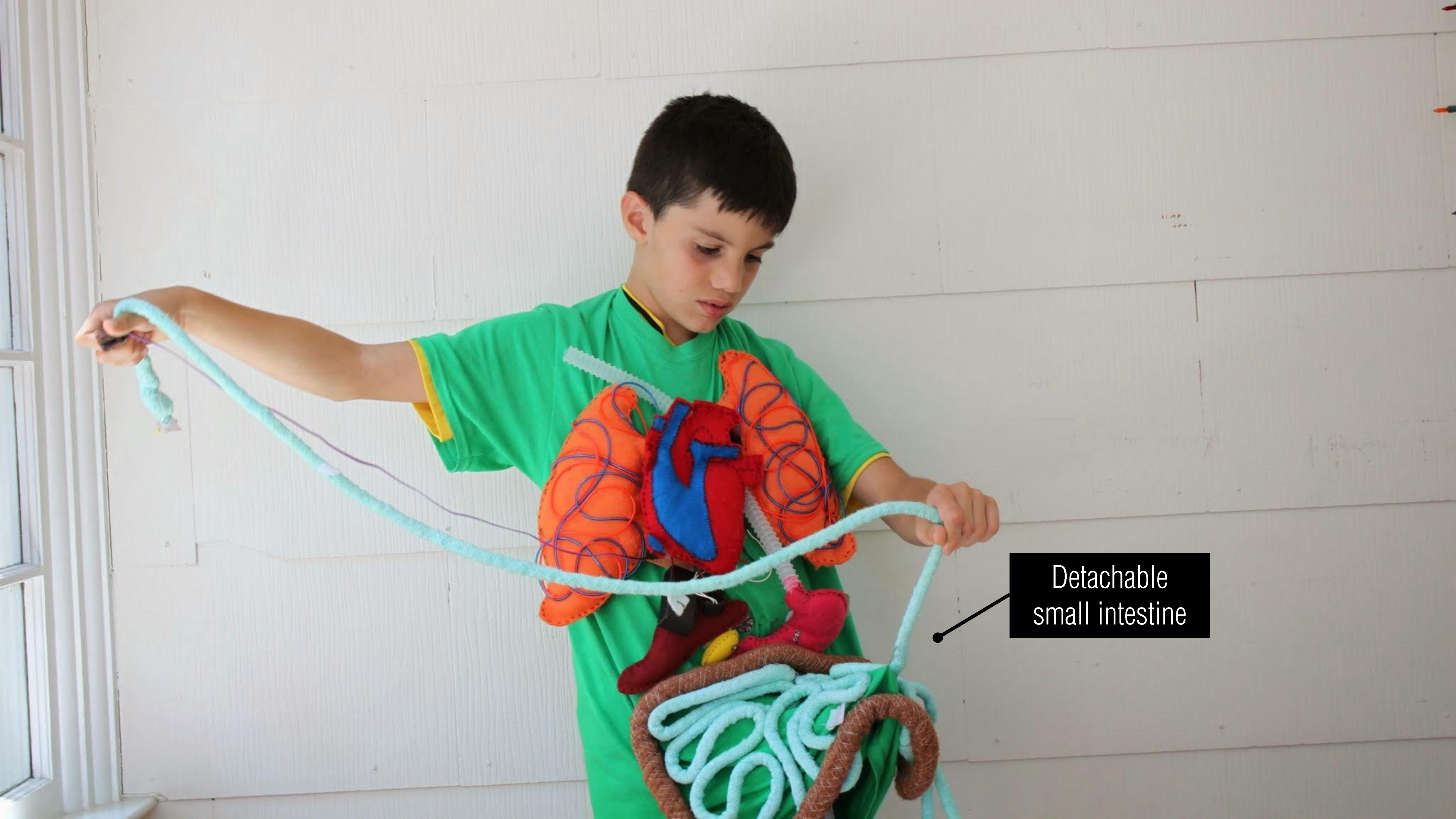
Labeled, Removable Anatomy
Heartrate, Breathing, Digestion
LEDs, Sound, Touchscreen
Arduino Uno, Smartphone

PROTOTYPE 4

Added Organs (*e.g.,* Bladder)
Heartrate, Breathing, Digestion
LEDs, Sound, Haptics, Touchscreen
Arduino BLE Mini, Smartphone


Optical heart
rate sensor


Optical heart
rate sensor


Detachable
small intestine

BODYVIS: FOUR GENERATIONS

PROTOTYPE 1

Stuffed fabric organs
Heartrate Only
LEDs, EL-Wire
Arduino Uno

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Improved Anatomy
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PROTOTYPE 4

Added Organs (*e.g.*, Bladder)
Heartrate, Breathing, Digestion
LEDs, Sound, Haptics, Touchscreen
Arduino BLE Mini, Smartphone


Esophagu
Lung
Lung
Liver
Large Intestine
Small Intestine

BODYVIS

HOW IT WORKS

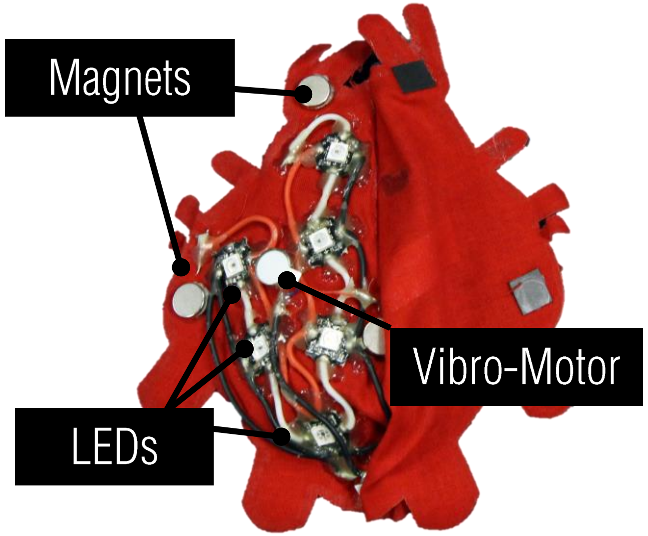
BODYVIS

HOW IT WORKS

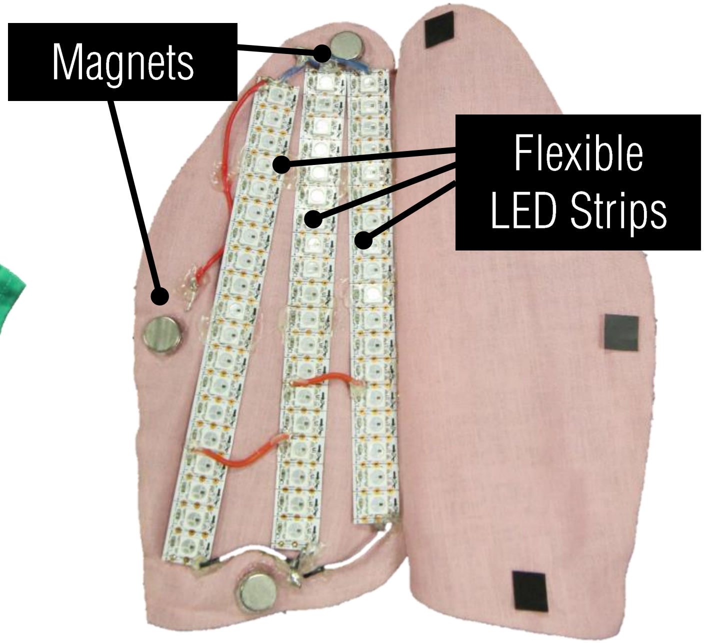
BODYVIS

HOW IT WORKS

HEART



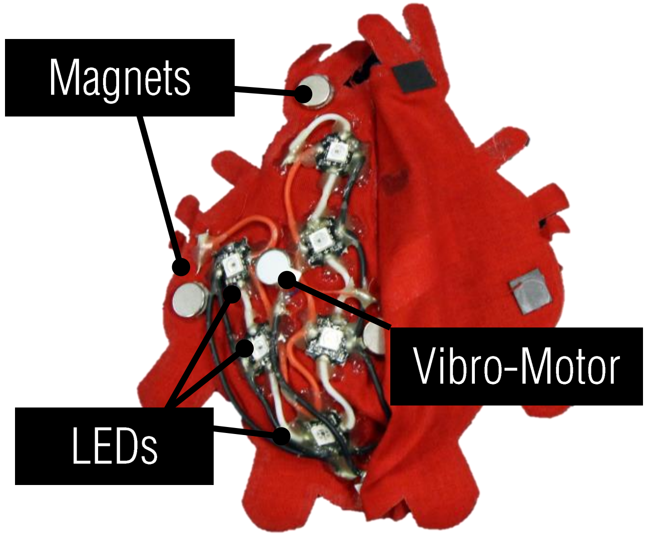
LUNGS



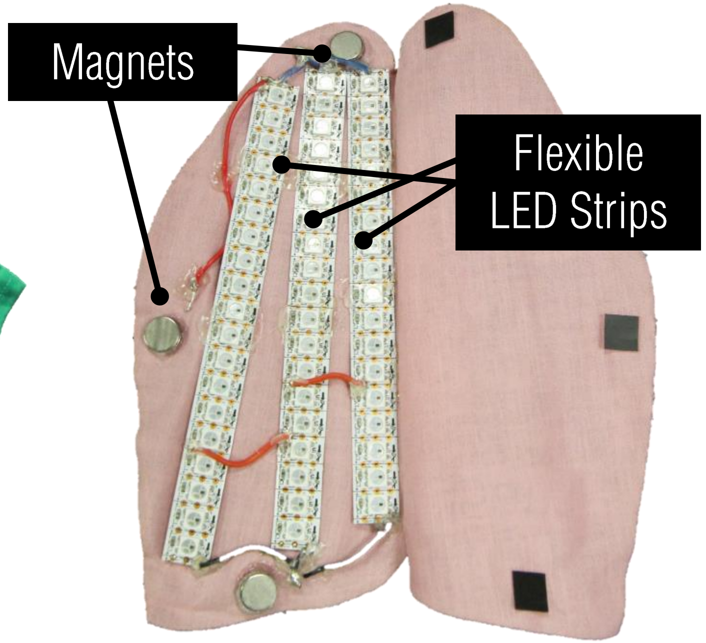
BODYVIS

HOW IT WORKS

HEART



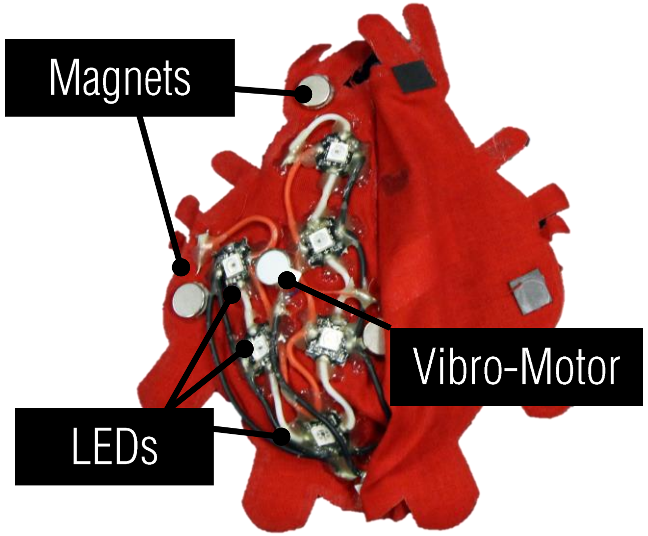
LUNGS



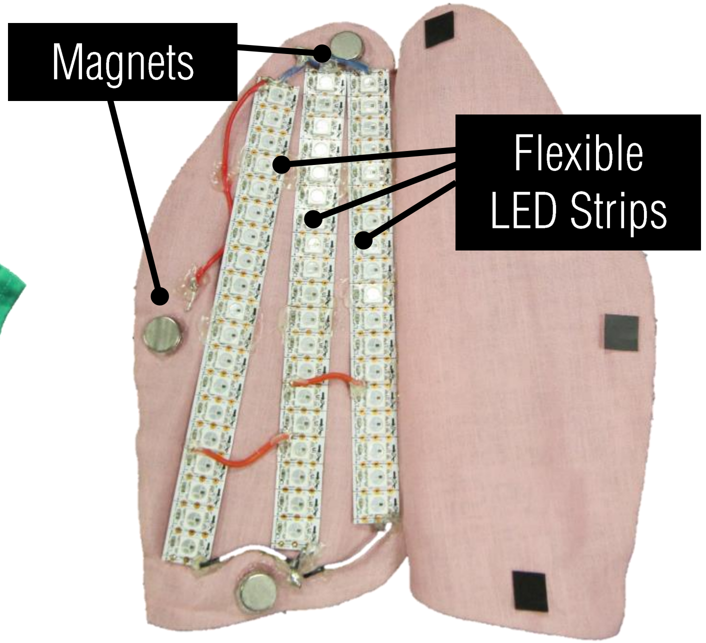
BODYVIS

HOW IT WORKS

HEART



LUNGS



STOMACH

BODYVIS

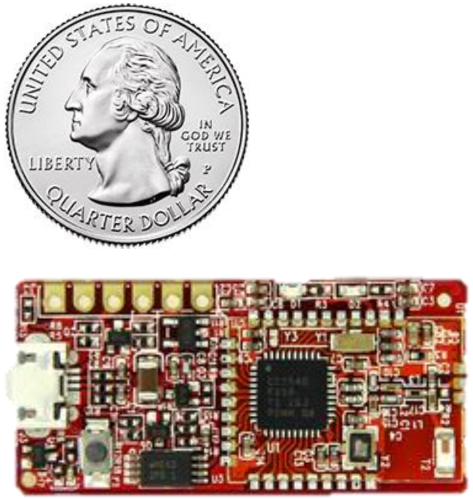
HOW IT WORKS

BODYVIS

SENSING SYSTEM

Wirelessly transmits
via Bluetooth

Wirelessly transmits
via BLE



ZEPHYR BIOHARNESS 3

Worn directly on skin
Senses heart, breathing, movement

SAMSUNG GALAXY S4 MINI

Serves as stomach
Processes physiological data
Plays sound & vibrates

REDBEARLAB BLE MINI ARDUINO

Sewn into shirt
Directly wired to LEDs, Vibro-motors,
digestion button, etc.

BODYVIS

EVALUATIONS

TEACHER INTERVIEWS

AFTER-SCHOOL PROGRAMS

SCIENCE CAMPS

ELEMENTARY SCHOOLS

DATA & ANALYSIS

Session video

Pre- & post-study questionnaires

Post-study interviews with children

Post-study interviews with staff

DATA & ANALYSIS

Session video

FOUR DIMENSIONS:

Physical actions (*e.g.,* gestures, interactions with shirt, movements)

Engagement (*e.g.,* facial expressions, comments; Carini *et al.,* 2006 & Jablon & Wilkinson, 2006)

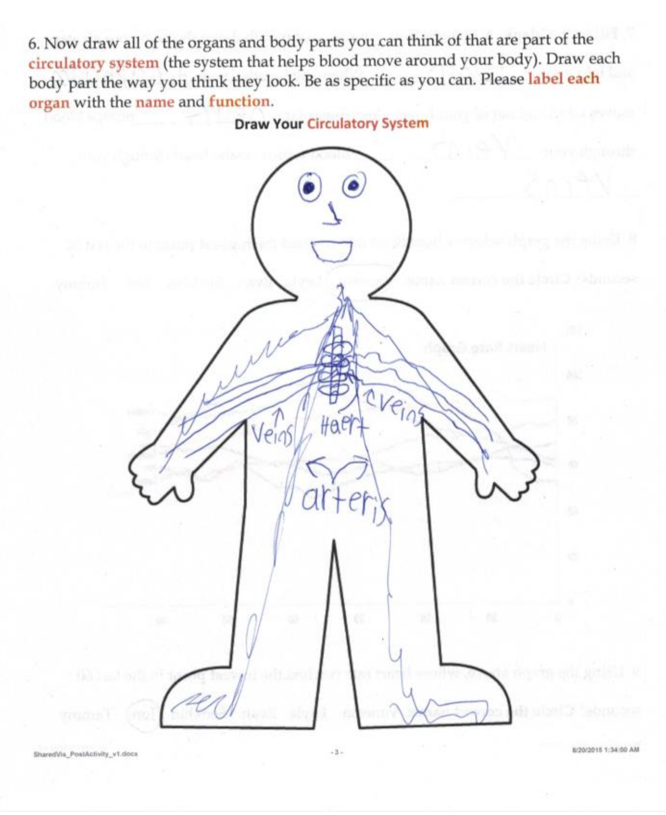
Spoken questions & observations (*e.g.,* "What happens if my heart stops beating?")

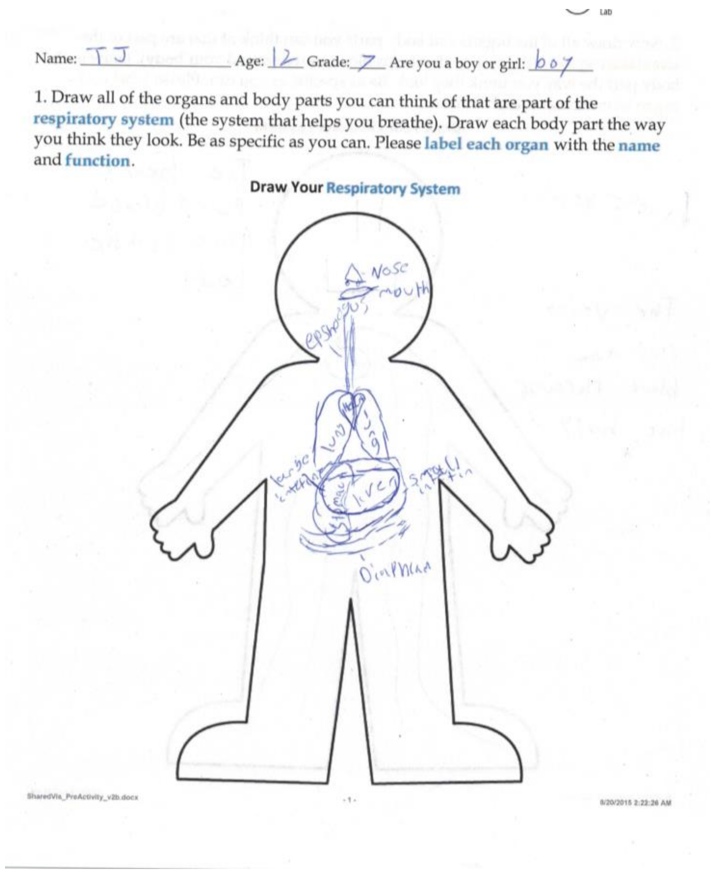
Design preferences (*e.g.,* likes, dislikes, new design ideas)

Video coding process based on Chi, 1997

DATA & ANALYSIS

Pre- & post-study questionnaires





BODYVIS INTERACTIONS

High Engagement

BODYVIS INTERACTIONS

High Engagement

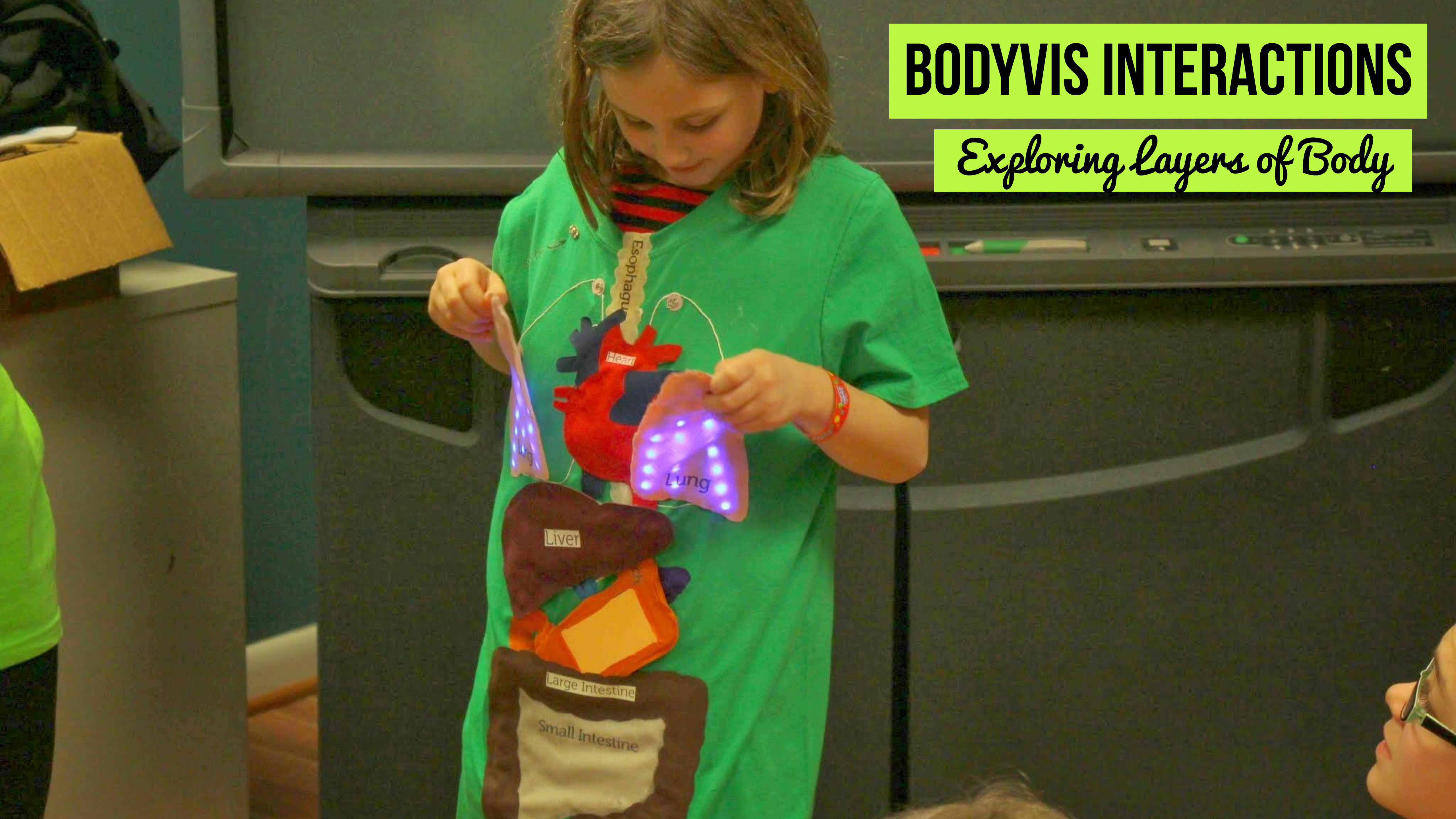
BODYVIS INTERACTIONS

Actively Engaging Body


BODYVIS INTERACTIONS
Actively Engaging Body
Balancing
Running
Eating
Touching
Flexing

