GesturePod: Enabling On-device Gesture-based Interaction for White Cane Users

Shishir G. Patil Don Kurian Dennis Chirag Pabbaraju Nadeem Shaheer
Harsha Vardhan Simhadri Vivek Seshadri Manik Varma Prateek Jain

Supplementary material

1 GESTUREPOD APP

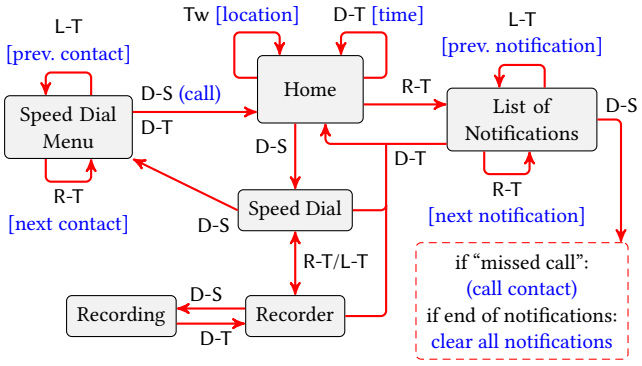


Figure 1: State machine for the Android App.

The interactive cane app works as a state machine, which is basically a system of gesture-action mappings. The app maintains its current state of execution at every point of time, and thereafter performs the corresponding action with respect to that state. The app launches in the home state, which is analogous to the standard home screen of a smartphone. Performing a double tap in the home state makes the app read out the current time, whilst remaining in the home state. A double tap in any other state reverts the state of the app back to the home state. Basically, a double tap is equivalent to the home button which any smartphone has.

The app speaks out the current location by getting the GPS coordinates when a twirl is performed in the home state. Thereafter, it maintains its state to the home state.

Performing a right twist in the home state makes the app recite the existing notifications in the smartphone. The app speaks out "You have x notifications", and doing a left twist at this stage is redundant and will simply repeat this line. Thereafter, scrolling through the notifications is achieved by the left twist - right twist pair - right twist to go one notification ahead, and left twist to scroll one notification back. At any point in time while scrolling through the notifications, performing a double tap resets the state of the app to the home state. While scrolling if the current notification is that of a missed call, performing a double swipe results in dialing the number to call the person. After having scrolled through all the notifications, there is an option available to flush all the notifications. This is achieved by performing a double swipe at the end of all the notifications.

Provided that the app has been launched, and either is alive or is running in the background, an incoming call on the phone can be accepted by performing a double swipe, whereas performing a double tap results in rejecting the call.

There is a "Quick Apps" menu as part of the app. This menu can be accessed by performing a double swipe in the home state. Two useful functionalities have been incorporated as part of this Quick Apps menu, namely, Speed Dial and Audio Recorder. Scrolling in the Quick Apps menu happens by means of left and right twists. Performing a double swipe at either of Speed Dial or Audio Recorder results in selecting it. Double swiping at Speed Dial presents a list of contacts stored beforehand as part of speed dial. Scrolling through these contacts is again possible with the help of the left twist-right twist pair. Double swiping now at any contact results in calling that number, and thereafter the call can be ended by performing a double tap.

Performing a double swipe at the audio recorder makes it start recording. Thereafter, a double tap stops the recording, and the recorded audio file gets stored on phone.

At every point in time, there will be a voice-over with respect to the option being selected. Also, a lengthy voice-over (eg. a lengthy location with unnecessary details like pin code, state, county etc.) can be interrupted and stopped by performing a double tap, and the app will cut the voice over and return to the home state.

Performing any gesture at a state other than the state-gesture pairings described above results in the app remaining in the same state. Also, not performing any gesture at a state other than the home state for a period of more than 7 seconds results in the app reverting to its home state.

2 CONFUSION MATRIX

Table 1 lists the confusion matrix for the data used for testing the model. The test data for Table 1 is obtained by randomly splitting the data from the data collection phase into a 80:20 split - 80 for training and 20 for testing.

Performed Gesture	Recognized Gesture						
	D-T	R-T	L-T	Tw	D-S	N-G	Recall
D-T	209	0	0	0	0	6	0.972
R-T	0	107	1	1	0	2	0.964
L-T	0	0	127	0	0	3	0.977
Tw	0	0	0	746	0	0	1.000
D-S	0	0	0	3	146	14	0.896
N-G	1	4	0	1	0	30007	1.000
Precision	0.995	0.964	0.992	0.993	1.000	0.999	

Table 1: Confusion matrix for test data.

