Intelligent Augmented Lifelike Avatar App for Virtual Physical Examination of Suspected Strokes

Kevin Yao

Department of Electrical and Computer Engineering, Texas A&M University, College Station, TX, ky0148@tamu.edu

TT & WF Chao Center for BRAIN, Systems Medicine and Bioengineering Department, Houston Methodist Hospital, Houston, TX

Abstract

Abstract– An intelligent-augmented lifelike avatar mobile app (iLAMA) that integrates computer vision and sensor readings to automate and streamline the NIH Stroke Scale (NIHSS) physical examination is presented. The user interface design is optimized for elderly patients while the app showcases an animated lifelike 3D model of a friendly physician who walks the user through the exam. The standardized NIHSS examination included in iLAMA consists of five core tasks. The first two tasks involve rolling the eyes to the left and then to the right, and then smiling as wide as the user can. The app determines facial landmarks and analyzes the palsy of the face. The next task is to extend the arm and hold the phone at the shoulder level, and the smart phone gyroscope is used to detect acceleration to determine possible weakness in the arm. Next, the app tracks the location of the hand keypoints and determines possible ataxia based on the precision and accuracy of the locations of the touches. Finally, the app determines the user's forward acceleration in walking and possible imbalances using the accelerometer. The app then sends analyzed results of these tasks to the neurologist or stroke specialist for review and decisions.

Clinical Relevance– The physical examination of a stroke patient is a time consuming and repetitive process, and there is a lack of infrastructure and resource to monitor patient in post-stroke recovery after they leave the hospital for home or rehabilitation facilities. iLAMA app aims to automate a subset of the NIHSS physical examinations in measuring motor function recovery and also allows individual patients to track their performance over time. It will be an essential component in monitoring rehabilitation recovery and therapy effectiveness after hospitalization and can easily scaled to lo help millions of patients at a fraction of the cost.

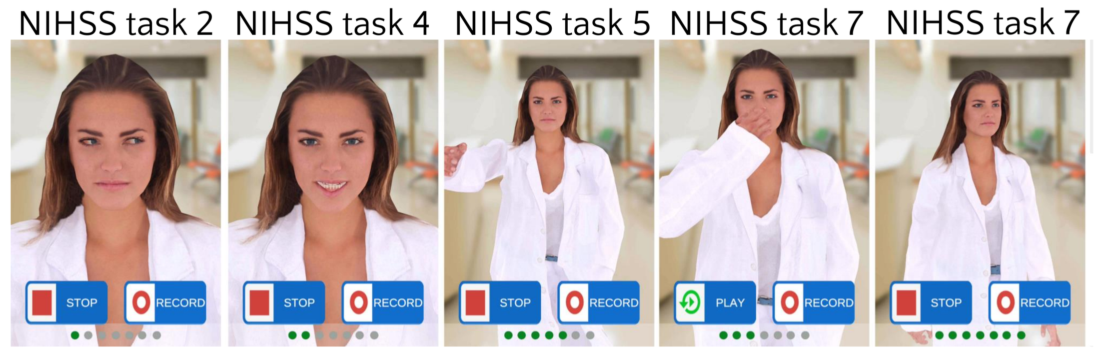
Introduction

BUT: Lack of infrastructure in tracking stroke patients' recovery after they leave the hospital

AND: Medical practitioners are overloaded with work from COVID-19

SOLUTION: A telemedicine app to help perform National Institutes of Health Stroke Scale (NIHSS) examination

Task 1	Task 2	Task 3	Task 4	Task 5
NIHSS task 2	NIHSS task 4	NIHSS task 5	NIHSS task 7	NIHSS task 7

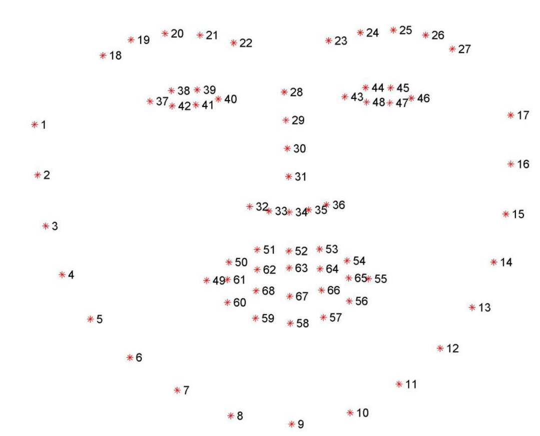


Task 1: Rolling eyes to left and right

The purpose of this test is to quantify the user's gaze palsy (GP). To do so, we ask the user to look at the camera, then roll his eyes to the left and right.