BODYVIS INTERACTIONS

Exploring Layers of Body



BODYVIS INTERACTIONS

Exploring Layers of Body

BODYVIS INTERACTIONS

Promoting Social Interaction

BODYVIS INTERACTIONS

Supporting Pretend Play

Some Unexpected Things

BODYVIS INTERACTIONS

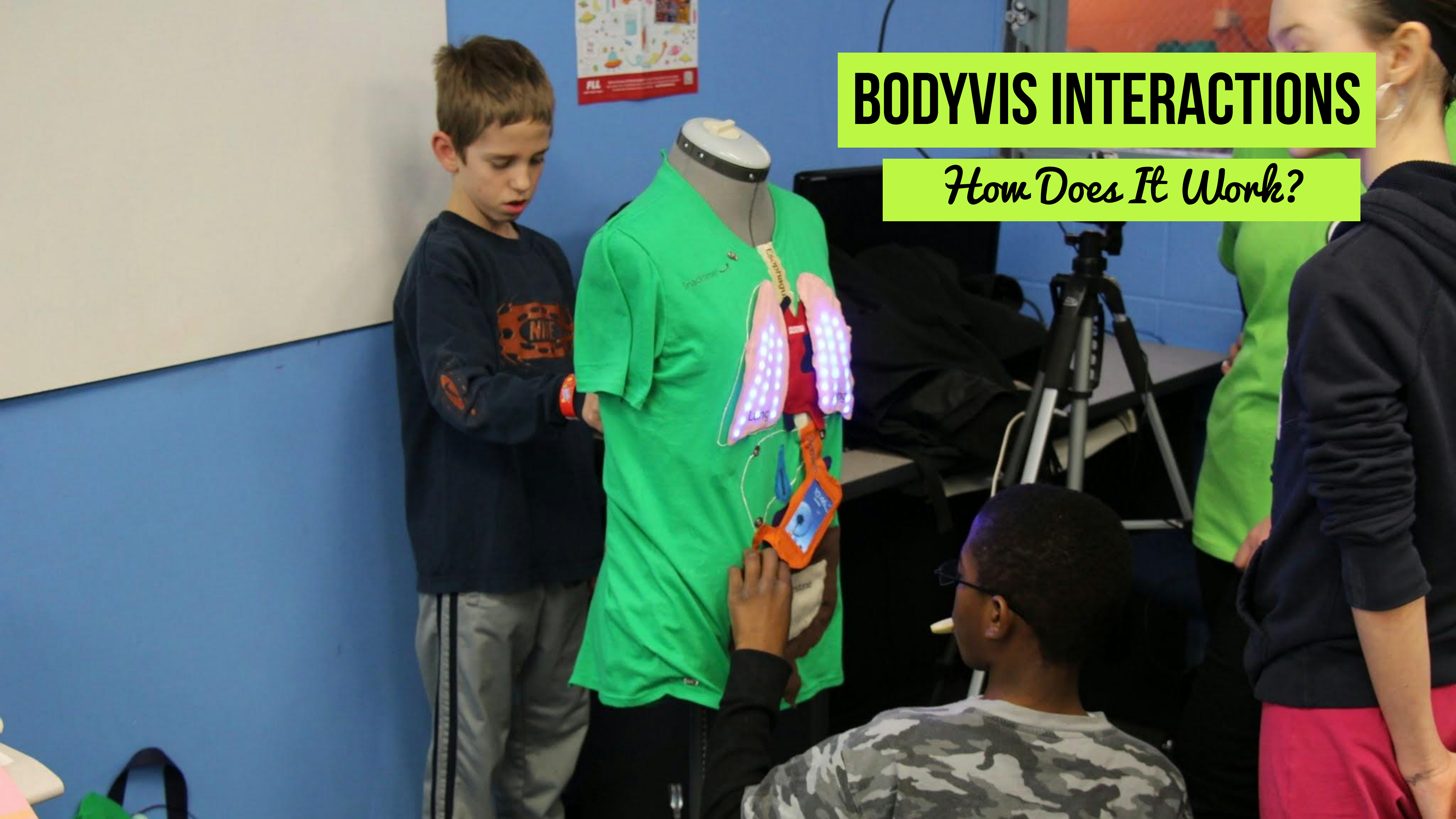
Disembodied Use

BODYVIS INTERACTIONS

Disembodied Use

BODYVIS INTERACTIONS

Disembodied Use


BODYVIS INTERACTIONS
How Does It Work?

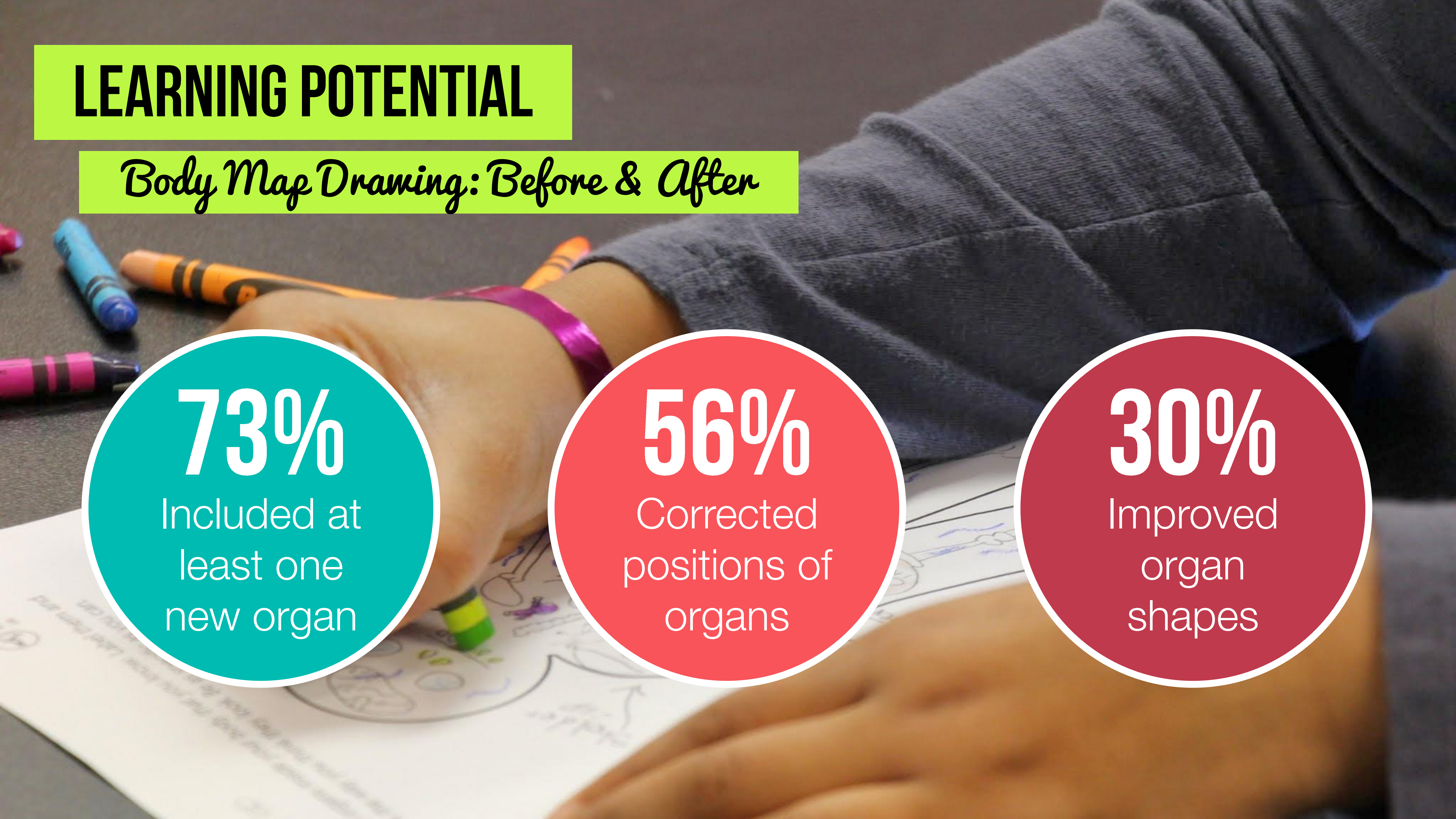
BODYVIS INTERACTIONS

How Does it Work?


LEARNING POTENTIAL
Pre- & Post-Questionnaires

LEARNING POTENTIAL

Body Map Drawing: Before & After



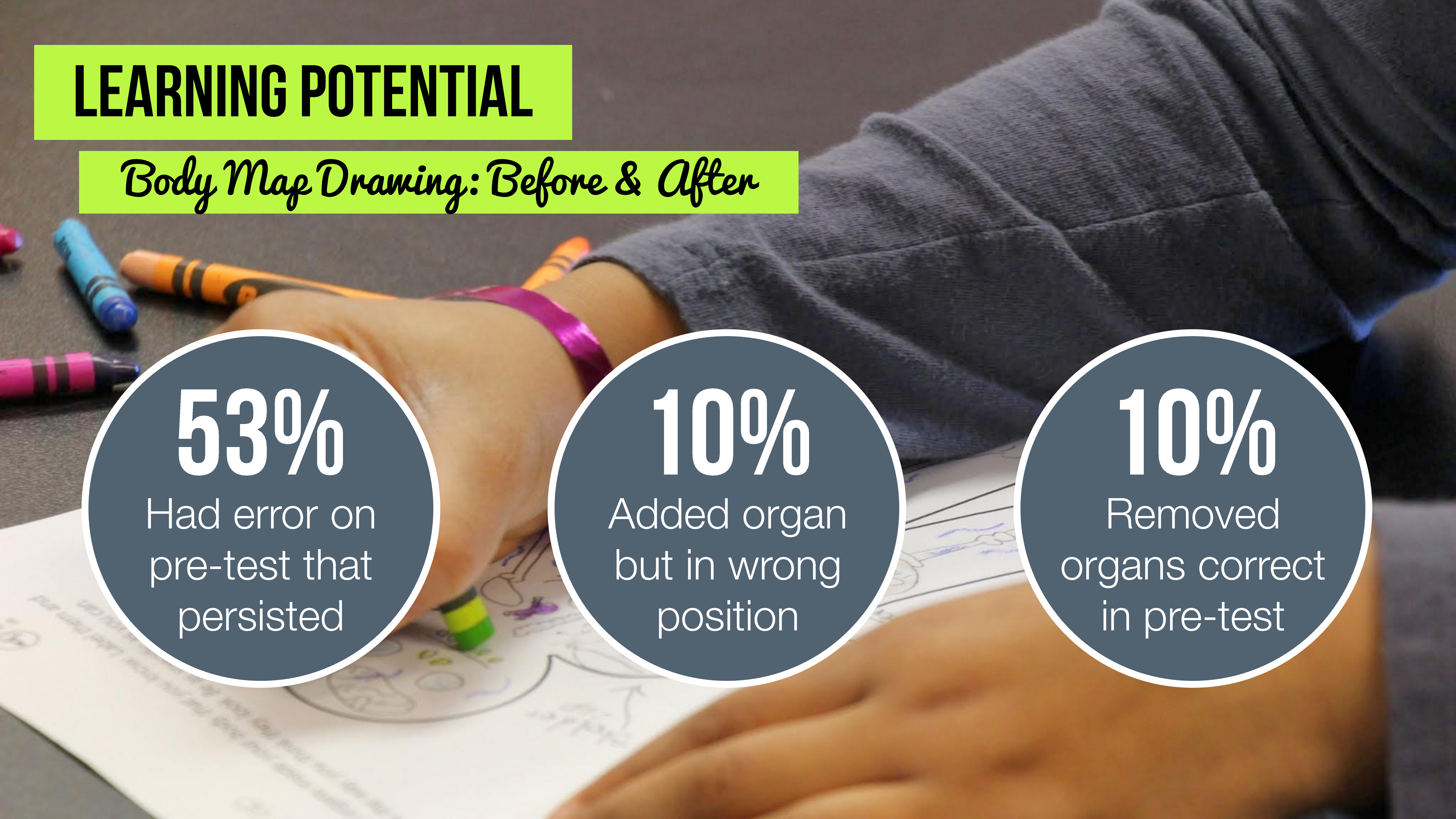
LEARNING POTENTIAL

Body Map Drawing: Before & After

73%
Included at least one new organ

56%
Corrected positions of organs

30%
Improved organ shapes



LEARNING POTENTIAL

Body Map Drawing: Before & After

53%
Had error on pre-test that persisted

10%
Added organ but in wrong position

10%
Removed organs correct in pre-test


Snack time!
Esophagus
Heart
Lung
Lung
Liver
Snack time!
Liver
Large Intestine
Small Intestine
Snack time!
Esophagus
Heart
Lung
Lung
Liver
Small Intestine