3 DIVERSITY OF USERS

3.1 In-Lab User study

(1) User 0:
- Born Blind
- Age: 20-30 yrs
- Handedness: Right
- Language: Telugu, Marathi, English, Hindi, Mother tongue- Kannada,
- Residence: Bengaluru, Karnataka
- Education: Arts
- Profession: Mobility Trainer for people with VI.

(2) User 1:
- Acquired Blindness
- Age: 20-30 yrs
- Handedness: Right
- Language: Kannada, English, Mother tongue - Kannada
- Residence: Bengaluru, Karnataka
- Education: Diploma in CA (chartered accountancy)
- Profession: Finance

(3) User 2:
- Born Blind
- Age: 20-30 yrs
- Handedness: Left
- Language: Kannada, English, Gujarati Mother tongue - Gujarati
- Residence: Bengaluru, Karnataka
- Education: Bachelor of Computer Application

- Profession: Accessibility tester

(4) User 3:
- Acquired Blindness
- Age: 20-30 yrs
- Handedness: Right
- Language: English, Mother tongue - Kannada
- Residence: Bengaluru, Karnataka
- Education: Arts
- Profession: Trainer.

(5) User 4
- Acquired blindness
- Age: 20-30 yrs
- Handedness: Left
- Language: English, Hindi, Kannada, Mother tongue - Marathi
- Residence: Belgaum, Karnataka
- Education: BBA
- Profession: Searching for a job in HR

(6) User 5:
- Acquired Blindness
- Age: 21 yrs
- Handedness: Right
- Language: English, Hindi, Kannada, Mother tongue - Telugu
- Residence: Bengaluru, Karnataka
- Education: 12th Arts
- Profession: Student.

(7) User 6
- Born Blind
- Age: 20-30 yrs
- Handedness: Right
- Language: Urdu, Kannada, Hindi, English, Mother tongue- Urdu,
- Residence: Bengaluru, Karnataka
- Education: Bachelor of Computer Application
- Profession: Mobility Trainer

(8) User 7
- Born Blind
- Age: 30-40 yrs
- Handedness: Right
- Language: English Mother tongue - Telugu
- Residence: Andhra Pradesh
- Education: Master of Arts
- Profession: NA

3.2 In-Wild User study

(1) P1:
- Born Blind
- Gender: Male
- Age: 30-40 yrs
- Handedness: Right
- Language: Kannada, Hindi, English, Tamil, Mother tongue- Kannada,
- Residence: Shivmogga, Karnataka
- Education: Diploma in Medicine
- Profession: Data entry

(2) P2:
- Acquired Blindness
- Gender: Male
- Age: 30-40 yrs
- Handedness: Right
- Language: English, Kannada, Telugu, Hindi, Mother tongue- Kannada,
- Residence: Raichur, Karnataka
- Education: BBA, Tumkur University
- Profession: Not working, undergoing training

(3) P3:
- Born Blind
- Gender: Male
- Age: 20-30 yrs
- Handedness: Right
- Language: Urdu, Kannada, Hindi, English, Mother tongue- Urdu,
- Residence: Bangalore, Karnataka
- Education: Bachelor of Computer Application
- Profession: Mobility Trainer