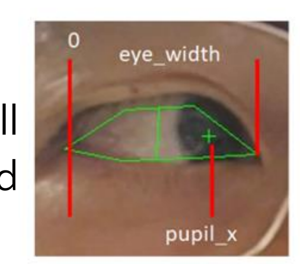
Methodology

1. Detect Facial Landmarks using supervision by registration (SBR)



2. Process landmarks to extract B&W image of the eye to determine pupil location

3. Calculate scores for each eye. Each eye will have a looking middle (M), looking left (L), and looking right (R) score



$$RR = \frac{R\_pupil\_x}{R\_eye\_width} * 100 \qquad RM = \left(1 - 2\left|0.5 - \frac{R\_pupil\_x}{R\_eye\_width}\right|\right) * 100 \qquad RL = \left(1 - \frac{R\_pupil\_x}{R\_eye\_width}\right) * 100$$

$$LR = \frac{L\_pupil\_x}{L\_eye\_width} * 100 \qquad LM = \left(1 - 2\left|0.5 - \frac{L\_pupil\_x}{L\_eye\_width}\right|\right) * 100 \qquad LL = \left(1 - \frac{L\_pupil\_x}{L\_eye\_width}\right) * 100$$

R eye analysis:

```
if RM>90:  #R eye not moving
        if both RR and RL are between 35 and 65: total gaze paresis (TGP) of R eye
        elif RR<65: partial gaze paresis (PGP) of R eye looking R
        elif RL<65: PGP of R eye looking L
        else: normal R eye
elif RM<90: #Right eye deviated from middle
        if RL <40 and RR>60: forced deviation (FD) of R eye to the R
        if RR<40 and RL>60: FD of R eye to the L
```

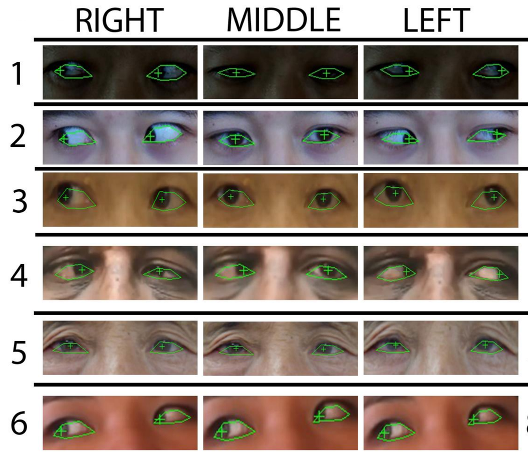
L eye analysis:

```
if LM>90:  #L eye not moving
        if both LR and LL are between 35 and 65: total gaze paresis (TGP) of L eye
        elif LR<65: partial gaze paresis (PGP) of L eye looking R
        elif LL<65: PGP of L eye looking L
        else: normal R eye
elif LM<90: #Left eye deviated from middle
        if LL <35 and LR>65: FD of L eye to the R
        if LR<35 and LL>65: FD of L eye to the L
```

Calculate NIHSS score:

```
if both eyes are either TGP or FD:  score=2
if only one eye is TGP, FD, or PGP: score=1
if both normal: score=0
```