BODYVIS INTERACTIONS

Wearers Look Downwards

1 BODYVIS

Responsive E-textile

2 SHAREDPHYS

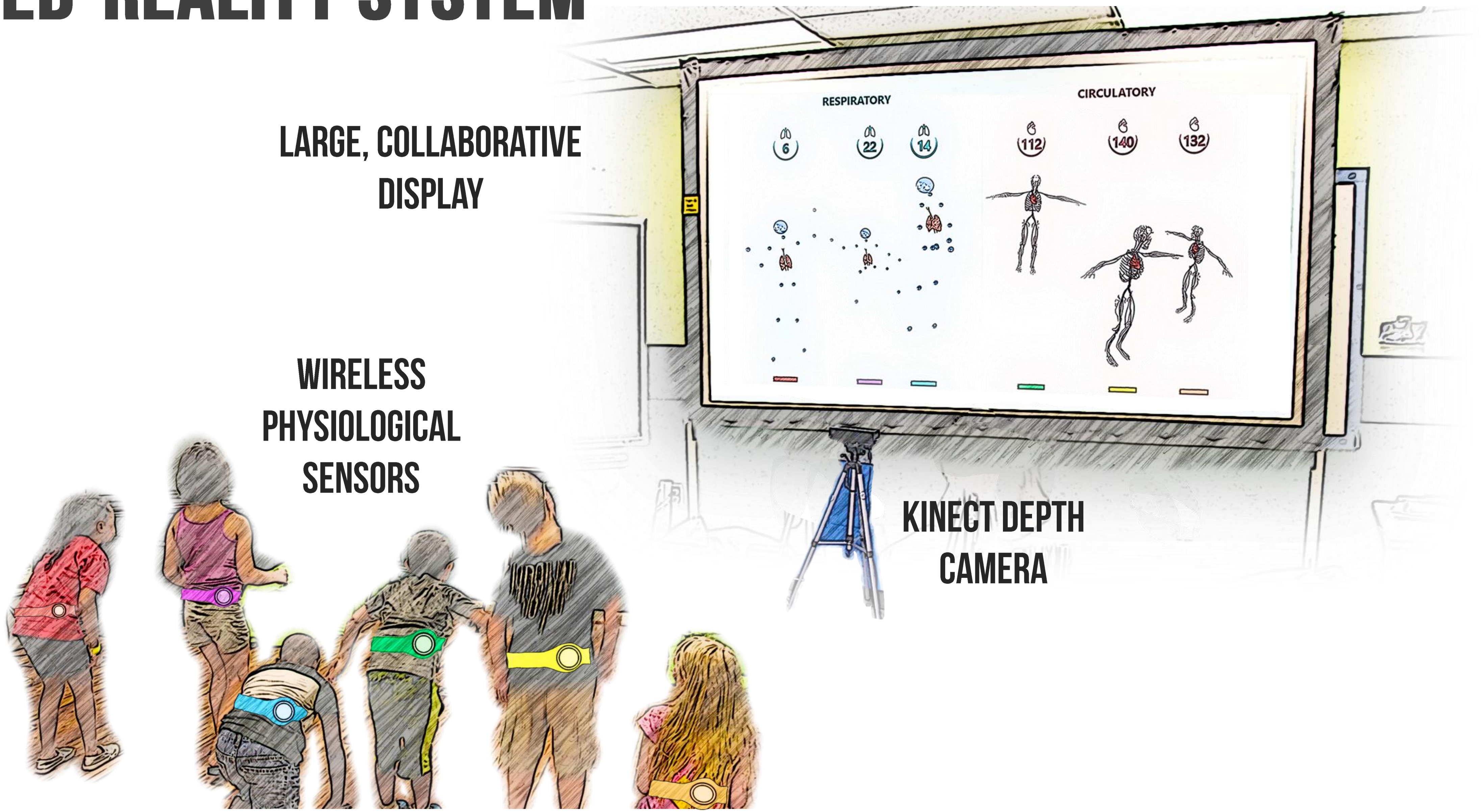
Collaborative Display

3 MAKERWEAR

Construction Kit

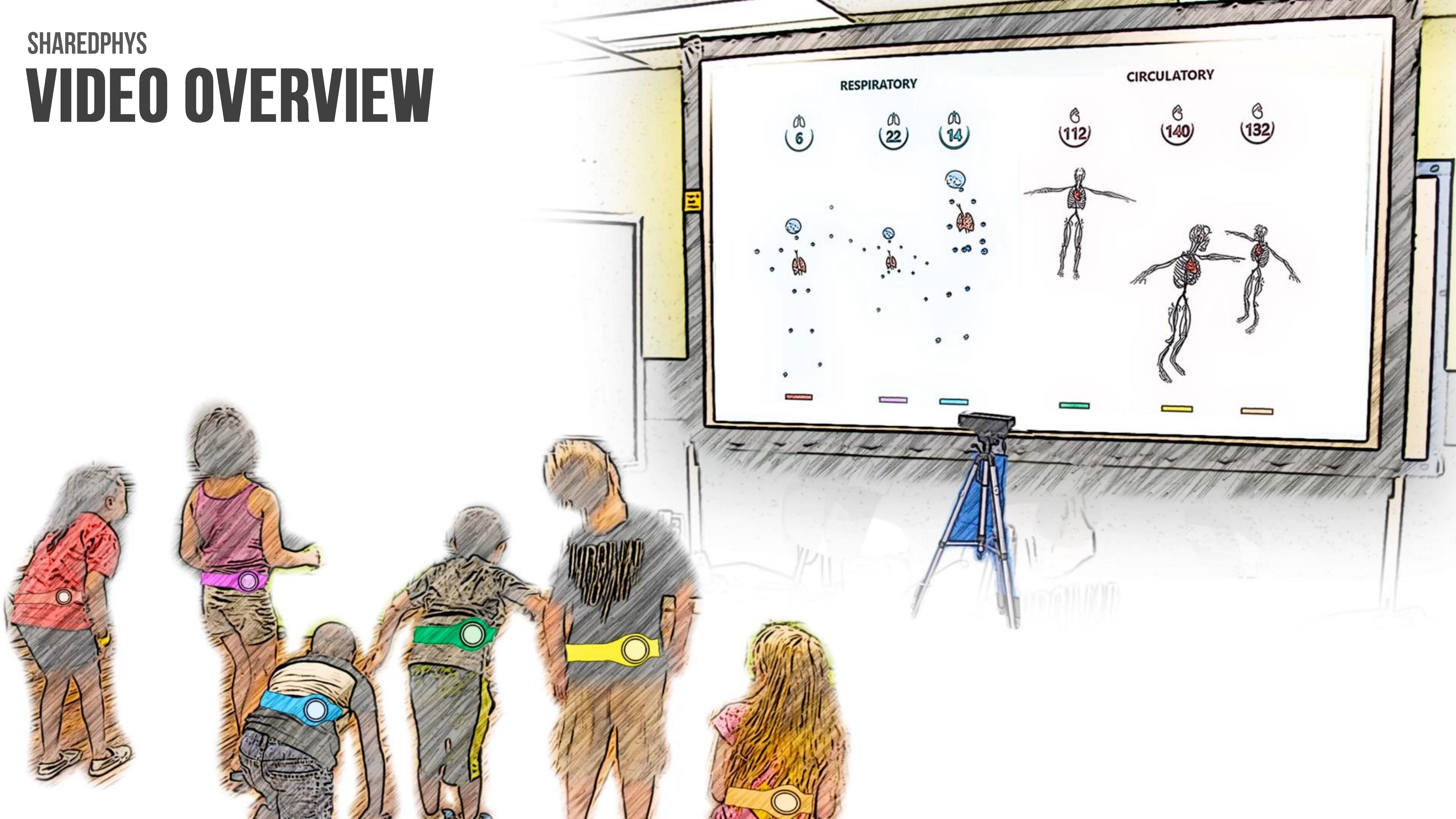
SHAREDPHYS

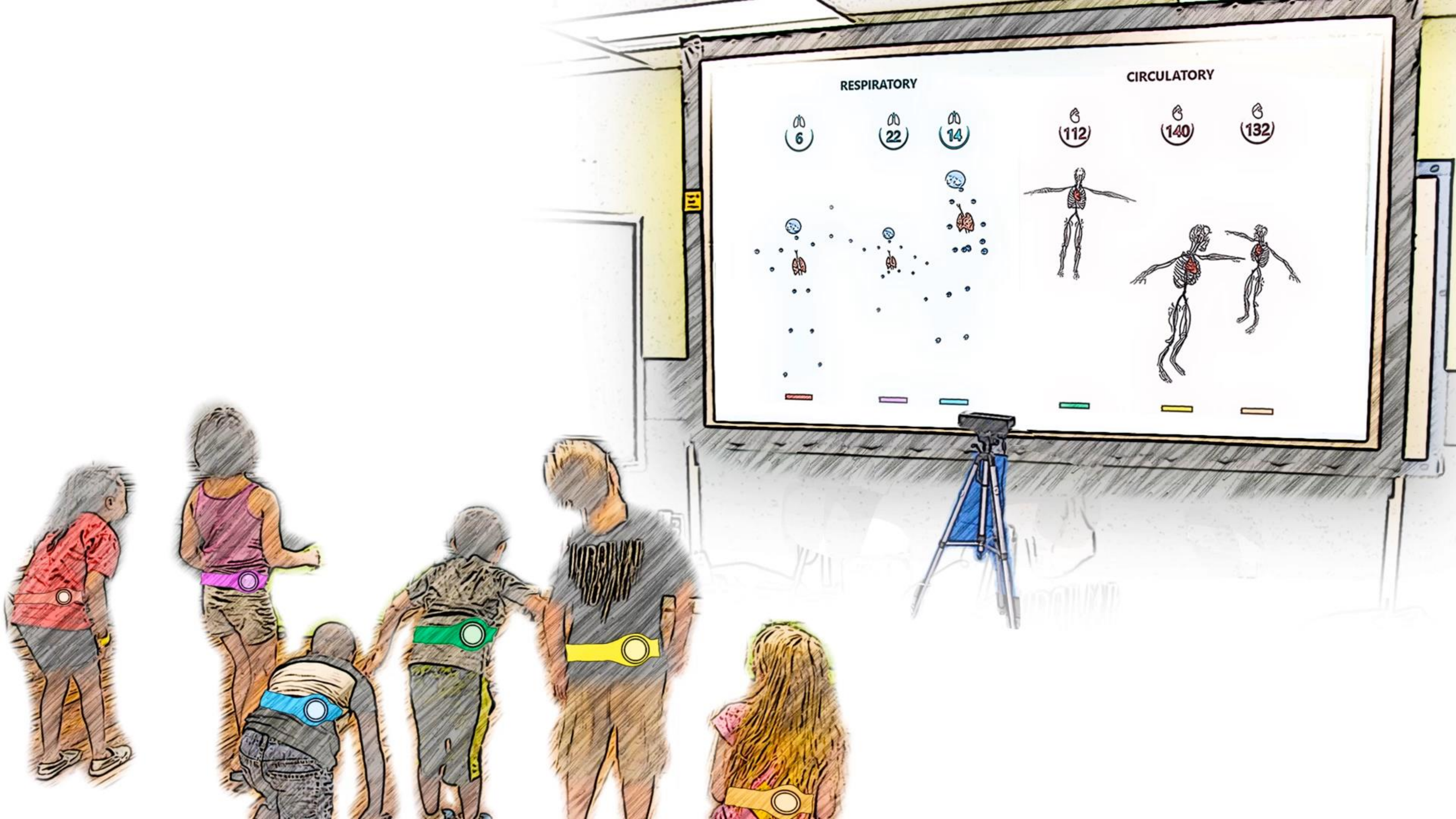
MIXED-REALITY SYSTEM



SHAREDPHYS

VIDEO OVERVIEW

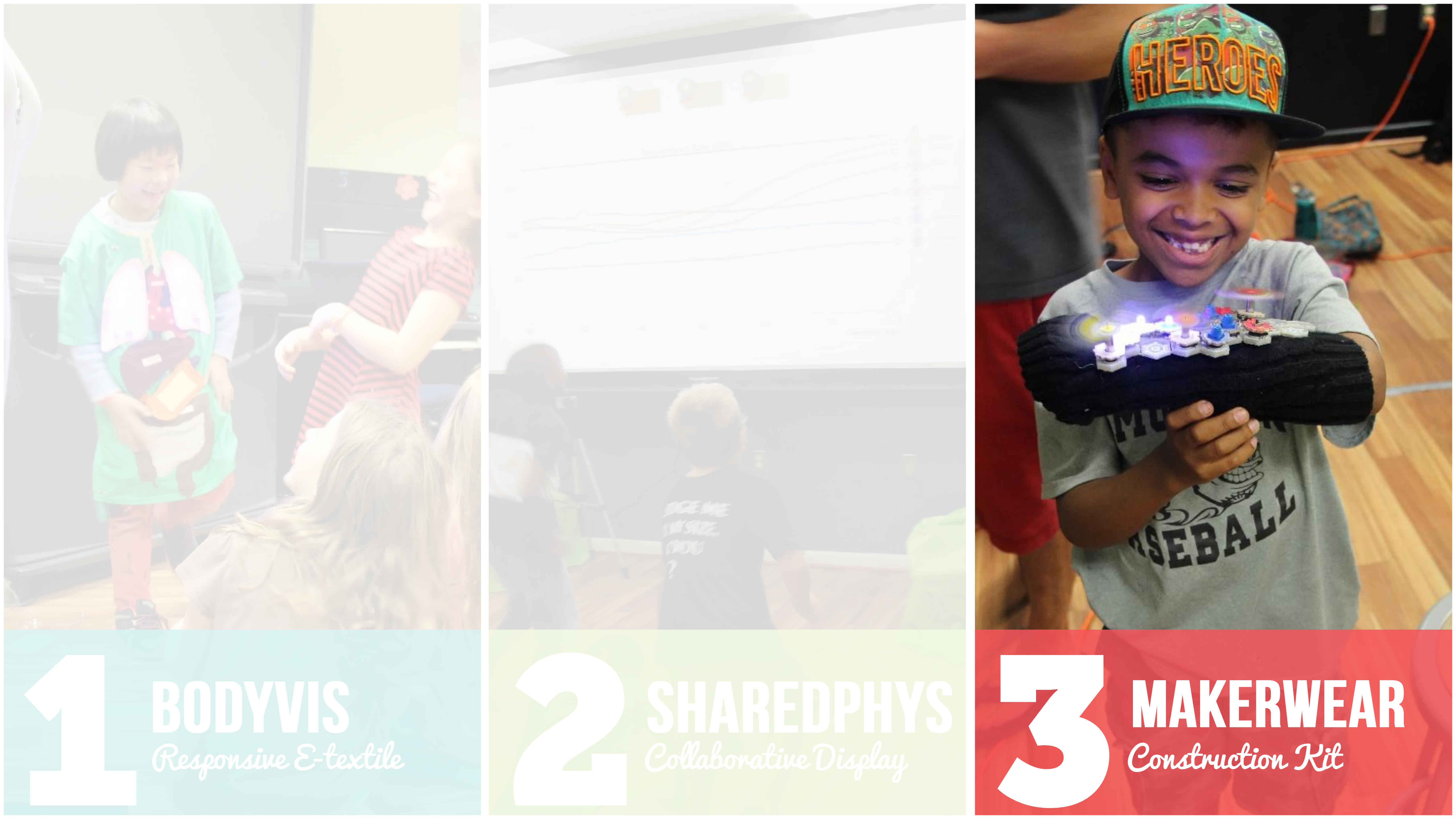



RESPIRATORY
CIRCULATORY
6
22
14
112
140
132

1 BODYVIS
Responsive E-textile

2 SHAREDPHYS
Collaborative Display

3 MAKERWEAR
Construction Kit

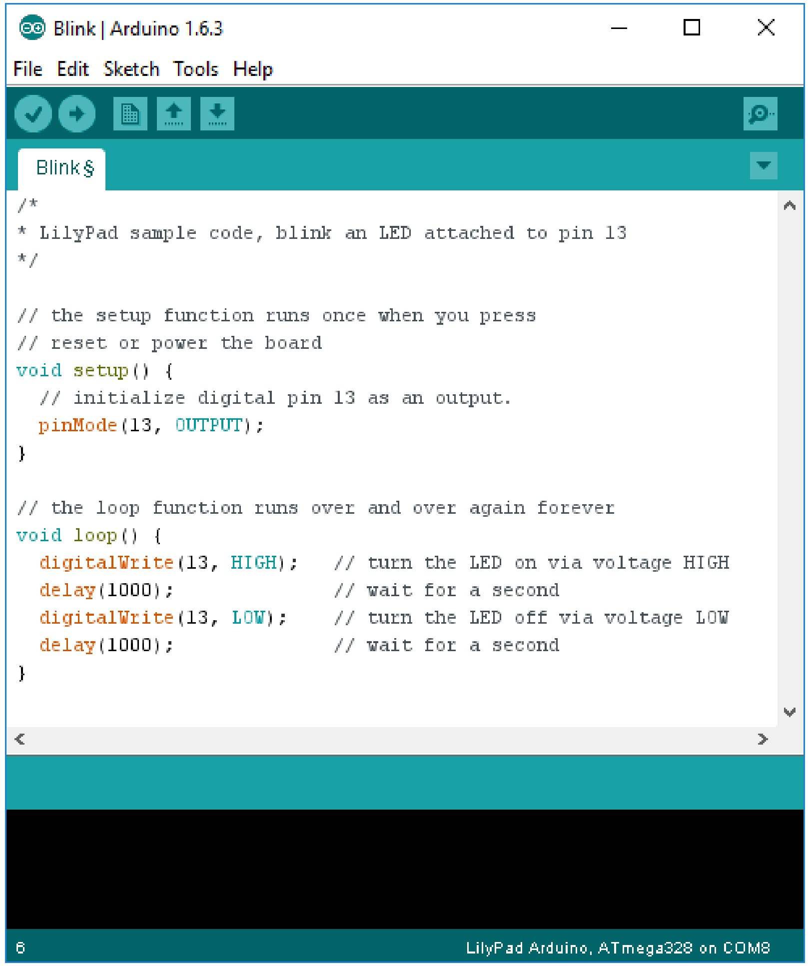

1 BODYVIS
Responsive E-textile
2 SHAREDPHYS
Collaborative Display
3 MAKERWEAR
Construction Kit


LILYPAD ARDUINO
LilyPad Arduino

See: Buechley & Hill, 2010; Kafai, Lee, *et al.,* 2014; Kafai, Fields, & Searle, 2014

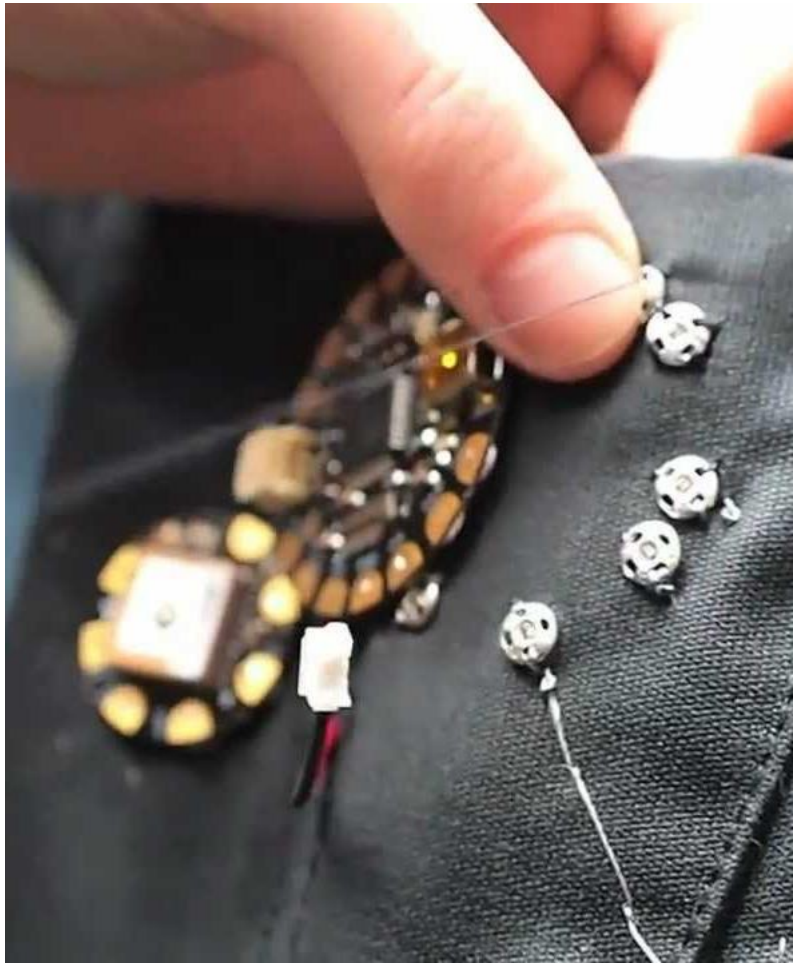
MAKERWEAR INTRODUCTION

CURRENT WEARABLE TOOLKITS

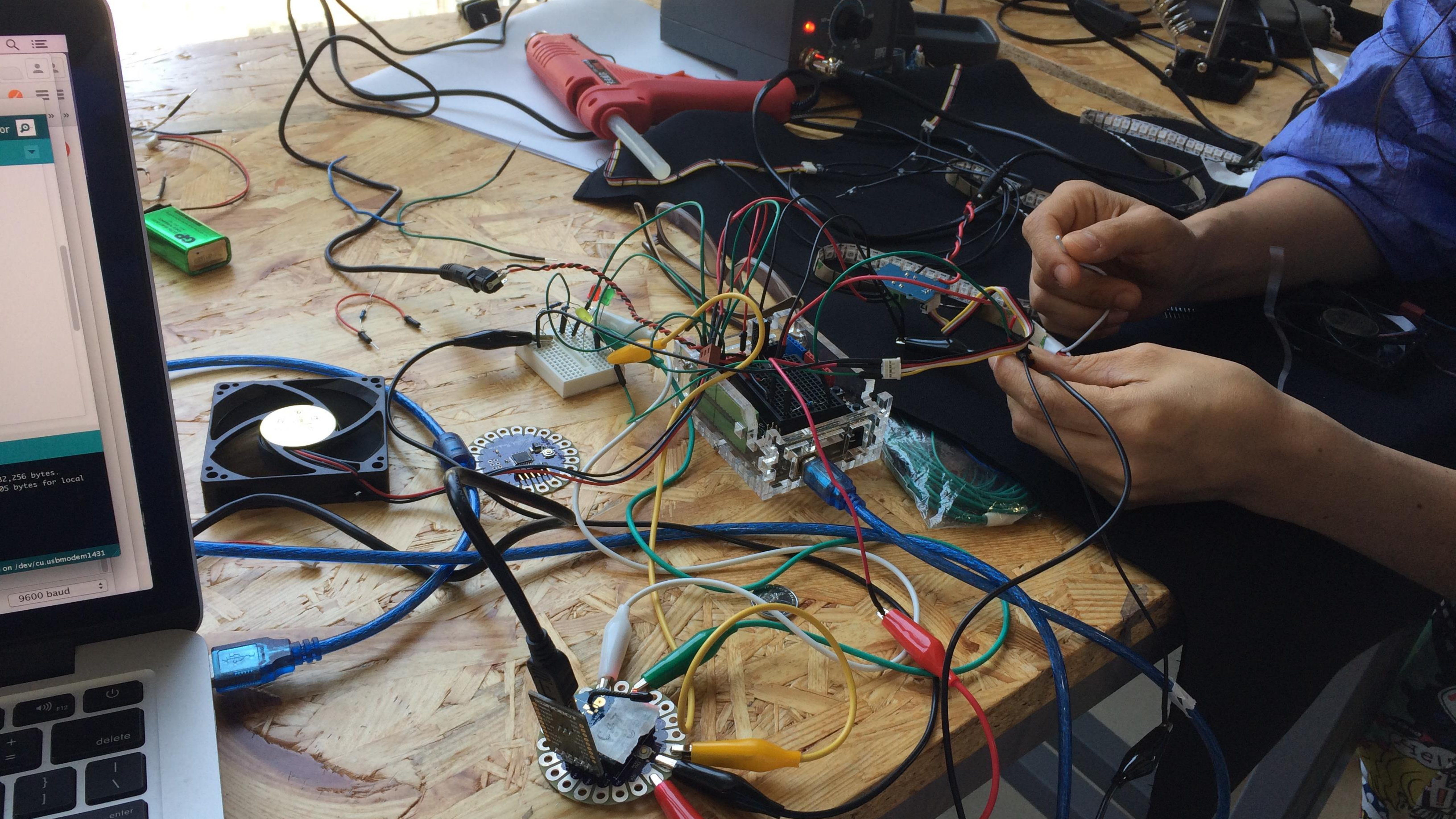


EMBEDDED PROGRAMMING

BASIC CIRCUIT & ELECTRONICS KNOWLEDGE



MANUAL SKILLS LIKE SEWING / SOLDERING


on /dev/cu.usbmodem1431
9600 baud
delete
enter

Buechley, 2006; Davis, *et al.,* 2013; DuMont & Lee, 2015; Dunne *et al.,* 2015; Kafai *et al.,* 2014; Katterfeldt *et al.,* 2009; Ngai *et al.,* 2013; Richard & Kafai, 2015; Searle, *et al.,* 2014

OVERARCHING RESEARCH QUESTIONS

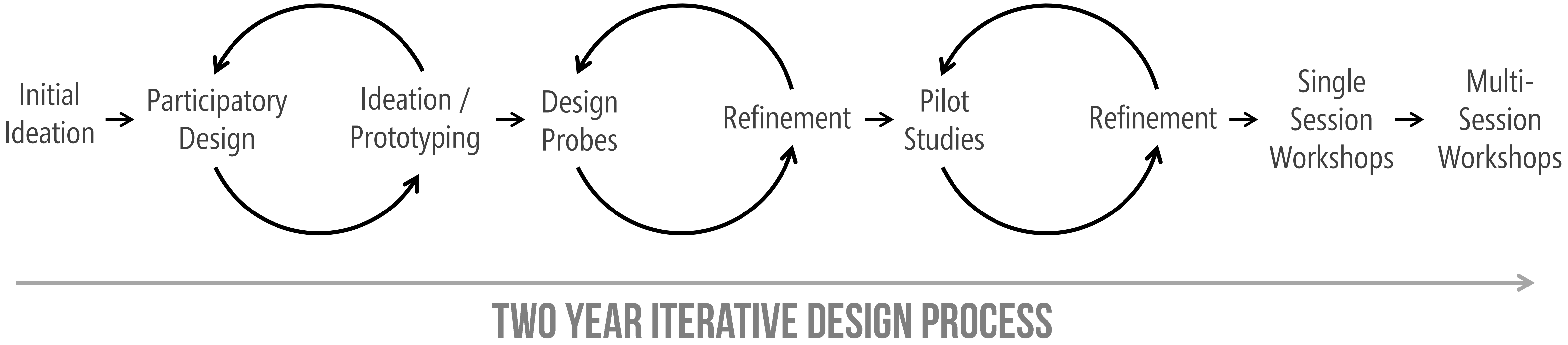
How can we enable young children (elementary age) to design & build their own interactive wearables?

What do children *want* to build and *how* can we support these goals?

How does working with our tools & techniques impact skill development & perceptions of STEM?