4 IN-LAB USER STUDY

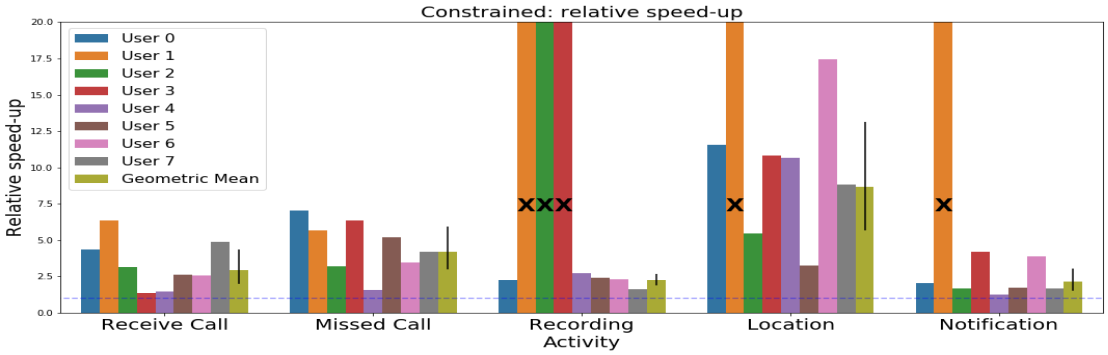


Figure 2: Relative speedup in constrained environments

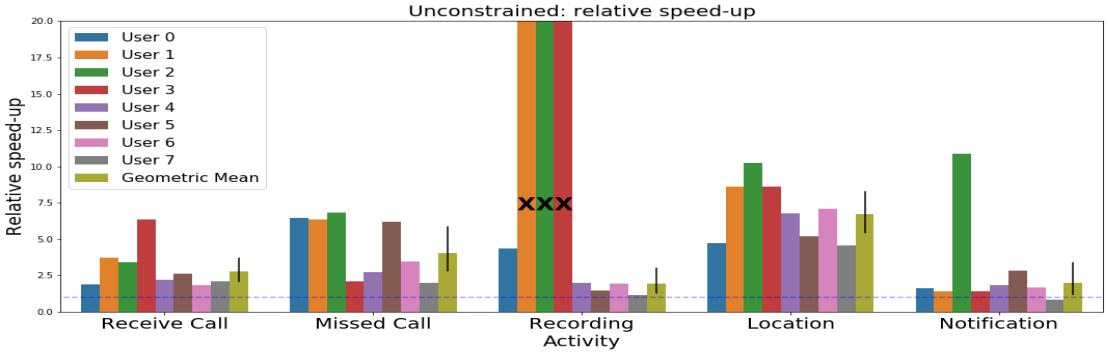


Figure 3: Relative speedup in unconstrained environments

Figure 2 plots the improvement in task completion times when both hands are occupied (constrained), when performing an activity on the users own-phone vs I-Cane. X means, users were not able to complete the activity. Figure 3 plots the improvement in task completion times when both hands are unoccupied (un-constrained), when performing an activity on the users own-phone vs I-Cane. X means, users were not able to complete the activity.

5 TIME TO PERFORM TASKS

This section reports the actual time taken to perform each activity (sec 4.2 of the paper), for each user.
Key:
Unconstrained w/o GesturePod -> Unconstrained setting; without GesturePod
Unconstrained w/ GesturePod -> Unconstrained setting; with GesturePod
Constrained w/o GesturePod -> Constrained setting; without GesturePod
Constrained w/ GesturePod -> Constrained setting; with GesturePod

Note: When the user was unable to complete a task - that cell has been left empty.