Results

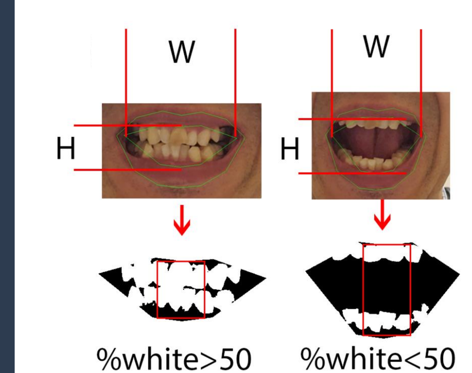


	RIGHT	MIDDLE	LEFT	RR	LR	RM	LM	RL	LL	DIAGNOSIS
1				85	76	100	100	75	84	NORMAL
2				87	83	93	100	74	79	NORMAL
3				75	69	96	93	54	63	R,L LOOK L PGP
4				31	57	62	92	76	80	1. R FD TO L 2. L LOOK R PGP
5				58	46	98	92	51	61	R,L TGP
6				81	84	38	16	19	16	R,L FD TO R

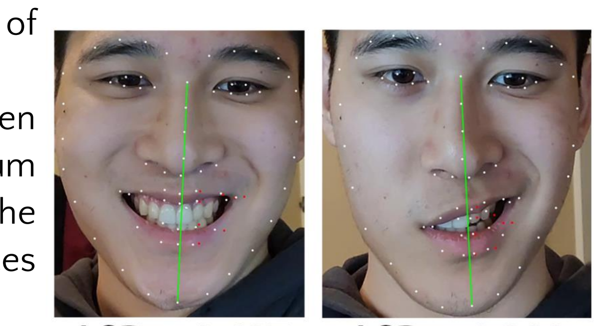
Our algorithm is able to classify the patients in these videos with their correct diagnosis

Task 2: Smile and show teeth

The purpose of this test is to quantify the user's facial paralysis. We analyze the ability of the user to open his/her mouth with a clenched jaw and the symmetry of the smile.

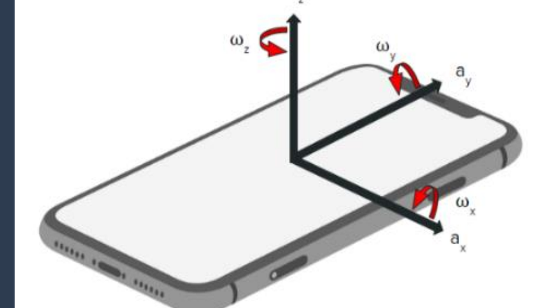


1. Detect facial landmarks using SBR model
2. Calculate width and height of the mouth. A valid mouth open is 0.15<height/width<0.4
3. Process image of the mouth to B&W
4. Teeth are white pixels. If percentage of white pixels in middle box is over 50%, the teeth is sufficiently clenched. If not, score=2
5. Draw line between nose and chin
6. Reflect landmarks on one side of the mouth to the other side
7. Calculate the distances between corresponding points and sum together for one frame. The average of the summed distances (ASD) for all frames is the score
8. Larger ASDs correspond with more asymmetry



Task 3: Hold arm still

The purpose of this test is to quantify the user's arm weakness. The user is asked to hold the phone at shoulder level for 10 seconds.



Acceleration score: $\sqrt{a_x^2 + a_y^2 + a_z^2}$

Rotation score: $\sqrt{\omega_x^2 + \omega_y^2 + \omega_z^2}$

The scores are calibrated based on a still hand (score=0) and a free falling hand (score=3)

Task 4: Touch nose

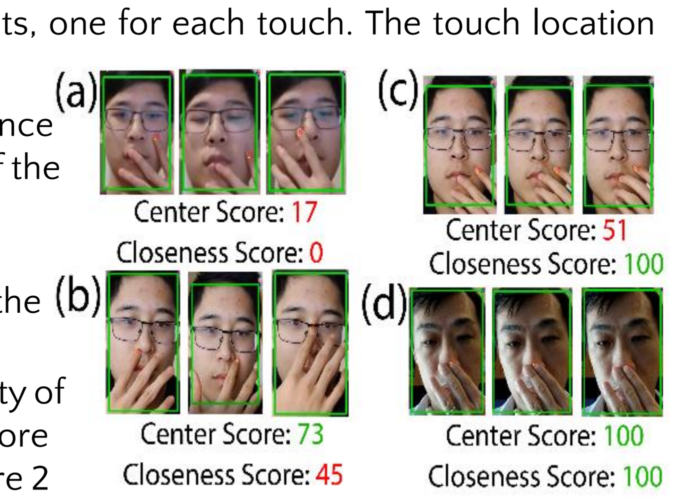
The purpose of this test is to quantify the user's arm ataxia. The users are asked to touch their nose three times with each of their arms, and we analyze their accuracy (how close the touch is to the nose) and precision (how close the touches are to each other)