MAKERWEAR

DESIGN & EVALUATION PROCESS



PARTICIPATORY DESIGN

Cooperative Inquiry

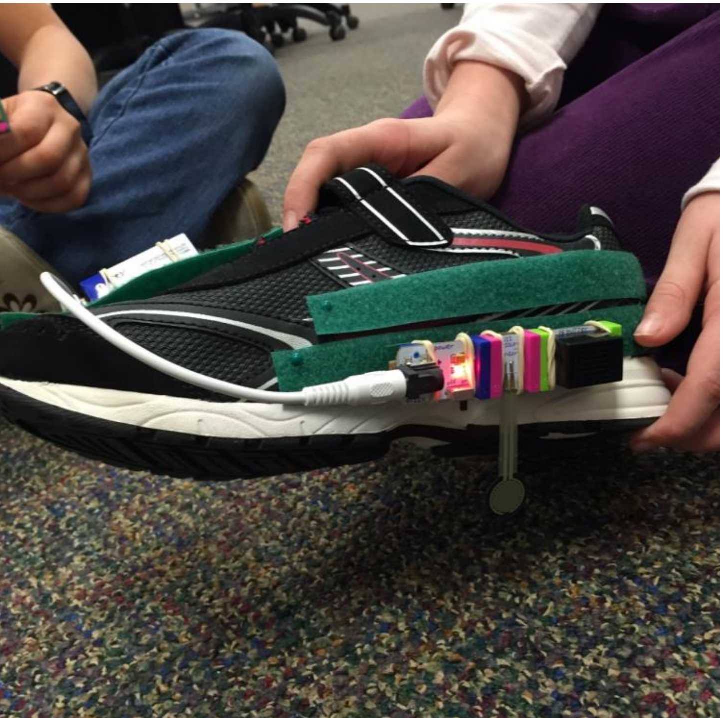
Cooperative Inquiry: Guha, Druin, & Fails, 2013

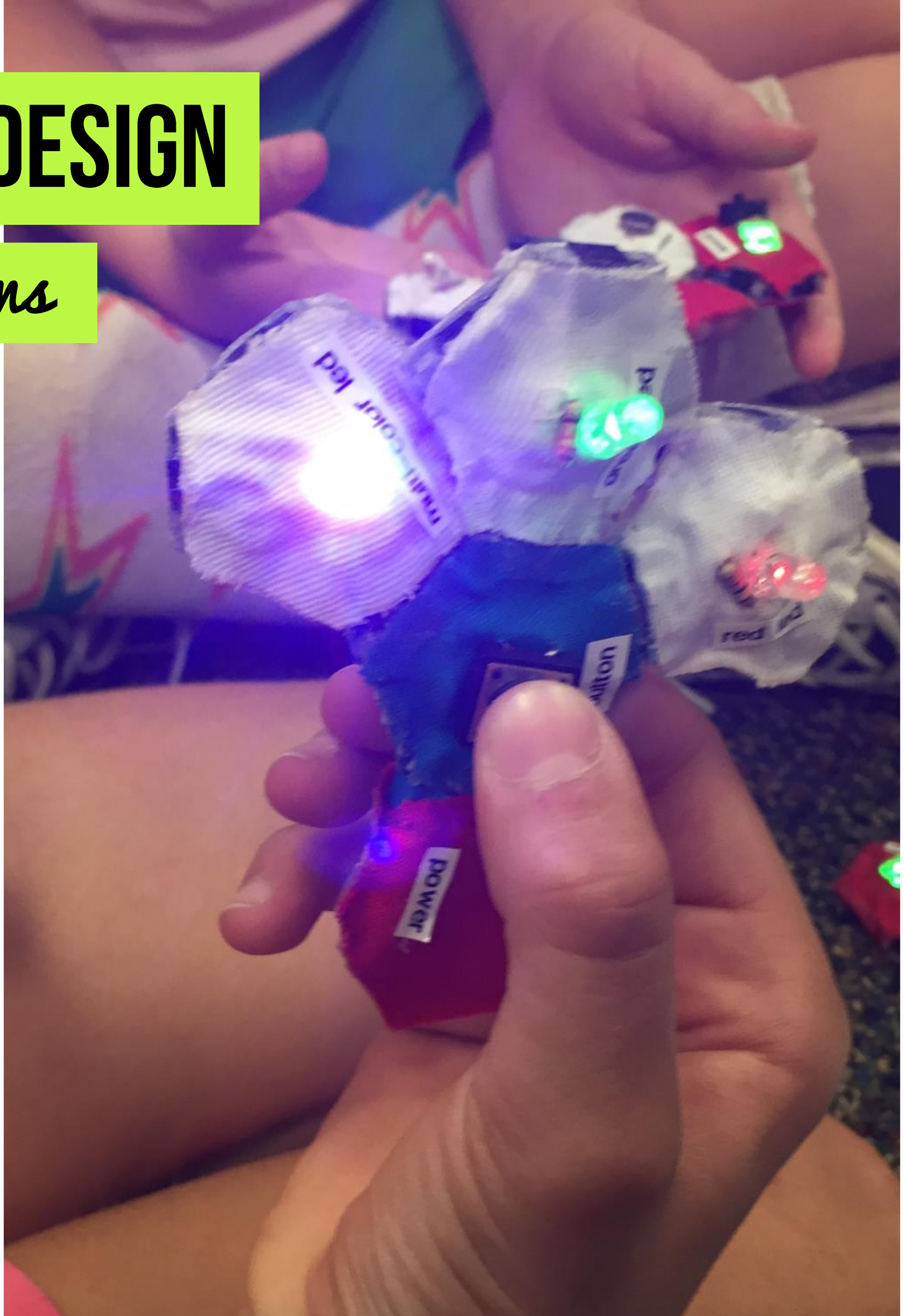
PARTICIPATORY DESIGN

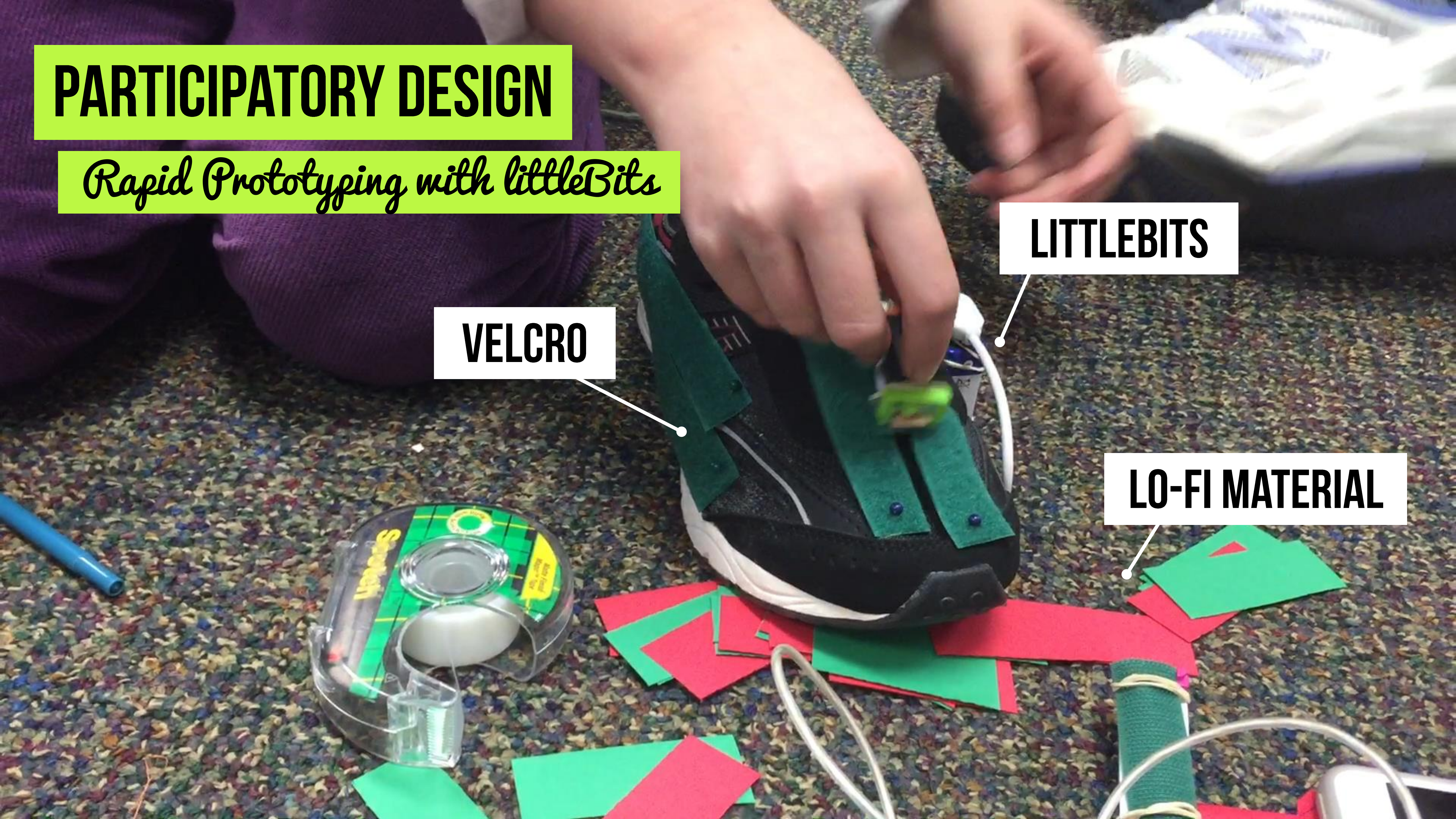
Initial Sessions

PARTICIPATORY DESIGN

Follow-up Sessions






PARTICIPATORY DESIGN
Rapid Prototyping with littleBits
LITTLEBITS
VELCRO
LO-FI MATERIAL

PARTICIPATORY DESIGN

Rapid Prototyping with littleBits

WHAT DO CHILDREN WANT TO DESIGN WITH WEARABLES?

React to body movement & physiology (*e.g.,* heartrate)

Recognize gestures & physical actions (*e.g.,* recognize a jump)

Support social interaction (*e.g.,* vibrate when friend nearby)

Augment play experiences (*e.g.,* freeze tag)

Respond to environment (*e.g.,* increase visibility at night)