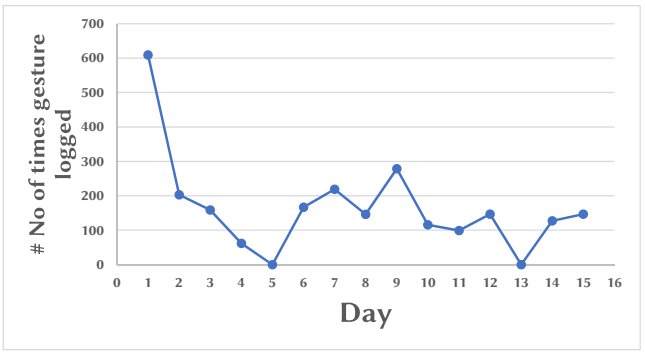
Activity	User	Unconstrained w/o GesturePod	Unconstrained w/ GesturePod	Constrained w/o GesturePod	Constrained w/ GesturePod
Activity - 1 Receive Call	P1	5.2	2.730976105	13.46840954	3.1
Activity - 1 Receive Call	P2	10.11564231	2.7	19.78944874	3.1
Activity - 1 Receive Call	P3	12.33292055	3.631571531	5.260566711	1.673005819
Activity - 1 Receive Call	P4	10.01370978	1.570236921	6.916656971	5.002531052
Activity - 1 Receive Call	P5	6.034094	2.757892	4.469197	3
Activity - 1 Receive Call	P6	6.980425	2.631703	8.577493	3.280473
Activity - 1 Receive Call	P7	5.152404	2.834493	8.268804	3.188365
Activity - 1 Receive Call	P8	8.410396	4.047242	12.20024	2.5
Activity - 2 Missed Call	P1	30.7	4.751892328	42.5725925	6.05
Activity - 2 Missed Call	P2	52.07452774	8.2	49.54486561	8.711936235
Activity - 2 Missed Call	P3	34.23061752	5	34.15661025	10.65153241
Activity - 2 Missed Call	P4	19.37274814	9.237239122	38.55786991	6.05
Activity - 2 Missed Call	P5	12.00941	4.407112	18.52366	11.80613
Activity - 2 Missed Call	P6	56.03289	9.065282	48.08472	9.20706
Activity - 2 Missed Call	P7	18.80454	5.421885	20.82511	5.997127
Activity - 2 Missed Call	P8	22.45832	11.22087	42.28166	10.01947
Activity - 3 Recording	P1	31.77492595	7.3	34.63191652	15.32358456
Activity - 3 Recording	P2		12.75896096		13.78266835
Activity - 3 Recording	P3		6.1		35.90752029
Activity - 3 Recording	P4		16.53		21.51289797
Activity - 3 Recording	P5	26.27678	13.04057	31.55919	11.45729
Activity - 3 Recording	P6	23.76891	15.98404	34.58695	14.37282
Activity - 3 Recording	P7	26.04901	13.53244	43.87546	19.10453
Activity - 3 Recording	P8	18.43705	16.01802	18.80939	11.56504
Activity - 4 Location	P1	16.4	3.452640772	31.19202757	2.695150852
Activity - 4 Location	P2	35.7448473	4.143391848		3.783958673
Activity - 4 Location	P3	28.9096477	2.822283506	12.55013728	2.304284573
Activity - 4 Location	P4	48.22097325	5.608032465	43.70120311	4.037730932
Activity - 4 Location	P5	18.60496	2.740597	29.71839	2.783325
Activity - 4 Location	P6	12.03972	2.321601	12.8902	3.964063
Activity - 4 Location	P7	33.19035	4.686809	55.48646	3.184349
Activity - 4 Location	P8	14.95532	3.2876143	21.42385	2.42154
Activity - 5 Notifications	P1	15.49026227	9.5	22.63168192	11
Activity - 5 Notifications	P2	10	7.022520065		6.909144402
Activity - 5 Notifications	P3	12.2121067	1.122459888	16.09768891	9.640318394
Activity - 5 Notifications	P4	27.47053146	19.57630491	45.7155292	10.84810495
Activity - 5 Notifications	P5	14.69943	8.084536	13.24858	10.66862
Activity - 5 Notifications	P6	29.87035	10.58926	23.19888	13.18908
Activity - 5 Notifications	P7	20.92887	12.30926	39.95782	10.28756
Activity - 5 Notifications	P8	19.41005	23.24878	17.89721	10.5178

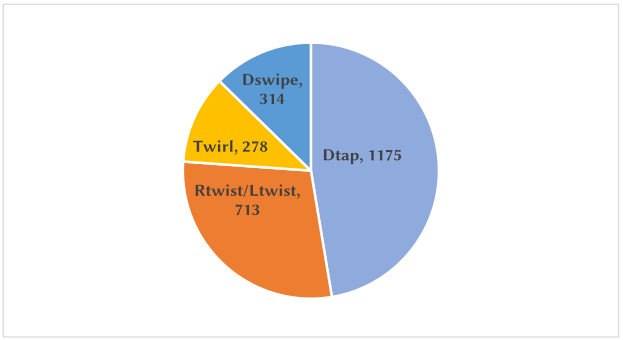
6 IN-WILD USER STUDY

We now present statistics from GesturePod usage from our in-wild user study. Recall that each of the user was given a GesturePod based interactive cane for 15 days.