1. Use Mediapipe's hand landmark detector to detect index finger location
2. Savgov filter to smooth results
3. OpenCV DNN Face detector to draw face bounding box. The nose location is approximated using the center of this box
4. Divide video into 3 segments, one for each touch. The touch location is where velocity is zero

Center (accuracy) score: distance the touch is from the center of the face box

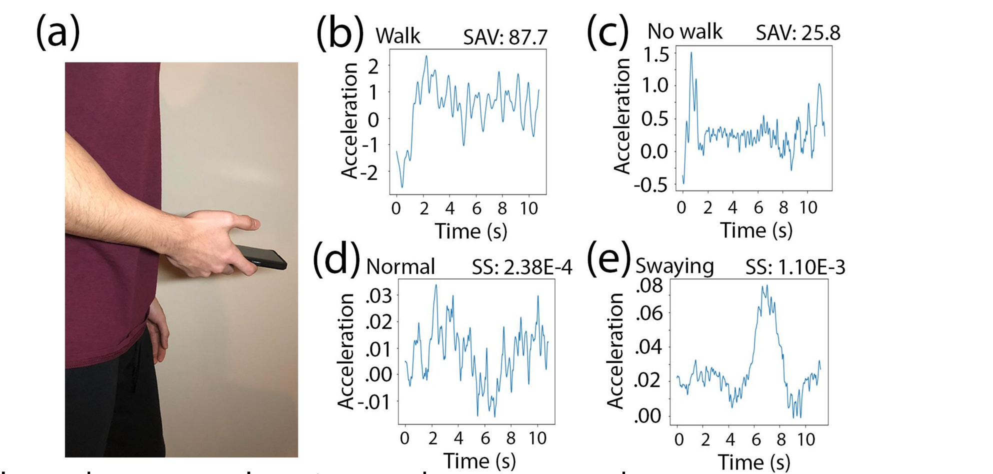
Closeness (precision) score: variance in position between the three touches

Minimum score gauges severity of ataxia. If ataxia in one limb, score 1. If present in both limbs, score 2



Task 5: Walking in a straight line

The purpose of this test is to quantify the user's lower body ataxia. The user is asked to walk in a straight line with their phone face up in front, like in (a).



1. Collect phone acceleration and gyroscope data
2. Detect initial forward acceleration of the phone.
   I. One second moving average filter the y acceleration, and sum the absolute values (SAV) of the acceleration for the first two seconds
   II. SAV for a user who walks forward (b) is 3 times larger than SAV for a user who shakes phone but does not walk (c)
   III. If no initial acceleration is detected, score 2.
3. Count the number of steps. If less than five steps are detected, score 2. Otherwise, analyze the swaying of the user
   I. 1.7 second moving average filter the x acceleration, sum the squared (SS) values for the entire 10 seconds.
   II. SS for user who walks normally (d) is 5 times lower than SS for user who sways to the side (e)
   III. If swaying is detected, score 2 or 1 depending on SS
4. Determine mean of rotation data. No rotation = score 0. 90 degree rotation = score 2. We choose a threshold to score 1.

Conclusion

We developed a mobile app with the following novel features

1. Showcases a lifelike, 3D avatar doctor that guides the user through five required tasks
2. Automatically grades the patient using the NIHSS scale
3. Potential to also perform other physical exams, such as annual checks

Possible use cases

- Personal use to gauge your risk for stroke, or to track your recovery
- For doctors to use so that
  a) Work is offloaded from their busy schedules
  b) Medical workers without NIHSS certification can still analyze results and treat patients
  c) Results are consistently calculated: no variability between examiners

Future work

- Validate in the hospital
- Develop virtual therapeutics feature: track your

Acknowledgements

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