DESIGN PROBE

STEM Educators

MAKERWEAR DESIGN PROBE

STEM EDUCATOR FEEDBACK

REACTIONS

Wearables as a design platform

High tinkerability

Wide walls

DESIGN IDEAS

New modules

Better support for lo-fi materials

Child-friendly iconography & text

THE MAKERWEAR SYSTEM

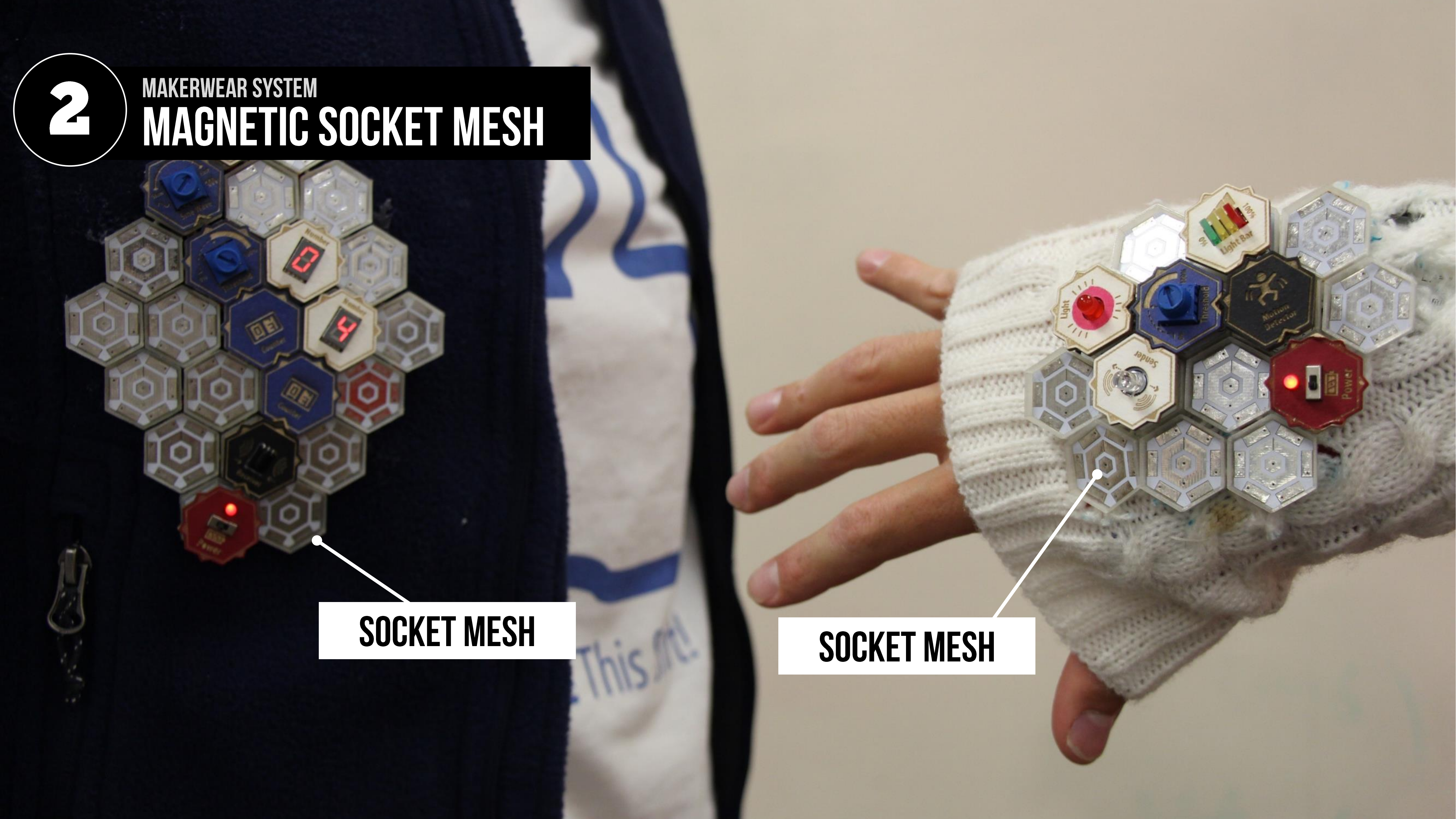
https://github.com/MakerWear

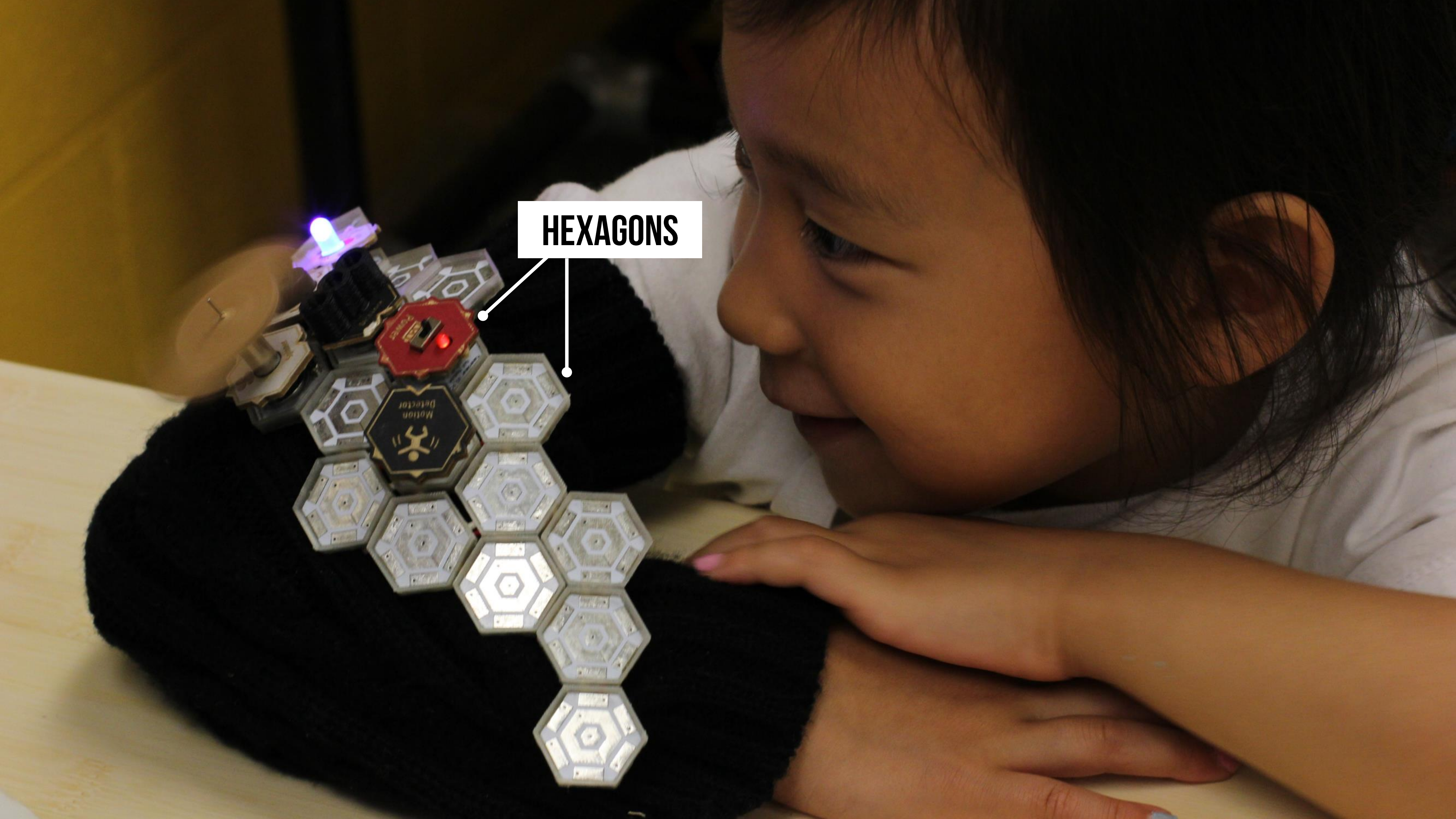

Light
Light
Light
Vibration

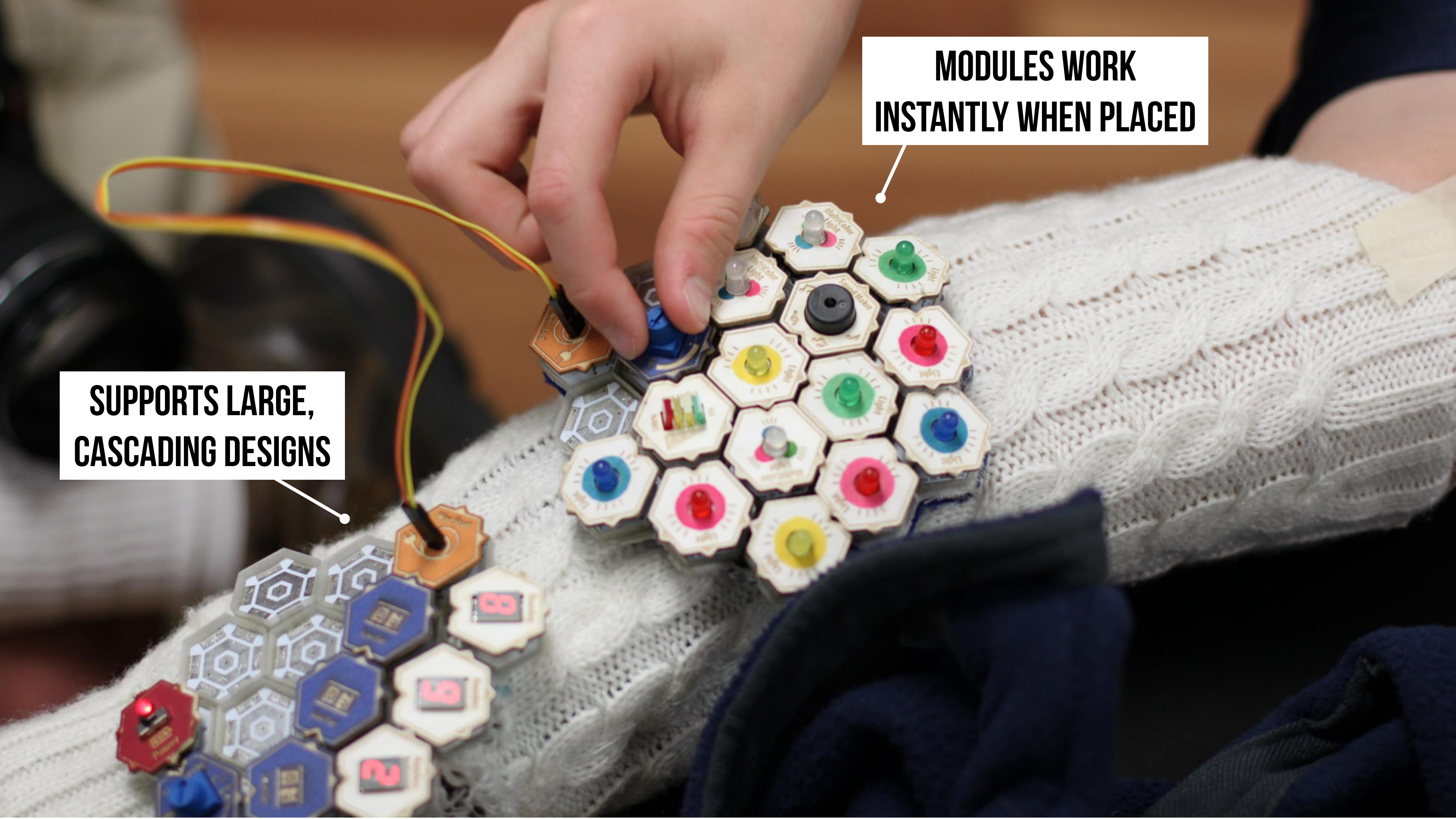
1

MAKERWEAR SYSTEM

TANGIBLE MODULES

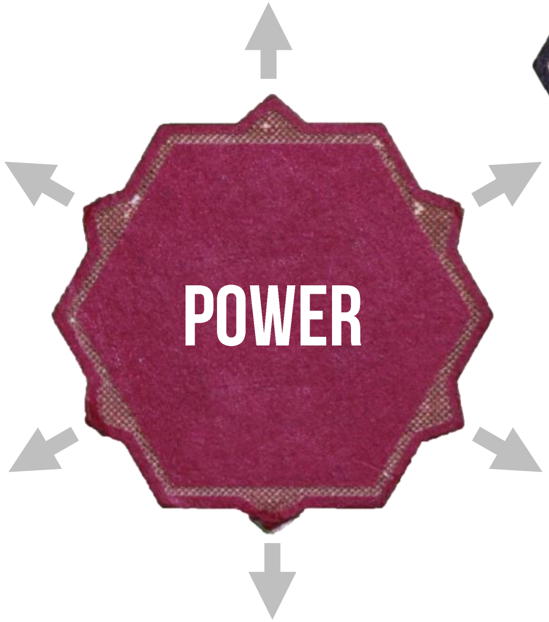

2
MAKERWEAR SYSTEM
MAGNETIC SOCKET MESH
SOCKET MESH
SOCKET MESH


HEXAGONS
Motion Detector

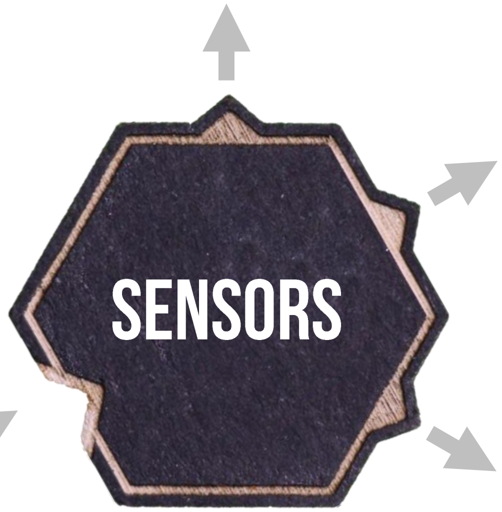

MODULES WORK
INSTANTLY WHEN PLACED
SUPPORTS LARGE,
CASCADING DESIGNS

MAKERWEAR SYSTEM

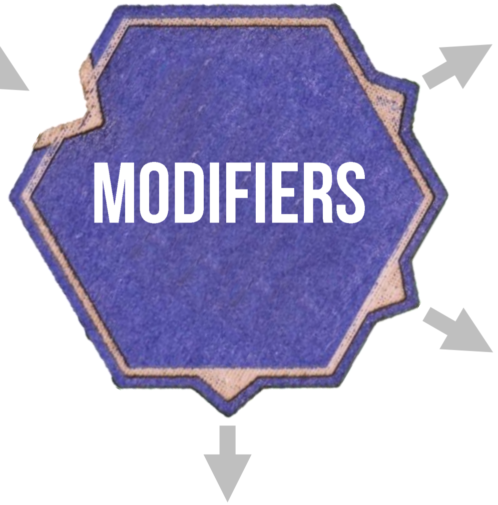
5 MODULE TYPES



Provides **power** to all connected modules

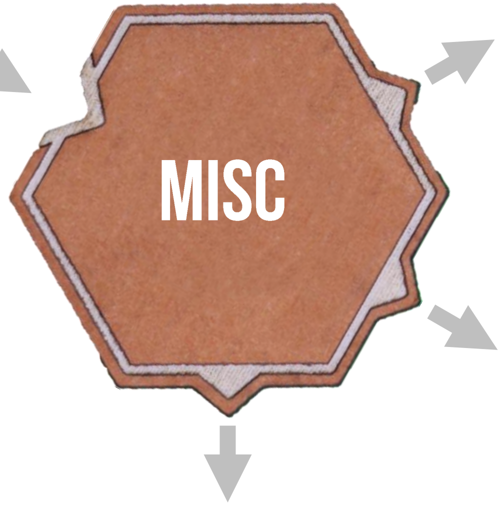


Sense & **translate** physical phenomena into analog signals



Transform signals into other types of signals

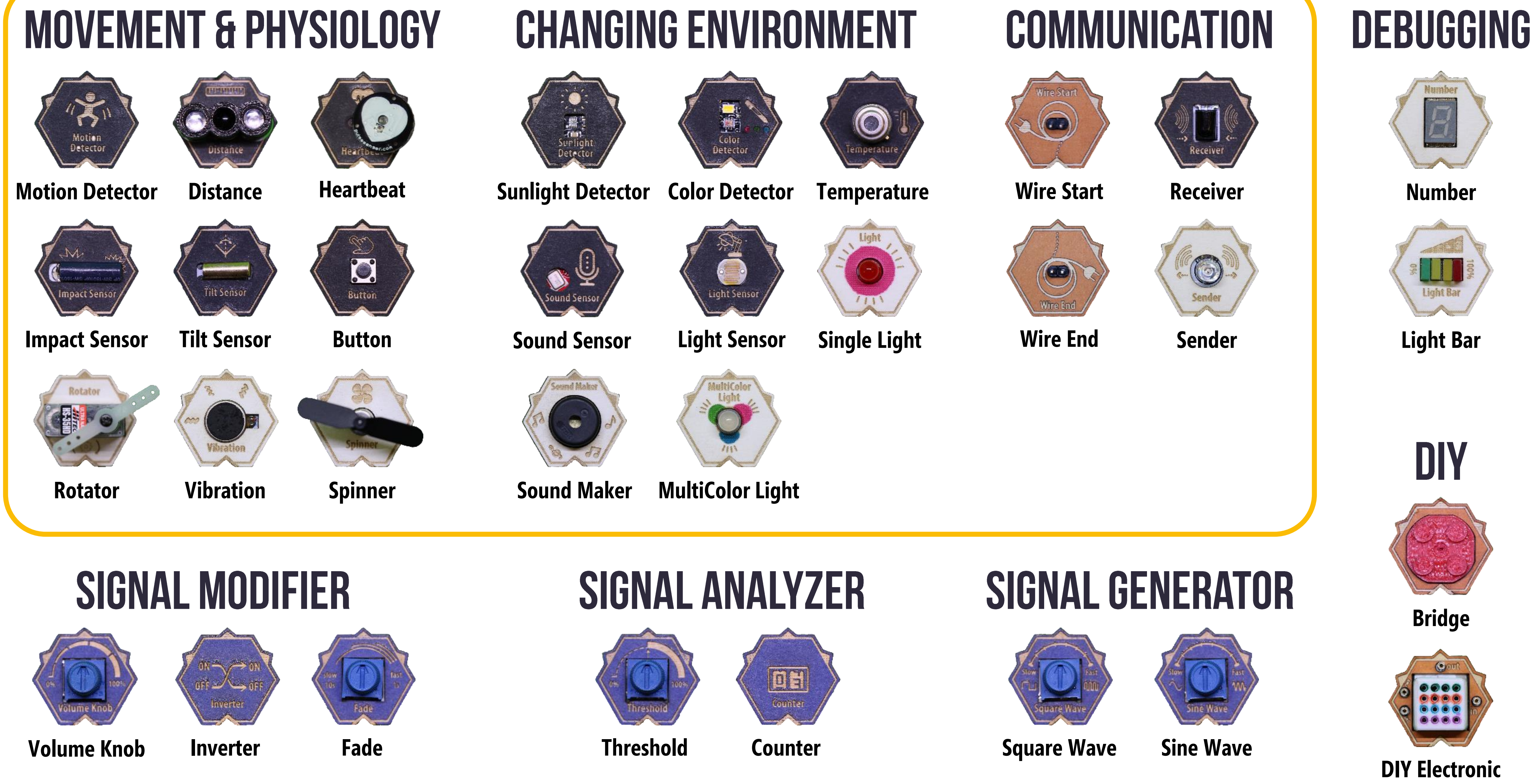
Translate signals into perceptual forms

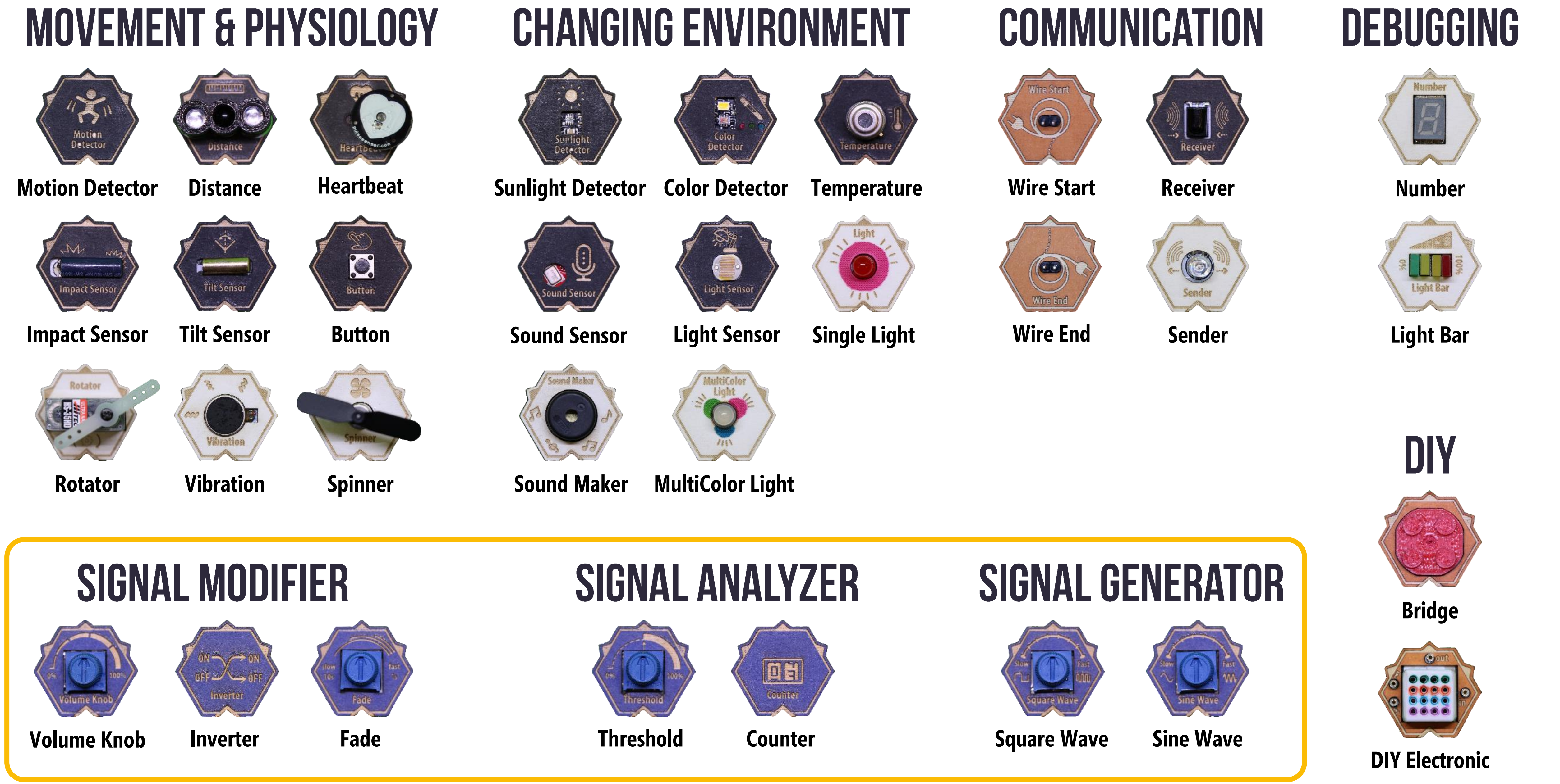


Miscellaneous (*e.g.,* DIY module)

MAKERWEAR SYSTEM

MODULE LIBRARY: 32 MODULES


MOVEMENT & PHYSIOLOGY
Motion Detector
Distance
Heartbeat
Impact Sensor
Tilt Sensor
Button
Rotator
Vibration
Spinner
CHANGING ENVIRONMENT
Sunlight Detector
Color Detector
Temperature
Sound Sensor
Light Sensor
Single Light
Sound Maker
MultiColor Light
COMMUNICATION
Wire Start
Receiver
Wire End
Sender
DEBUGGING
Number
Light Bar
DIY
Bridge
DIY Electronic
SIGNAL MODIFIER
Volume Knob
Inverter
Fade
SIGNAL ANALYZER
Threshold
Counter
SIGNAL GENERATOR
Square Wave
Sine Wave


MOVEMENT & PHYSIOLOGY
Motion Detector
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Counter
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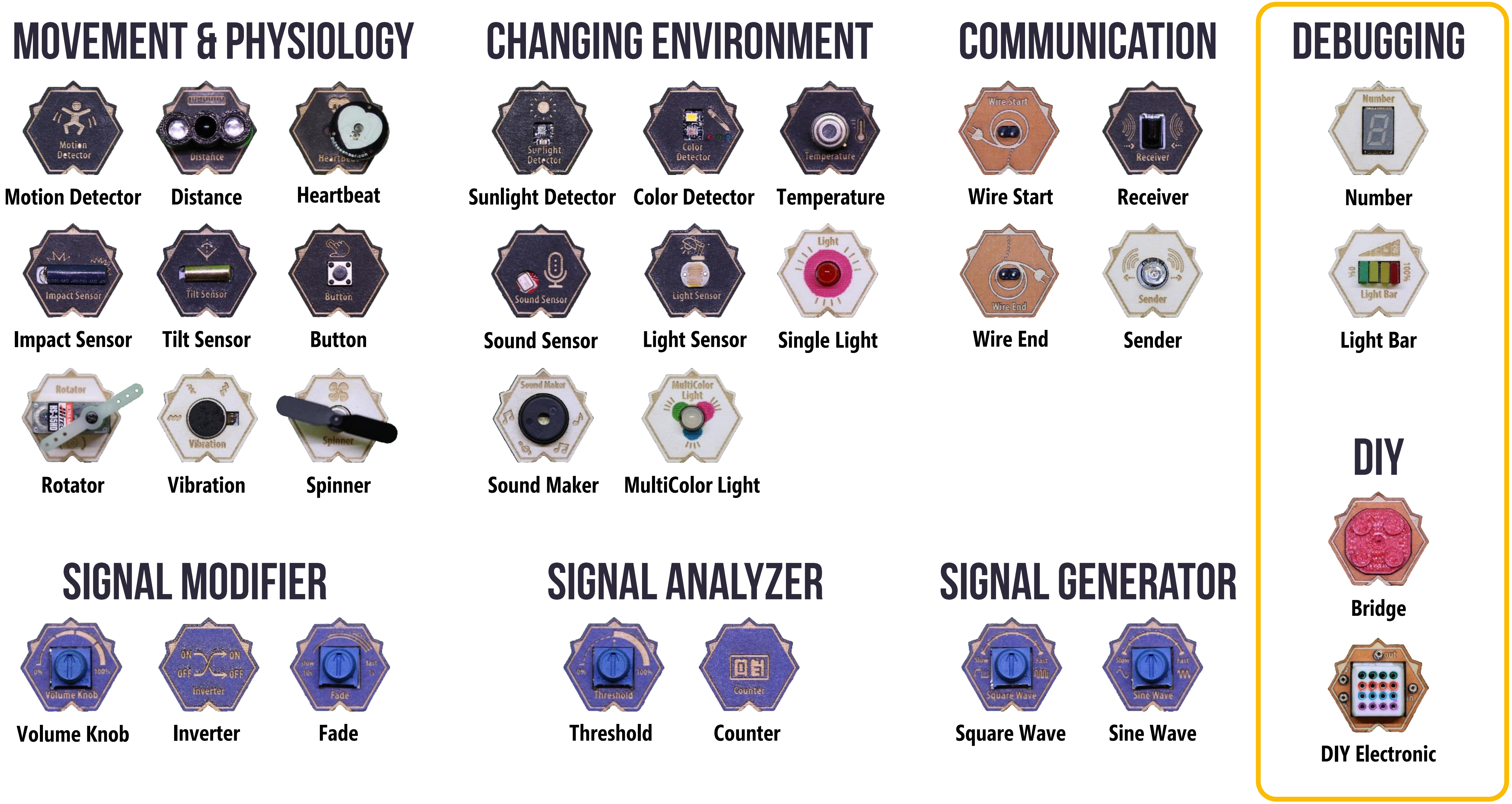
Square Wave
Sine Wave


MOVEMENT & PHYSIOLOGY
Motion Detector
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Heartbeat
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Button
Rotator
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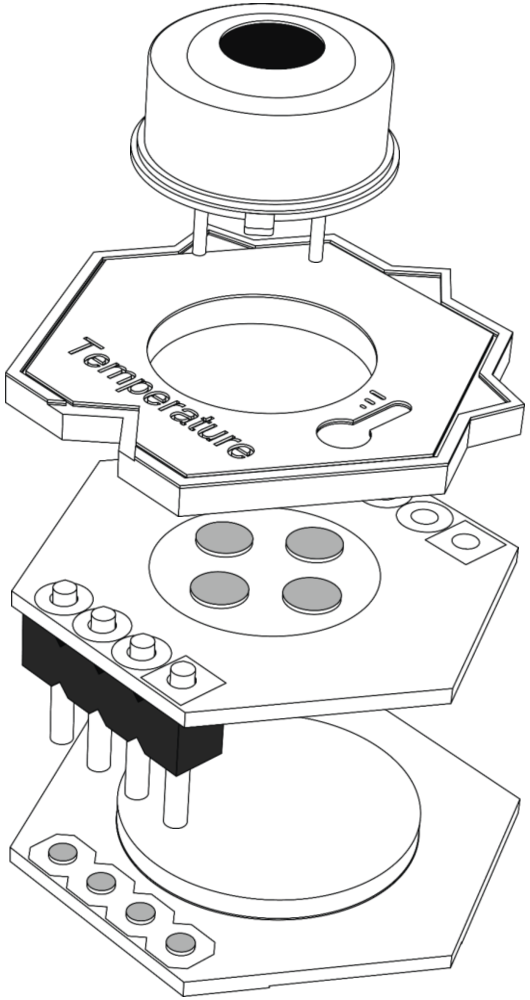
CHANGING ENVIRONMENT
Sunlight Detector
Color Detector
Temperature
Sound Sensor
Light Sensor
Single Light
Sound Maker
MultiColor Light
COMMUNICATION
Wire Start
Receiver
Wire End
Sender
DEBUGGING
Number
Light Bar
DIY
Bridge
DIY Electronic
SIGNAL MODIFIER
Volume Knob
Inverter
Fade
SIGNAL ANALYZER
Threshold
Counter
SIGNAL GENERATOR
Square Wave
Sine Wave