User	Day	Day #	Count	Comments
P1	29-May	1	609	
	30-May	2	203	
	31-May	3	159	
	01-Jun	4	62	
	02-Jun	5	0	Holiday, did not go out of house.
	03-Jun	6	167	
	04-Jun	7	219	
	05-Jun	8	146	
	06-Jun	9	279	
	07-Jun	10	116	
	08-Jun	11	99	
	09-Jun	12	147	
	10-Jun	13	0	Sunday, did not go out of home.
	11-Jun	14	127	
	12-Jun	15	147	
P2	09-Aug	1	447	
	10-Aug	2	444	
	11-Aug	3	36	
	12-Aug	4	48	
	13-Aug	5	8	Battery was low - was travelling, unable to charge
	14-Aug	6	32	
	15-Aug	7	33	
	16-Aug	8	69	
	17-Aug	9	144	
	18-Aug	10	152	
	19-Aug	11		
	20-Aug	12	147	
	21-Aug	13	0	Getting engaged, family visiting, sister doesn't like him using cane
	22-Aug	14	127	
	23-Aug	15	147	
P3	21-Aug	1	441	
	22-Aug	2	0	Religious Festival
	23-Aug	3	0	Religious Festival
	24-Aug	4	200	
	25-Aug	5	478	
	26-Aug	6	70	
	27-Aug	7	2708	
	28-Aug	8	484	
	29-Aug	9	858	
	30-Aug	10	1400	
	31-Aug	11	495	
	01-Sep	12	1120	
	02-Sep	13	85	
	03-Sep	14	0	Mother's Anniversary
	04-Sep	15	0	Mother's Anniversary

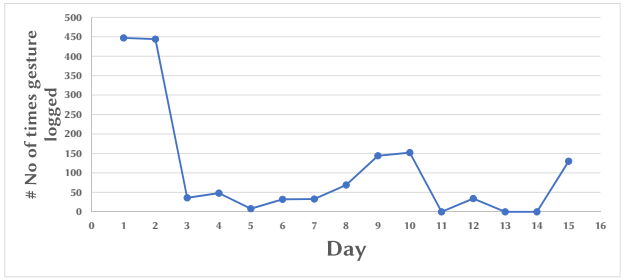
Table 2: The number of gestures logged through our app each day, during the In-Wild Study, for user P1, P2 and P3.

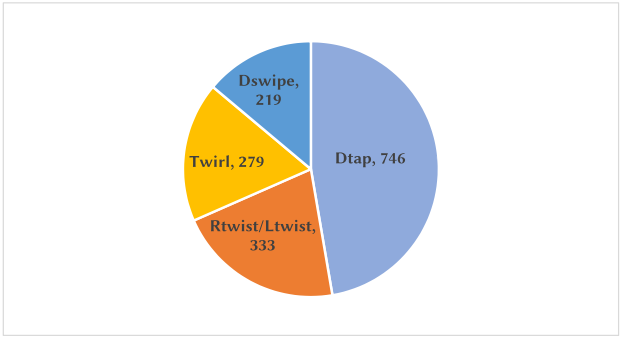




(a) Number of gestures detected on each day, for user P1. **(b) Distribution of gestures for user P1, for the entire study.**

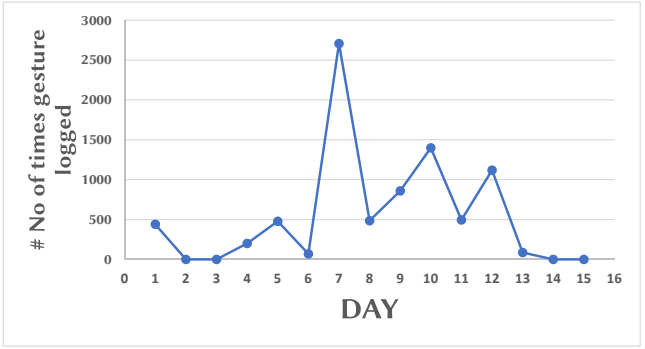
Figure 4: User P1 gesture statistics for the duration of In-Wild study

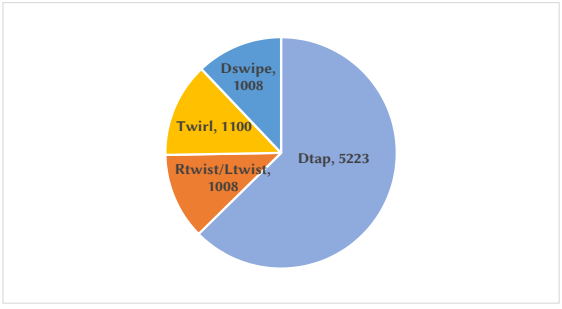




(a) Number of gestures detected on each day, for user P2. **(b) Distribution of gestures for user P2, for the entire study.**

Figure 5: User P2 gesture statistics for the duration of In-Wild study





(a) Number of gestures detected on each day, for user P3. **(b) Distribution of gestures for user P3, for the entire study.**

Figure 6: User P3 gesture statistics for the duration of In-Wild study

7 SUS RATINGS

This section represents the System Usability Scale (SUS) ratings provided by users of in-wild study. An independent individual, not associated with the study, nor the organization to which the authors belong to, conducted this study.

Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS
P1	3	1	5	1	4	2	5	1	5	1	90.0
P2	4	2	3	1	4	2	4	3	5	2	75.0
P3	4	1	5	1	5	2	5	1	5	1	95.0

Table 3: In-Wild study users' SUS ratings

Questions	Q1	I think that I would like to use this system frequently.
	Q2	I found the system unnecessarily complex.
	Q3	I thought the system was easy to use.
	Q4	I think that I need the support of a technical person to use this system.
	Q5	I found the various functions in this system well integrated.
	Q6	I thought there was too much inconsistency in the system.
	Q7	I would imagine that most people would learn to use this system quickly.
	Q8	I found the system very cumbersome to use.
	Q9	I felt very confident using the system.
	Q10	I needed to learn a lot of things before I could get going on this system

Table 4: Questions for the SUS study

Anchors	1	Strongly disagree
	2	Disagree
	3	Neutral
	4	Agree
	5	Strongly agree

Table 5: Anchors for SUS study

8 EXPLORATORY INTERVIEWS

In this section we present the insights from our exploratory interviews involving 15 participants with visual impairment, from three NGO's participated in our study. For anonymity we shall refer to these NGO's as NGO1, NGO2 and NGO3.

(1) All fifteen participants commented that they used the cane.
(2) Typically, persons with partial blindness used the cane for 1-2 hrs each day and persons with complete blindness used the cane between 3-7 hrs each day.
(3) Participants, typically used the cane when they were outside the confines of their home and office. When at home/office participants placed their cane:
   - Folded and placed in Bag
   - Under the chair
   - on the chair, behind their back while sitting,
   - resting behind the door while at home / office cabin,
   - One participant from NGO1 used a pouch tucked to his belt, to keep the folded cane
(4) Poll of phones used by participants:
   - Apple iPhone: 1
   - Android Smartphone: 6

- Nokia E5: 2
- Nokia 1100: 3, Karbon: 2, MTS Talking Mobile: 1

(5) Apps most frequently used by participants (with polls, there no cap on the number of apps, each user could name):
- Whats-App: 7
- Phone used for calling functionality only (no other app used): 5
- Uber/Ola - Ride sharing apps: 4 (Comment: Uber is accessible, OLA is not)
- Facebook: 3
- Youtube: 3
- Google Maps: 4
- Share-it: 1
- Camera: 1

(6) The scenarios in which participants in our study, found impediments in using the phone:
- "Touch-screen phones are difficult to access with single hands"
- "When I am alone, and there are lots of notifications to be read"
- "When one hand is occupied(with purse) and other hand has phone"
- "When answering calls in bus"
- "When I am in bus and I need to know where I am"
- "I can get to read a SMS only after it is sent and not while typing it."

(7) Participants wished the following existing apps to be made more accessible:
- Google Maps for location
- Contacts
- Speed dial (Comment: Guessing speed dial is interrelated to contacts)
- Typing in general
- Recorder for recording important points during meetings.
- Whats-App
- Knowing current time

(8) Application wish list(in no particular order):
- Reply with automated text while travelling in bus.
- Searching contact numbers.
- Button for cane to fold itself.
- Seeing AI to be implemented on the cane, action with cane could describe the surrounding.
- Record important points in meetings.
- Record important points in mobility training class, to go home and replay.
- While travelling in Bus, conductor does not mention which stop, so use cane to let us know, which bus stop it is so we can keep ourselves self updated on time to reach destination.
- Having sickle in one hand and cane in another while going to farm makes it difficult to pull out phone, prefer to use cane to answer/reply to calls.
- Speed dials, and call the last caller.
- Detect potholes.
- Use of cane to send beeping sound, while crossing the road.