MAKERWEAR SYSTEM

MODULE EXPLODED VIEW

Temperature Sensor

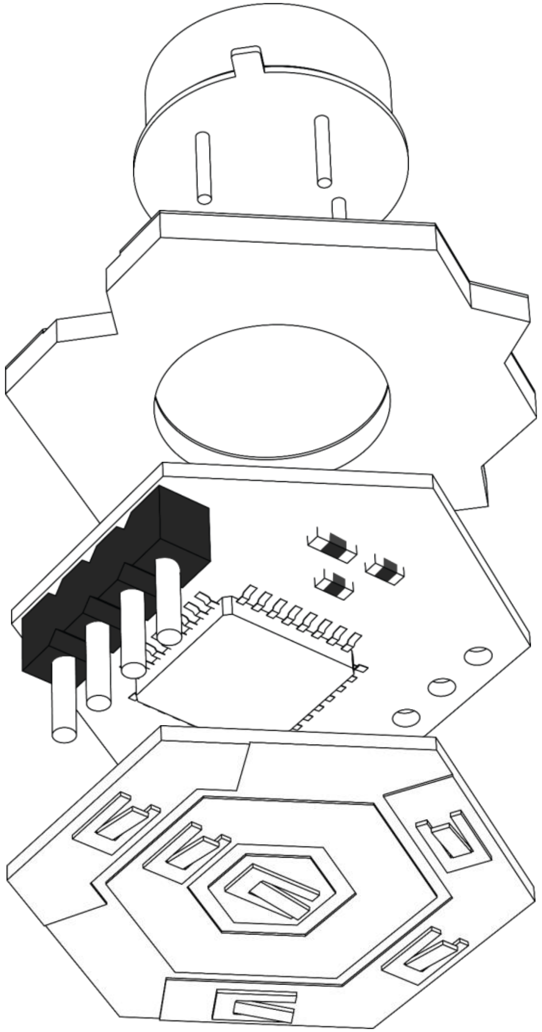


LAYER 1
Exposed electronic component

LAYER 2
Laser cut module cover

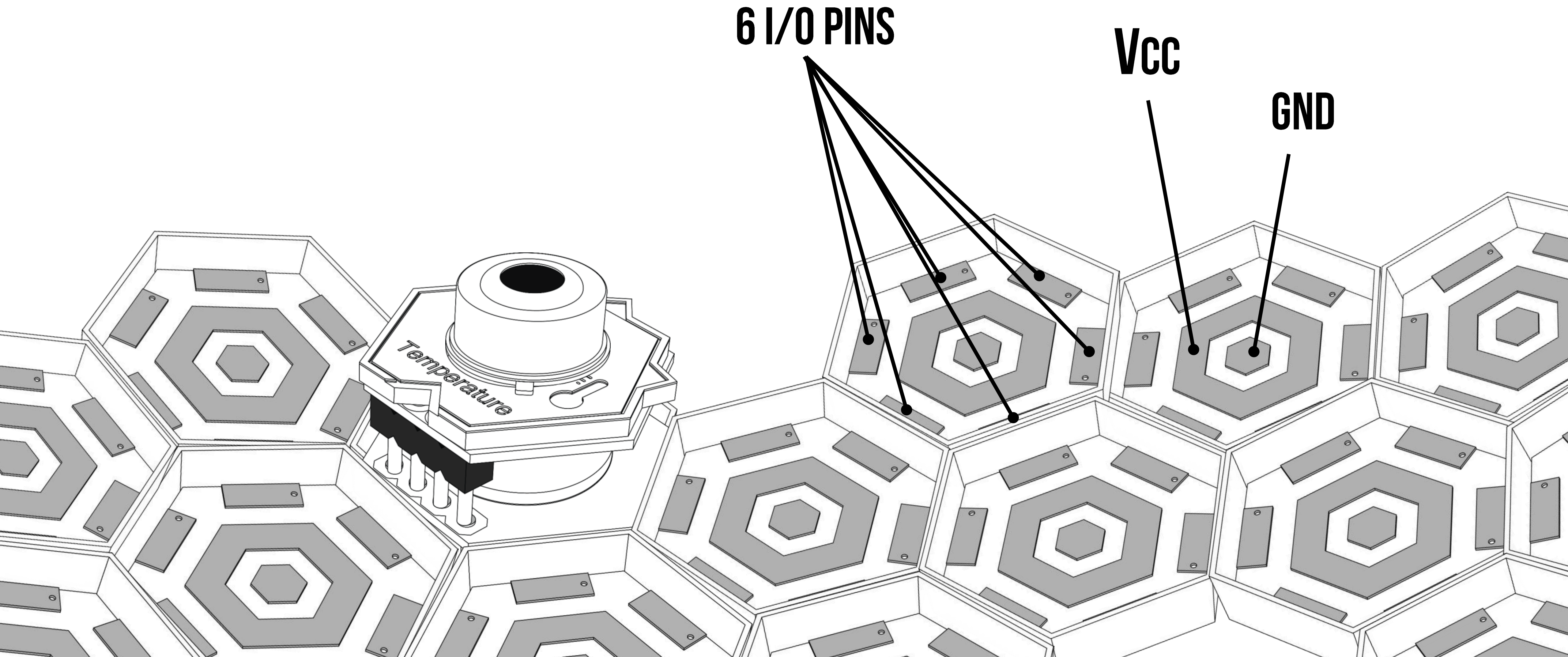
LAYER 3
Custom PCB with embedded microcontroller & SMD components

LAYER 4
Custom PCB with neodymium magnet & contact spring for socket connection



MAKERWEAR SYSTEM

SOCKET MESH



MAKERWEAR SYSTEM

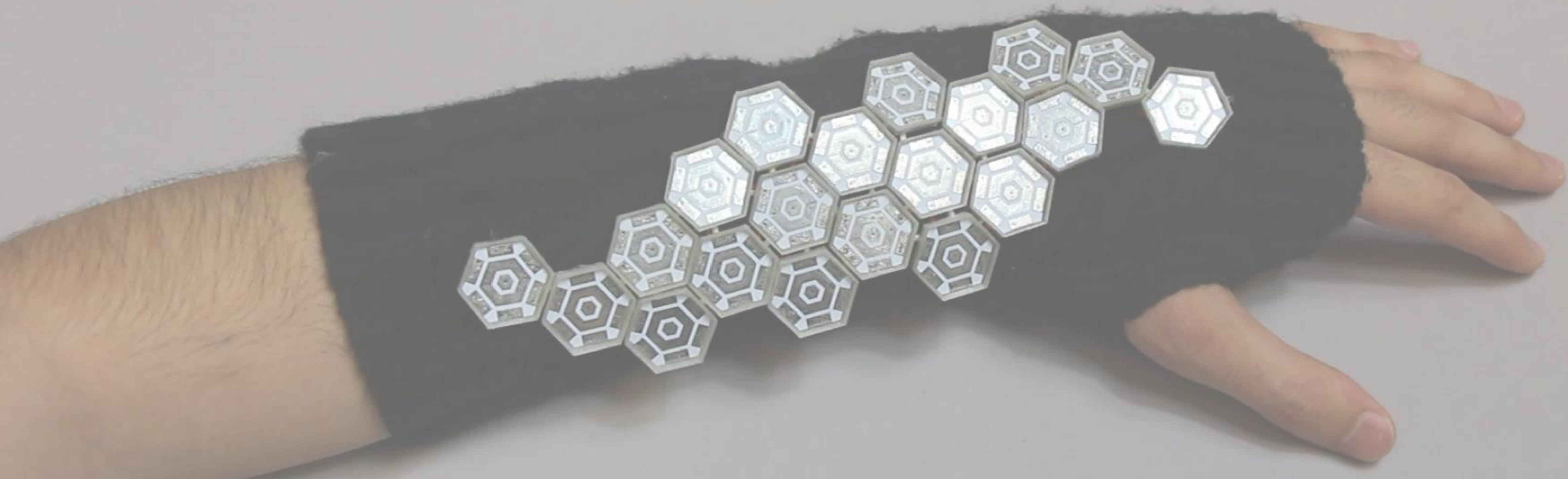
TWO TYPES OF SOCKET MESHES

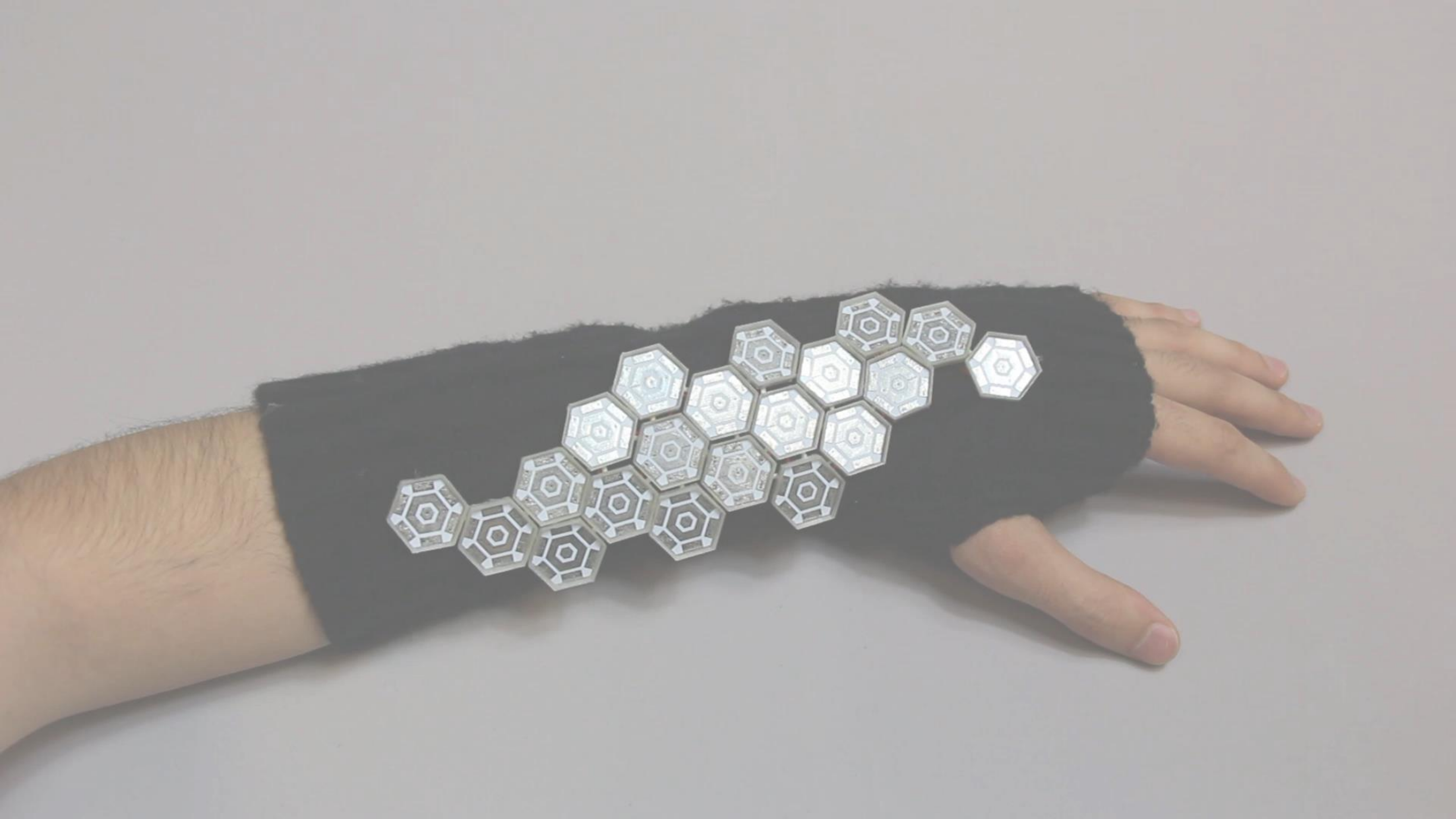


1. SEWN INTO CLOTHES

2. FABRIC PATCH

CREATING WITH MAKERWEAR





MAKERWEAR EVALUATION

WORKSHOP-BASED EVALUATIONS

32 children (16 female; ages 5-12; *avg*=8.3)

Two single-session workshops (*N*=13)

Three four-session workshops (*N*=19)

Workshops common method for e-textile studies. *E.g.,* Buechley *et al.,* 2006; Katterfeldt *et al.,* 2009; Searle *et al.,* 2014; Richard & Kafai, 2015;

MAKERWEAR EVALUATION

WORKSHOP SESSIONS & DEMOGRAPHICS

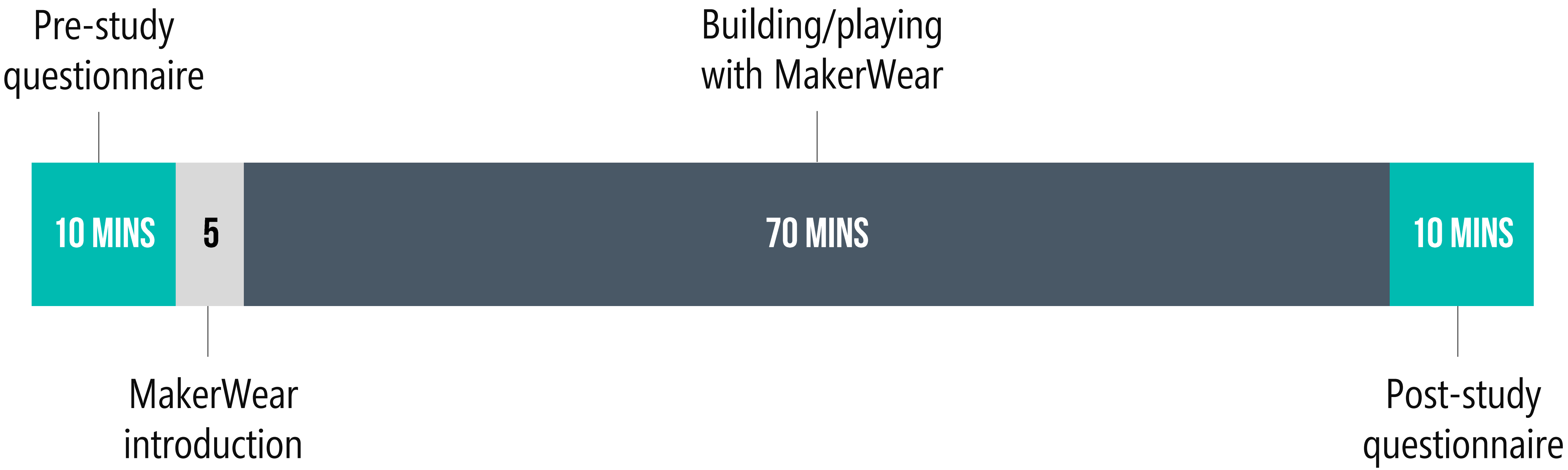
	Group	Ages (Avg)	N (female)
SINGLE SESSION	1	5-7 (6.0)	5 (5)
	2	8-12 (9.9)	8 (3)
MULTI-SESSION	1	5-7 (6.3)	7 (3)
	2	8-9 (8.8)	6 (1)
	3	8-12 (10.2)	6 (4)
	Total	**5-7 (8.3)**	**32 (16)**

WORKSHOP SESSIONS & DEMOGRAPHICS

	Group	Ages (Avg)	N (female)	Uses computer at least a few times a week	Has used a graphical programming system (*e.g.,* Scratch)	Has used an electronic kit (*e.g.,* Snap Circuits, Lego Mindstorms, littleBits)
SINGLE SESSION	1	5-7 (6.0)	5 (5)	100%	40%	20%
	2	8-12 (9.9)	8 (3)	88%	38%	50%
MULTI-SESSION	1	5-7 (6.3)	7 (3)	100%	57%	57%
	2	8-9 (8.8)	6 (1)	83%	50%	66%
	3	8-12 (10.2)	6 (4)	83%	83%	66%
	Total	**5-7 (8.3)**	**32 (16)**	**91%**	**53%**	**53%**

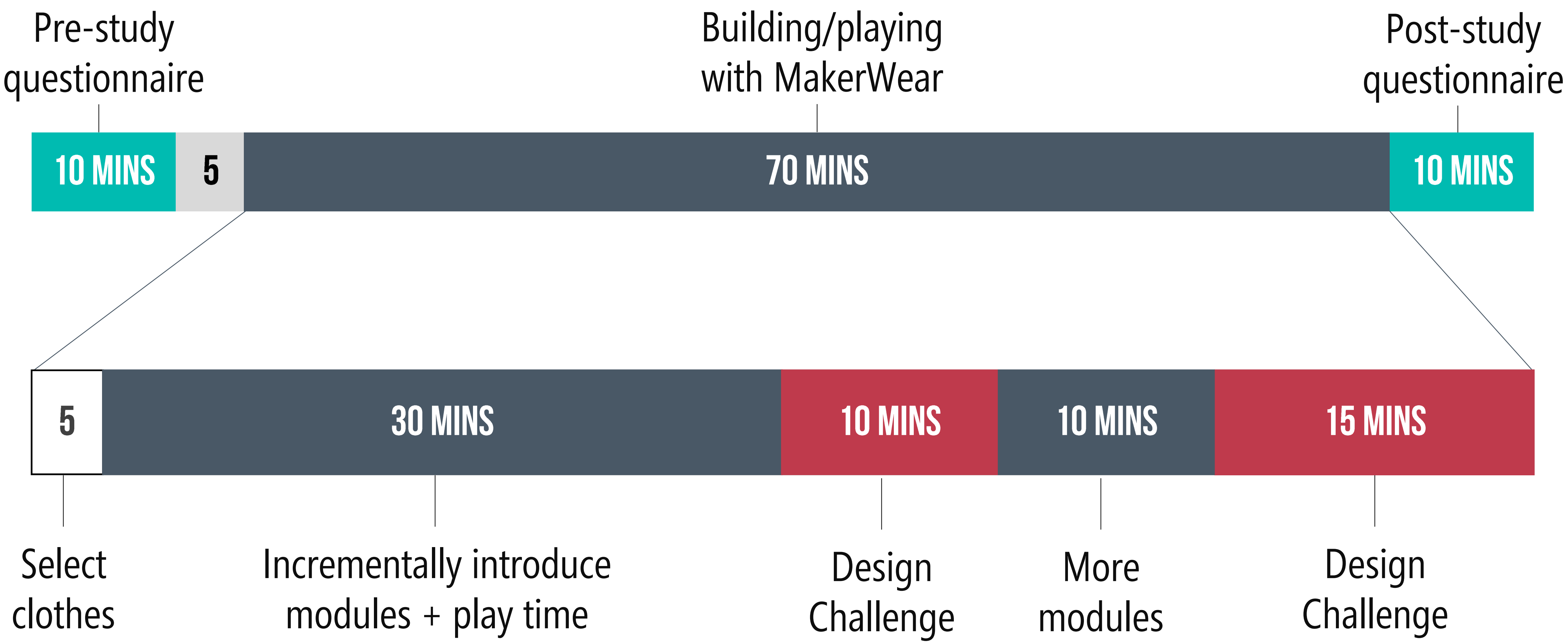
MAKERWEAR EVALUATION

SINGLE-SESSION WORKSHOP PROCEDURE

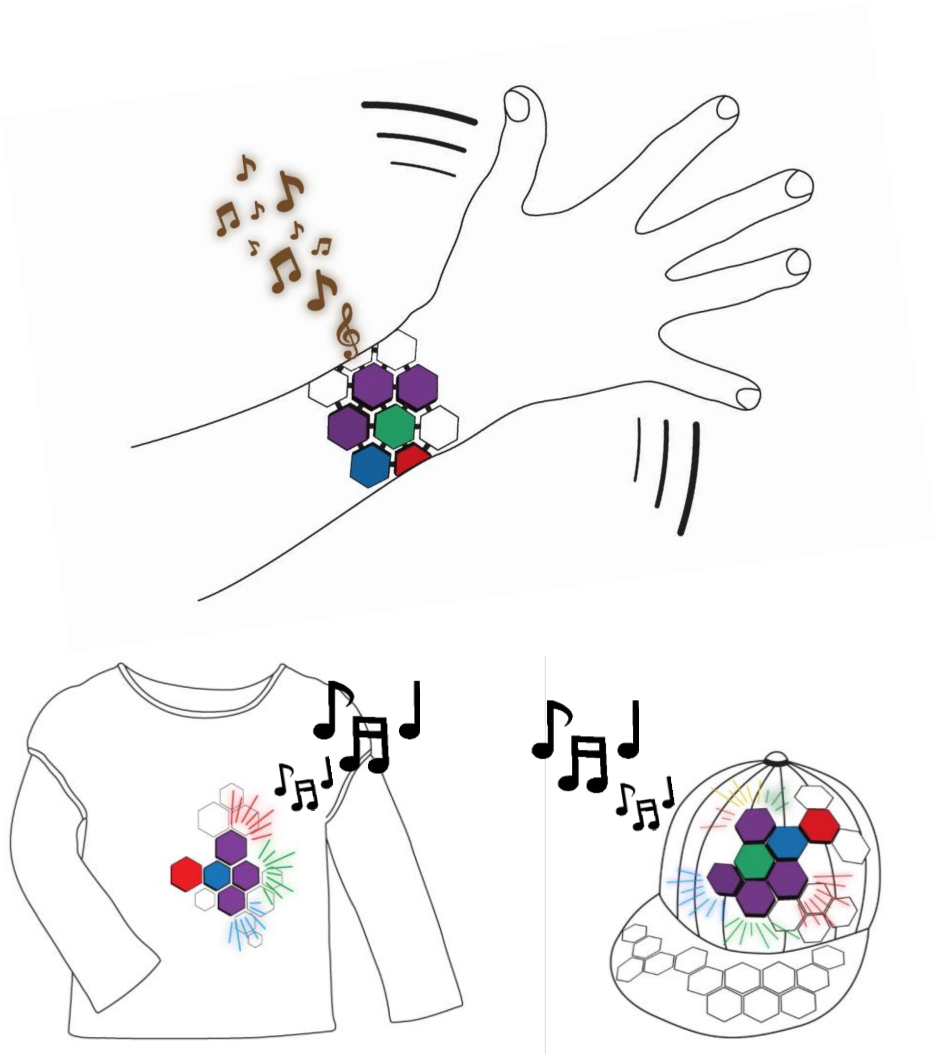


MAKERWEAR EVALUATION

SINGLE-SESSION WORKSHOP PROCEDURE



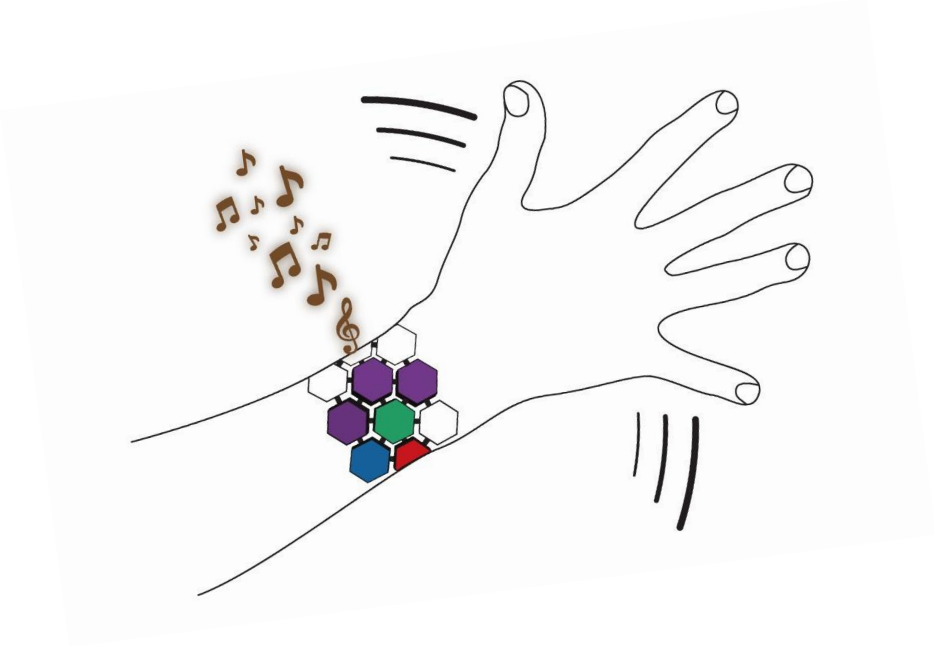
EASY DESIGN CHALLENGE

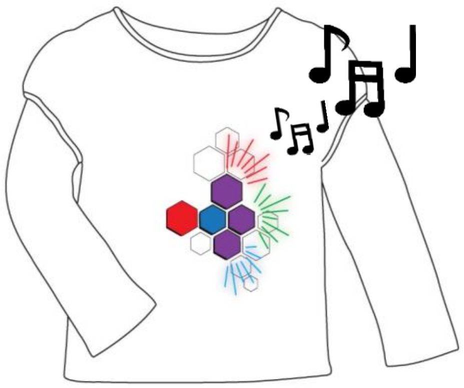


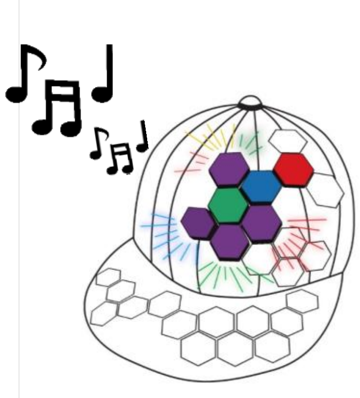
DESIGN PROMPT: WEARABLE INSTRUMENT

Build your own wearable instrument that **makes music** and **lights up** when you **move.**

EASY DESIGN CHALLENGE







DESIGN PROMPT: WEARABLE INSTRUMENT

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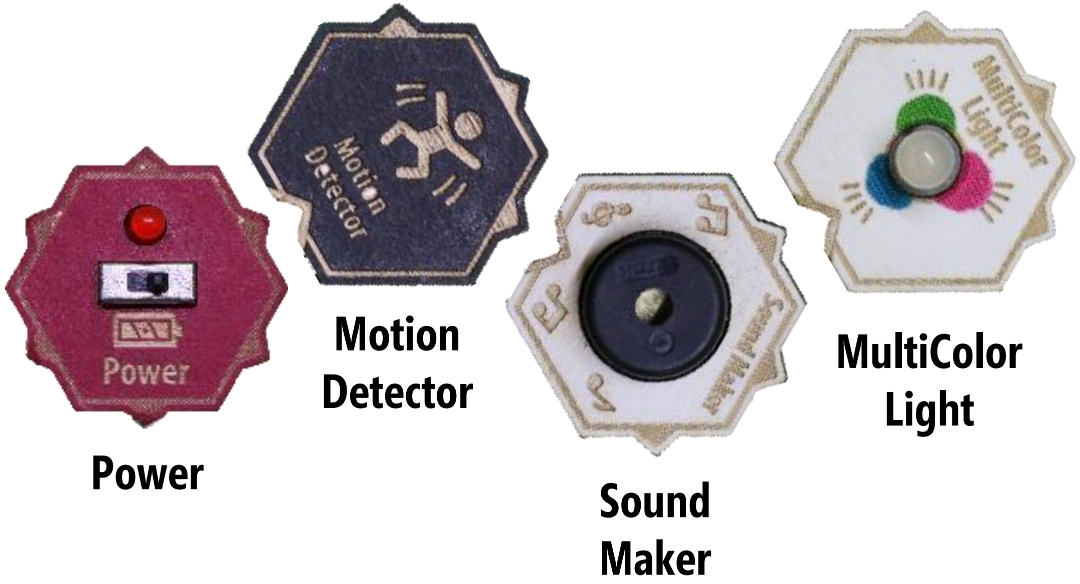
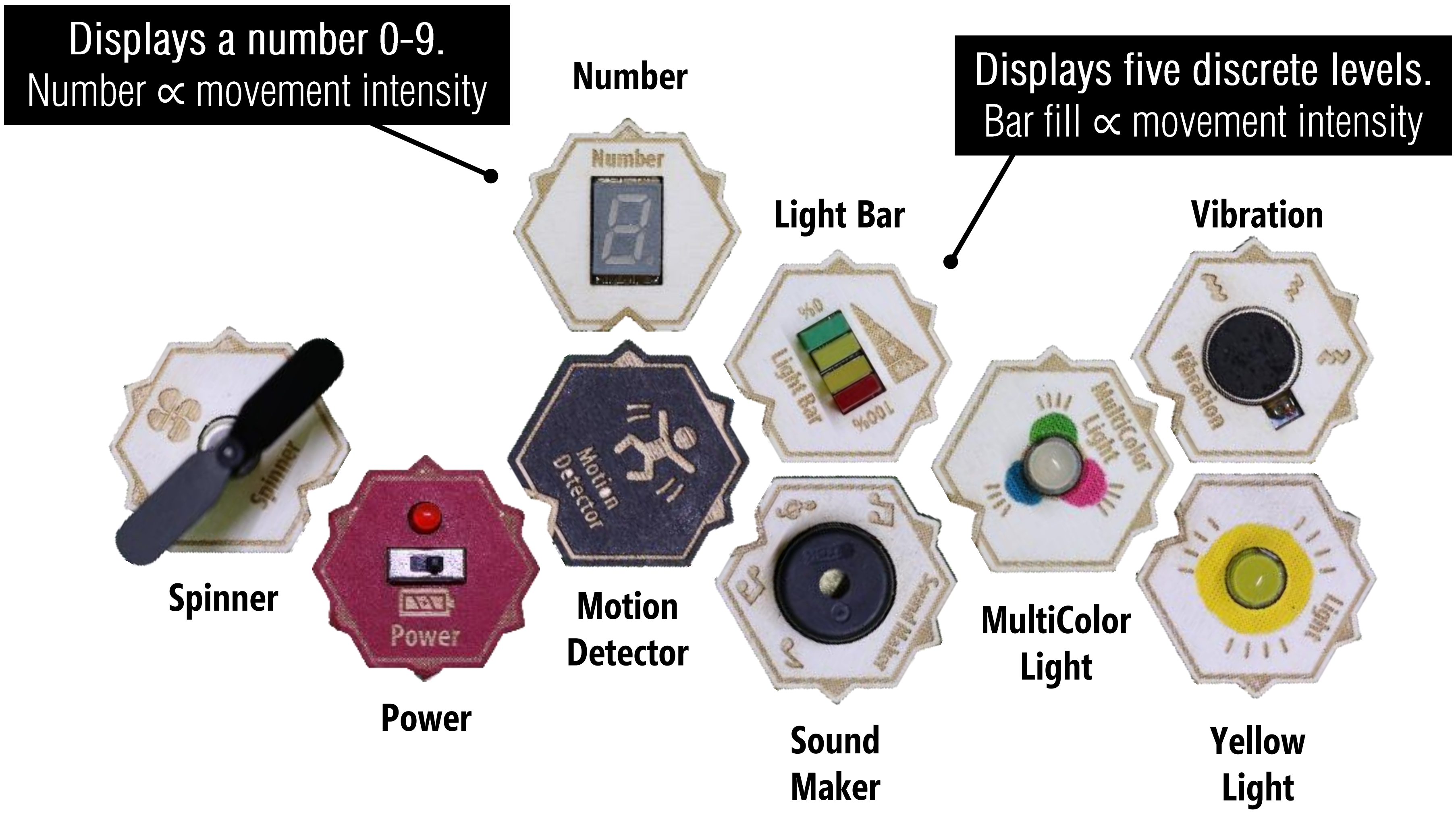
EXAMPLE SOLUTION




Displays a number 0-9.
Number ∝ movement intensity
Number
Displays five discrete levels.
Bar fill ∝ movement intensity
Light Bar
Vibration
Spinner
Power
Motion Detector
Sound Maker
MultiColor Light
Yellow Light

MAKERWEAR WORKSHOPS

EXAMPLE DESIGN CHALLENGE

DESIGN PROMPT: WEARABLE INSTRUMENT

Build your own wearable instrument that **makes music** and **lights up** when you **move.**

HARDER DESIGN CHALLENGE

DESIGN PROMPT: BUZZ LIGHTYEAR

Build a wearable for **Buzz Lightyear** that has two modes:

1. In attack mode, you shoot “laser beams” (lights).

2. In defend mode, you activate a LEGO shield.

The two modes are **automatically activated** based on your arm’s position (up *vs.* out) but the **catch** is that you cannot attack & defend at the same time.

HARDER DESIGN CHALLENGE

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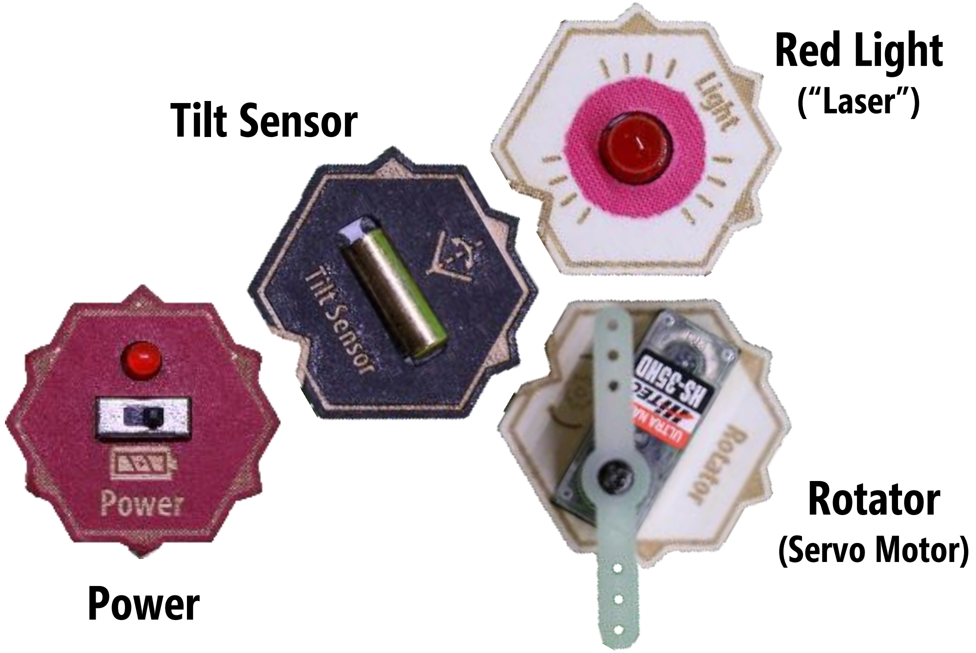
EXAMPLE SOLUTION



HARDER DESIGN CHALLENGE

DESIGN PROMPT: BUZZ LIGHTYEAR

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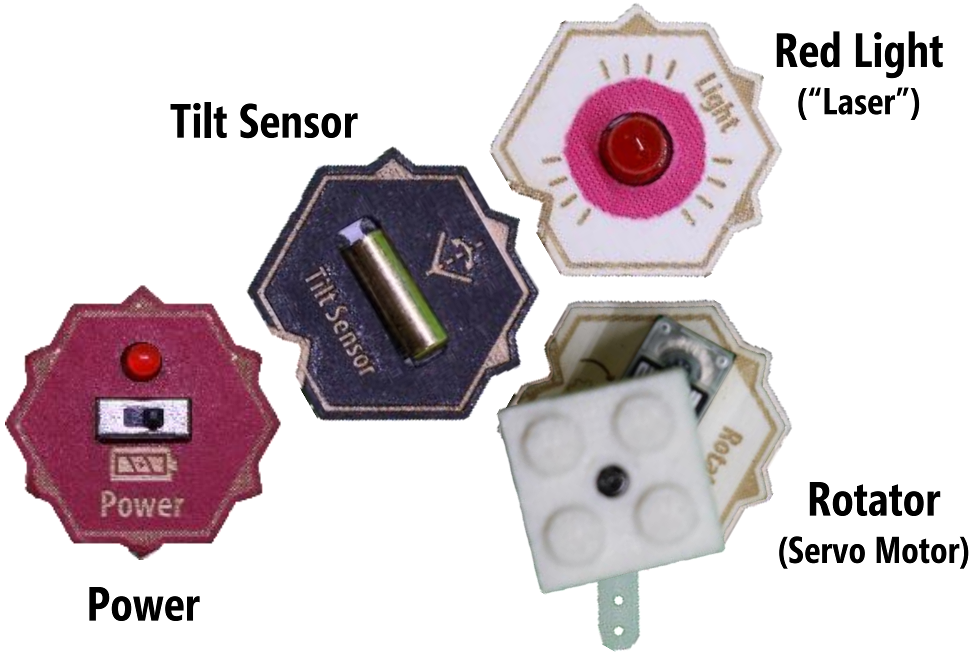
EXAMPLE SOLUTION



Oops! Both the "laser" and shield are activated at the same time!

HARDER DESIGN CHALLENGE

DESIGN PROMPT: BUZZ LIGHTYEAR

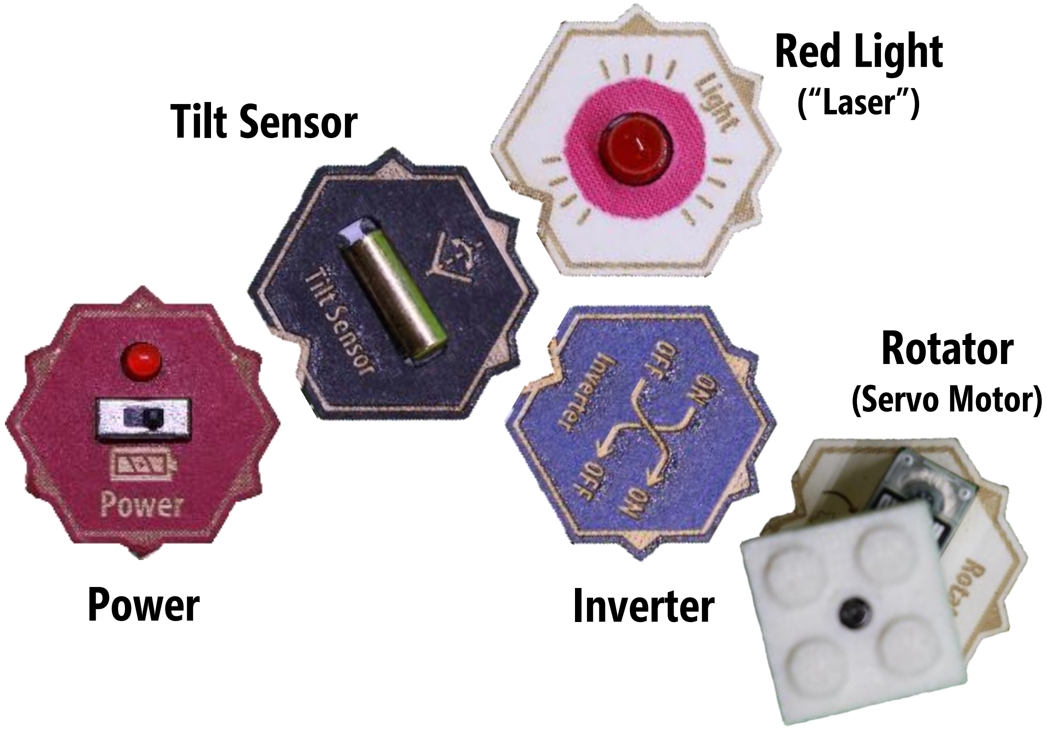
Build a wearable for **Buzz Lightyear** that has two modes:

1. In attack mode, you shoot "laser beams" (lights).

2. In defend mode, you activate a LEGO shield.

The two modes are **automatically activated** based on your arm's position (up *vs.* out) but the **catch** is that you cannot attack & defend at the same time.

EXAMPLE SOLUTION



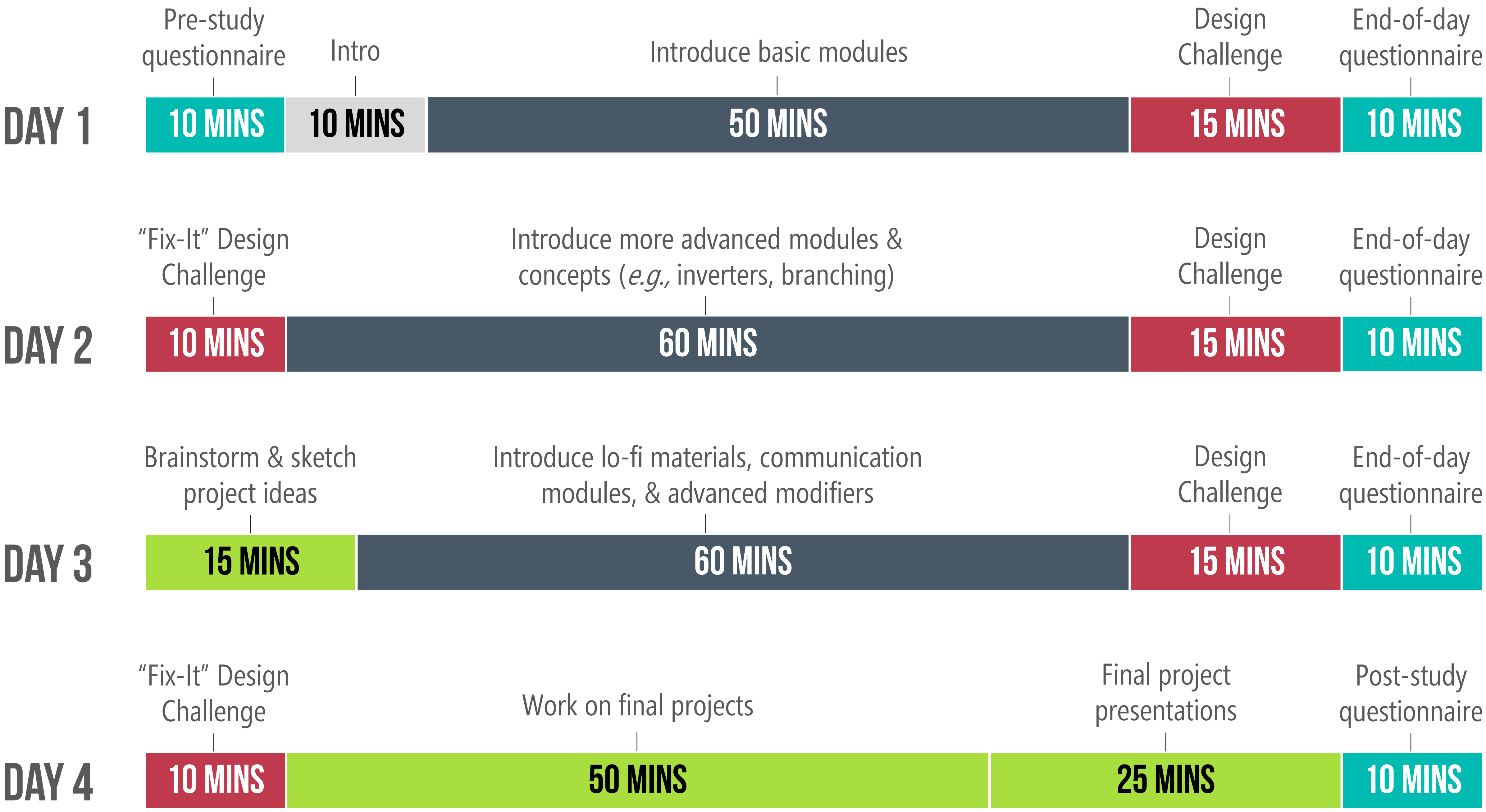
MAKERWEAR EVALUATION

MULTI-SESSION WORKSHOP PROCEDURE

DAY 1

Pre-study questionnaire	Intro	Introduce basic modules	Design Challenge	End-of-day questionnaire
10 MINS	10 MINS	50 MINS	15 MINS	10 MINS

Aspects of multi-session procedure based on Marina Bers *TangibleK Robotics Program;* Bers *et al.*, 2014; Sullivan & Bers, 2016


DAY 1
Pre-study questionnaire
10 MINS
Intro
10 MINS
Introduce basic modules
50 MINS
Design Challenge
15 MINS
End-of-day questionnaire
10 MINS
DAY 2
"Fix-It" Design Challenge
10 MINS
Introduce more advanced modules & concepts (e.g., inverters, branching)
60 MINS
Design Challenge
15 MINS
End-of-day questionnaire
10 MINS
DAY 3
Brainstorm & sketch project ideas
15 MINS
Introduce lo-fi materials, communication modules, & advanced modifiers
60 MINS
Design Challenge
15 MINS
End-of-day questionnaire
10 MINS
DAY 4
"Fix-It" Design Challenge
10 MINS
Work on final projects
50 MINS
Final project presentations
25 MINS
Post-study questionnaire
10 MINS

MAKERWEAR EVALUATION

RESEARCH FOCI

How children make with MakerWear, what they make, & challenges therein

Overall understanding (*e.g.,* actions vs. sensors)

Computational thinking (*e.g.,* sequencing, branching)

Subjective factors (*e.g.,* enjoyment)

RESEARCH FOCI (MULTI-SESSION ONLY)

What children designed & built for their final projects & why

How children progressed in their understanding & use of MakerWear

Age-related differences

DATA & ANALYSIS

Session video

Design challenge performance (Radar *et al.*, 1997)

End-user creations (Duncan *et al.*, 2014; Hansen *et al.*, 2015)

Artifact-based interviews (Brennan & Resnick, 2012)

Pre & post-study questionnaires


MAKERWEAR FINDINGS


MAKING WITH MAKERWEAR
Two Work Styles


MAKING WITH MAKERWEAR
Two Work Styles
GIRLS


MAKING WITH MAKERWEAR
Appropriating Modules for Debugging
SENSORS
Motion Detector
Sensor


SENSORS
Motion Detector
Sensor

MAKING WITH MAKERWEAR

Use of Wire Module


MAKING WITH MAKERWEAR
Use of Wire Module


MAKING WITH MAKERWEAR
Wire Mediates Play & Facilitates Co-Design


MAKING WITH MAKERWEAR
Creating New Behaviors

MAKERWEAR FINAL PROJECTS

WHAT DID CHILDREN MAKE?

SPORTS/FITNESS

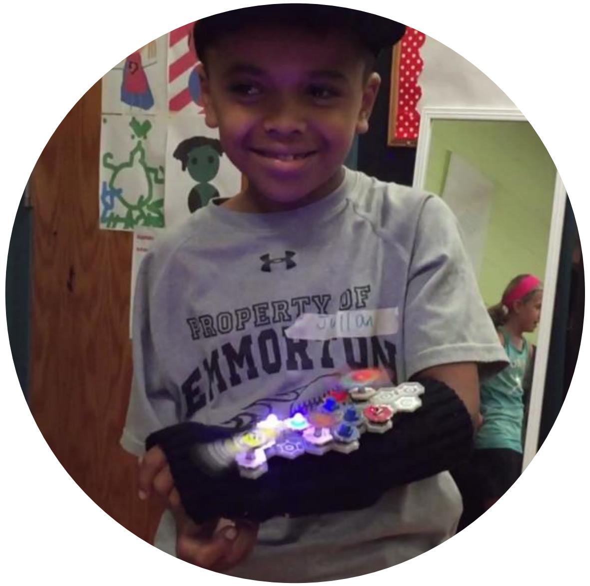
38%

ROLE PLAY

31%

SOCIO-DRAMATIC PLAY

19%



OTHER

13%

MAKERWEAR FINAL PROJECTS

WHAT DID CHILDREN MAKE?

Motion Detector
Distance
Impact Sensor
Tilt Sensor

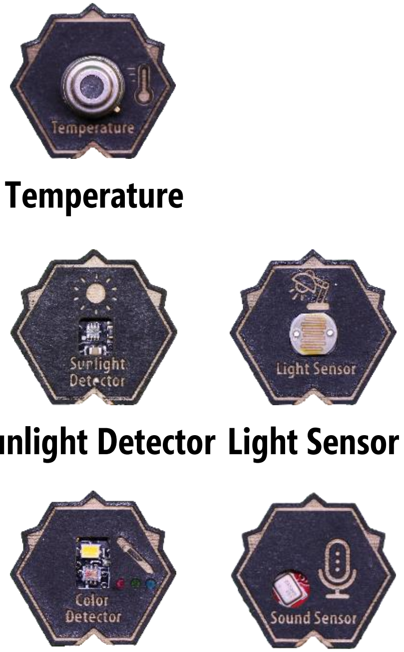
MOVEMENT

33%

Volume Knob
Button

MANUAL INPUT

24%



Temperature
Sunlight Detector
Light Sensor
Color Detector
Sound Sensor

ENVIRONMENT

19%

Heartbeat

PHYSIOLOGY

14%

Wire Start
Receiver
Wire End
Sender

SOCIAL

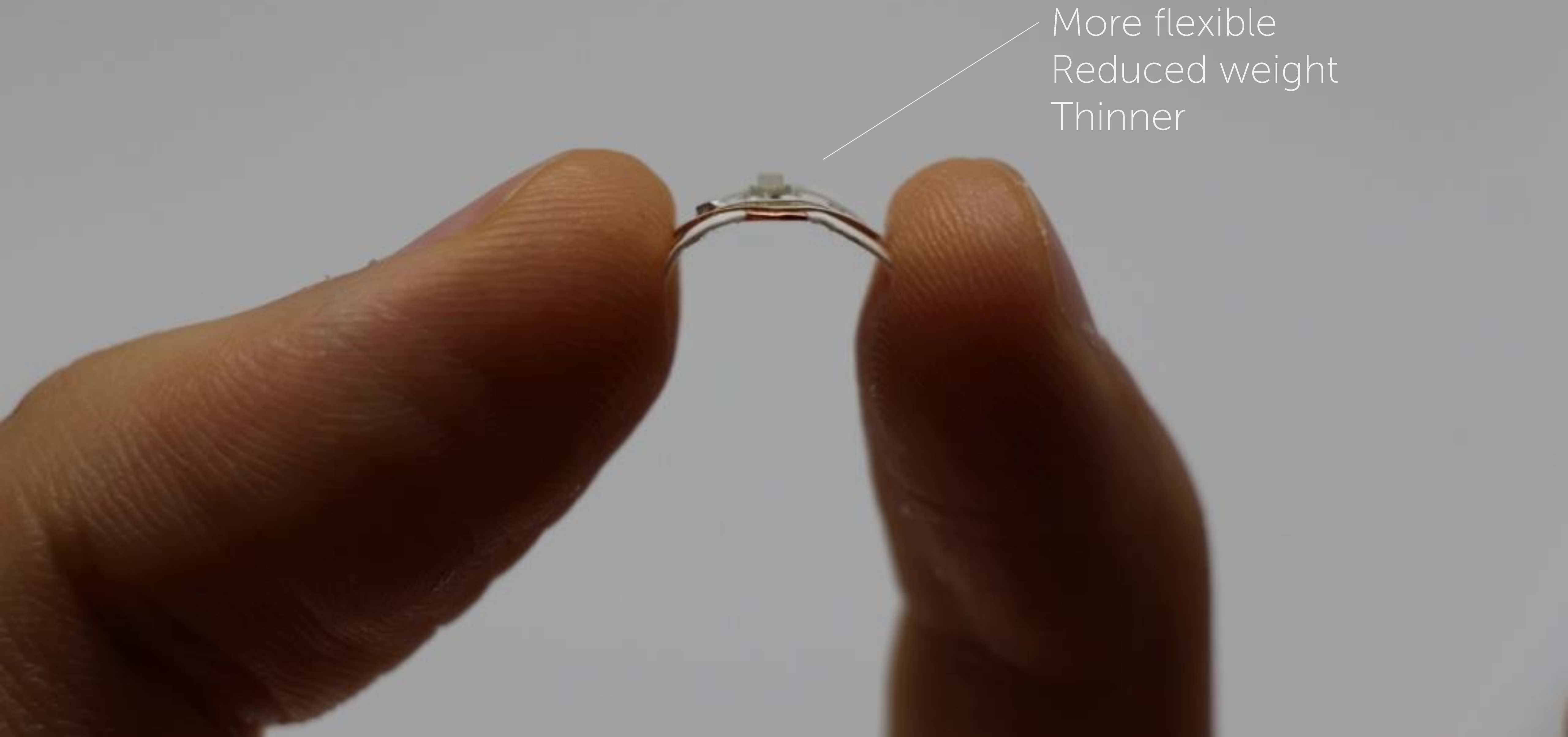
10%


MAKERWEAR FINAL PROJECTS
VIDEO SUMMARY
Wrecking Ball
Maker: Boy, 6 year old
A button-activated superhero wrecking ball armband

MAKERWEAR FUTURE WORK

MAKERWEAR FUTURE WORK

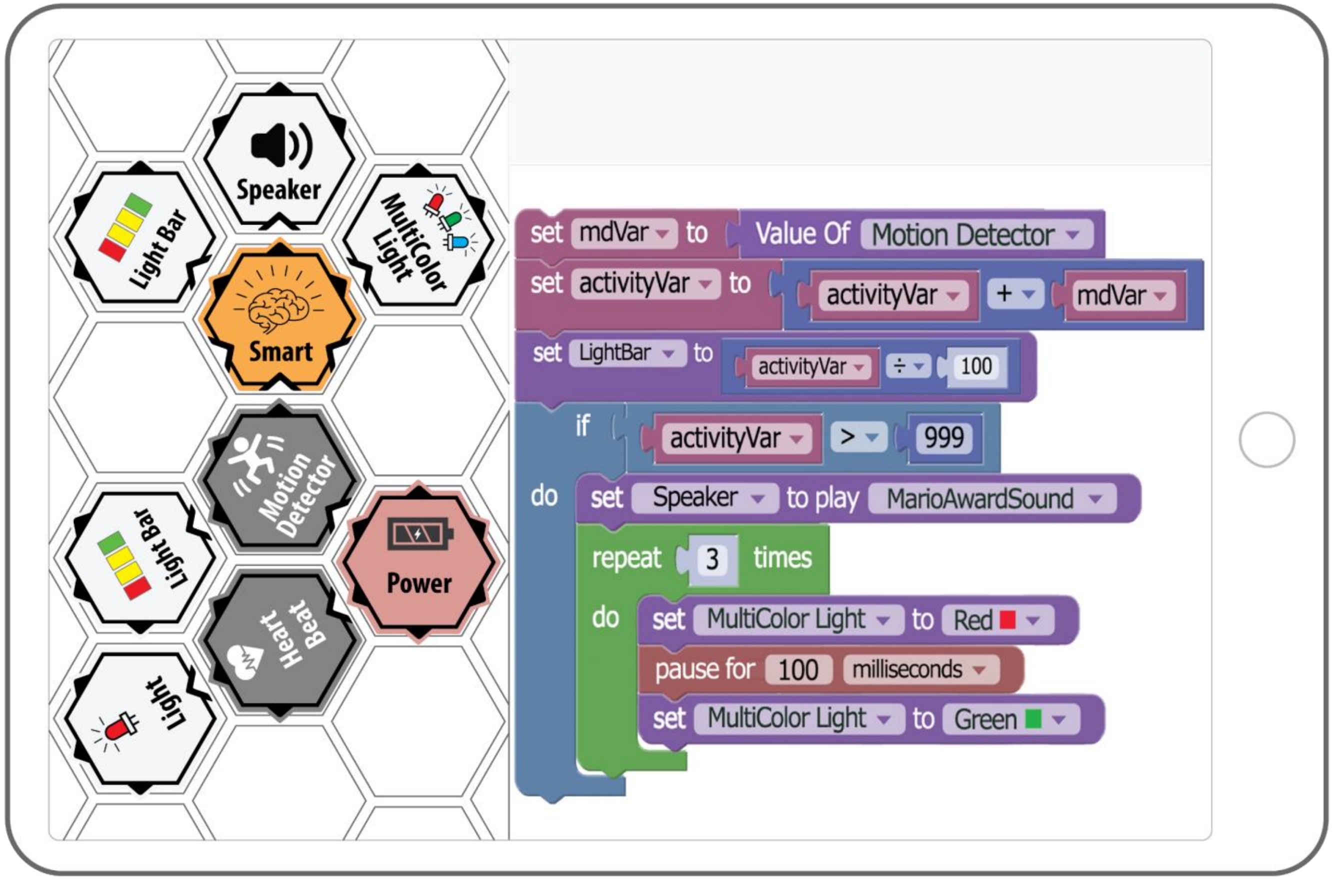
FORM FACTOR



FUTURE WORK

HYBRID TANGIBLE-GRAPHICAL PROGRAMMING INTERFACE

Modules will be wirelessly programmable via a custom tablet programming interface



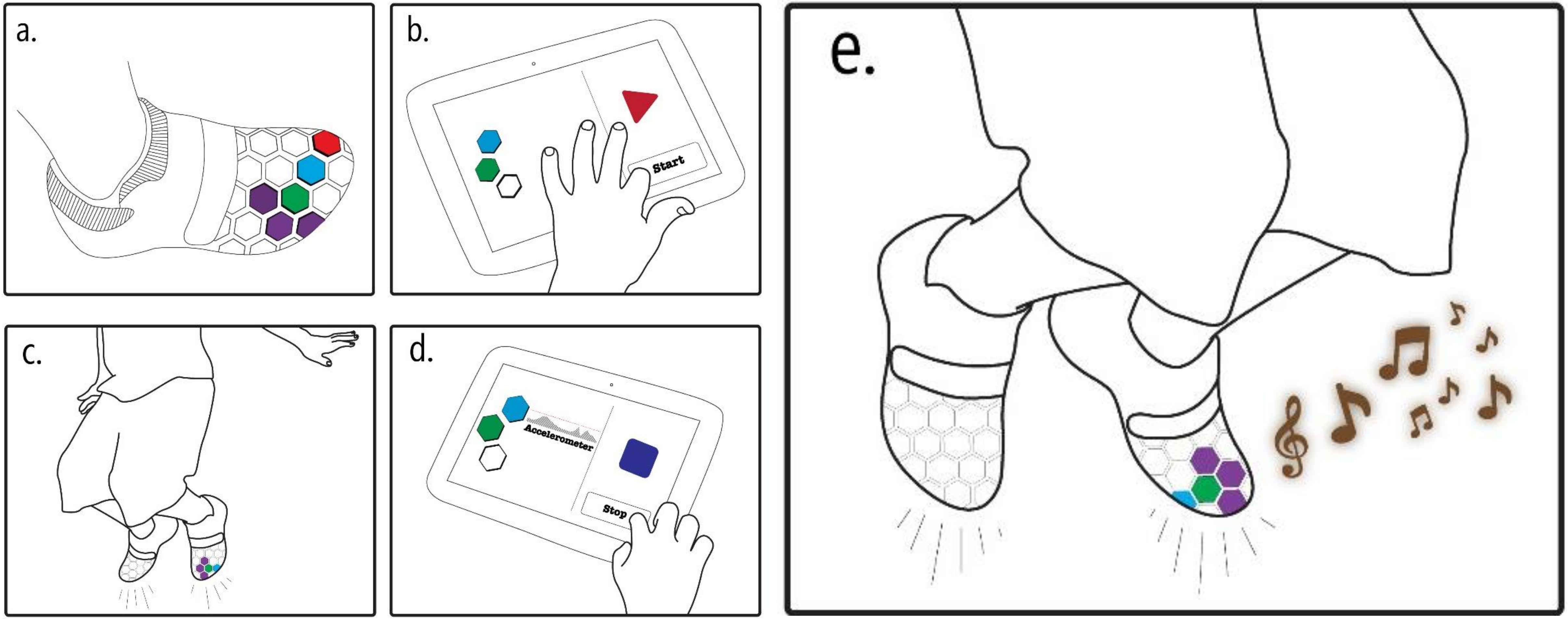
Sample Application:

Making a fitness tracker using a *Motion Detector* and a *HeartBeat Detector*.

FUTURE WORK

INTERACTIVE MACHINE LEARNING

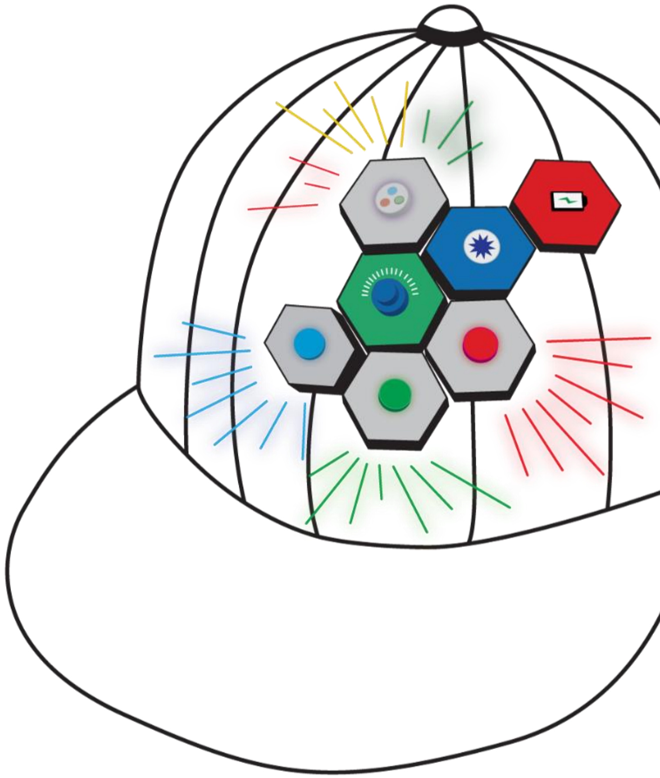
Children can program complex behavior via a novel machine learning interface



FUTURE WORK

SUPPORTING SCIENTIFIC INQUIRY

Children can build their own scientific instruments that allow them to investigate and compare phenomena over time and across contexts.



MAKEABILITY LAB

FOUR FOCUS AREAS

ENVIRONMENTAL SUSTAINABILITY

HEALTH & WELLNESS

ACCESSIBILITY

STEM EDUCATION

How many generations in all of human history have had the opportunity to **rise to a challenge** that is **worthy of our best efforts**? A challenge that can pull from us more than we think we can do.

-AL GORE

TED CONFERENCE, MARCH 2008

ACKNOWLEDGEMENTS

FUNDING SOURCES

Congressionally Directed Medical Research

MAPPING ACCESSIBILITY OF THE WORLD

NSF #1302338, Google, IBM

PI Froehlich, Co-PI David Jacobs

HMD SOUND AWARENESS

Google Faculty Research Award

PI Leah Findlater, Co-PI Froehlich

HANDSIGHT TOUCH VISION

Department of Defense CDMRP

PI Froehlich, Co-PIs Leah Findlater & Rama Chellappa

BODYVIS & SHAREDPHYS

NSF #1441184

PI Froehlich, Co-PI Tamara Clegg

MAKERWEAR

NSF CAREER #1652339

PI Froehlich

STEM EDUCATION

PARTNERS

KID MUSEUM

BOYS & GIRLS CLUBS

futuremakers

KIDS MAKE THINGS BETTER™.COM

CYC Center for Young Children

PGCPS

Great By Choice

Prince George's County Public School System

WE ARE CASA

CASA

SOMOS CASA

UNIVERSITY OF MARYLAND 1856

COLLEGE OF EDUCATION

STEM Masters in Education Program

University of Maryland Kidsteam

ACKNOWLEDGEMENTS

IMAGE CREDITS

All photos by Jon Froehlich or Makeability Lab students except

REUTERS/Muzaffar Salman

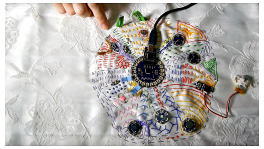
Found http://www.businessinsider.com/us-trusts-10-lessons-of-2013-2013-12

Unknown

Found https://chravellinx.wordpress.com/2014/12/15/11-dec-mantytie-valimotie/

Gettystock

Found http://www.huffingtonpost.com/2014/08/21/use-fitness-tracker_n_5697749.html



LilyPad Arduino Interactive Pad by Agy Lee

Found https://youtu.be/agYGhwc3NOk

Electronic Fashion Camp by Amy Florence

Found https://www.flickr.com/photos/amypickup/sets/72157631039891148/with/7769553484/

I Heart LilyPad Arduino by Rain Ashford

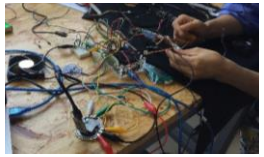
Found https://www.slideshare.net/Rainycat/i-lt3-lilypad-Arduino

Manual Sewing Skills by Leah Buechley

Found https://www.flickr.com/photos/leahbuechley/2595747031/

Example E-Textile Projects

Please see respective PowerPoint slide in notes section for attributions



Thinking Fabrics by Cindy Hu

Found http://ima.nyu.sh/documentation/author/yh1437/

Girls Make It

Found http://www.girlsmakeit.org/

Leaf by Thomas Helbig

Found https://thenounproject.com/search/?q=environmental+sustainability&i=120238

Health by Timothy Miller

Found https://thenounproject.com/search/?q=health&i=396737

Accessible Icon Project

Found http://accessibleicon.org/#use

Microscope

Found https://thenounproject.com/search/?q=science&i=860760

ACKNOWLEDGEMENTS

VIDEO CREDITS

All videos by Jon Froehlich or Makeability Lab students except

How I See It (Reading Braille)
By Ginny Owens
https://youtu.be/xfuxuxmoGXU

Kyren and the Mysterious World of Sight: Growing Up Blind
By Attitude
https://youtu.be/fYLdlO96uaM

Living Paintings: Bringing the Visual World to Life for Blind People
By Charity Bank
https://youtu.be/yZ5-4vqPtjg

Blind Boy Finds His Voice
By Attitude
https://youtu.be/q6uQOHuIfMM

How Blind People Find Braille Signs
By Tommy Edison
https://youtu.be/fYLdlO96uaM

MAKING WITH A SOCIAL PURPOSE

Jon Froehlich | Assistant Professor | Computer Science

Human Computer Interaction Laboratory

MAKEABILITY LAB

COMPUTER SCIENCE
UNIVERSITY OF MARYLAND

UNIVERSITY OF MARYLAND