MODEL TO IDENTIFY THE CORRECT SITTING POSTURE FOR PREVENTING THE SPINAL CURVATURE OF CHILDREN

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Abstract

Nowadays, children are exposed to electronic devices such as televisions, computers, phones, etc. more and more. With long study and entertainment time, children sit in the wrong posture can cause eye and spine diseases, etc. We research a model to diagnose sitting postures and it gives warnings if there are bad posture. The first part of the report is the points on the body used as reference points for the calculation. The second part is the mathematical formulas to determine the standard sitting posture. And the last part is the coding pipeline for developing a sitting posture diagnosis program.

Keywords: correct sitting posture, good sitting posture, bad sitting posture, body land marks

I. INTRODUCTION

The study of human postural movement is an important field of research because of its many benefits. Many researchs have been conducted using different models [3][6][8] and some contexts. In order to better understand the mathematical aspects when applying these models, in this study we introduce geometric formulas to calculate the tilt angle during the motion.

Part 1 will introduce body positions, coordinate origins and axes for orientation to compare sitting postures. Part 2 is the formulas for calculating neck-back angle, back angle, shoulder-hip angle. These angles are the basis for diagnosing whether sitting posture is good or not when exceeding a given threshold in a certain period of time. Part 3 introduces how to develop a recognition program with a pipeline that includes general steps from preprocessing the camera frame, to metrics calculation. Then there is the rules based classification model. If one of the poses exceeds the allowed threshold, the program generates a warning.

II. BODY LANDMARKS

In computer vision, to study body movements, we determine body positions to calculate the deviation when sitting. This is a list of 33 body positions:

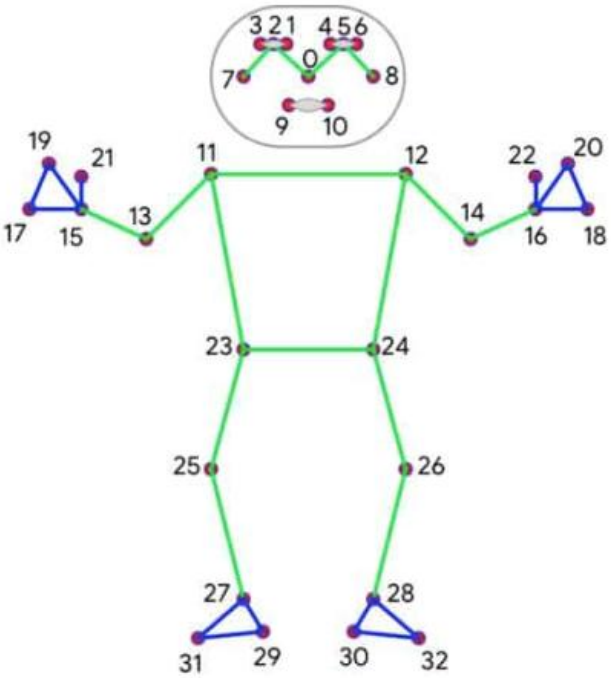
Vùng	Điểm	Ký hiệu	Mô tả
Head	Nose, LeftEar, RightEar	P_n, P_{le}, P_{re}	Head position
Shoulder	LeftShoulder, RightShoulder	P_{ls}, P_{rs}	Two shoulders
Hip	LeftHip, RightHip	P_{lh}, P_{rh}	Two hips

Knee	LeftKnee, RightKnee	Plk, Prk	Two knees
Ankle	LeftAnkle, RightAnkle	Pla, Pra	Two ankles
Middle spine	MidShoulder, MidHip	Ps, Ph	Midpoint of shoulders and hips

We consider

$$Ps = (Pls + Prs)/2 \quad \text{and} \quad Ph = (Plh + Prh)/2.$$

They are the reference axes for a human body posture.



0. nose
1. right eye inner
2. right eye
3. right eye outer
4. left eye inner
5. left eye
6. left eye outer
7. right ear
8. left ear
9. mouth right
10. mouth left
11. right shoulder
12. left shoulder
13. right elbow
14. left elbow
15. right wrist
16. left wrist
17. right pinky knuckle #1
18. left pinky knuckle #1
19. right index knuclke #1
20. left index knuckle #1
21. right thumb knuckle #2
22. left thumb knuckle #2
23. right hip
24. left hip
25. right knee
26. left knee
27. right ankle
28. left ankle
29. right heel
30. left heel
31. right foot index
32. left foot index

Fig: BlazePose Topology

III. 3D GEOMETRIC ANALYSIS

A good sitting posture can be defined by spatial geometry: the line through the hips–shoulders–neck–nose is approximately parallel to the vertical axis. The shoulders and hips are on the same horizontal plane. The head–back angle is > 160°. The back–sagittal angle is < 10°. The knees are perpendicular and symmetrical. A poor sitting posture occurs when one or more of the geometric angles exceed this threshold.

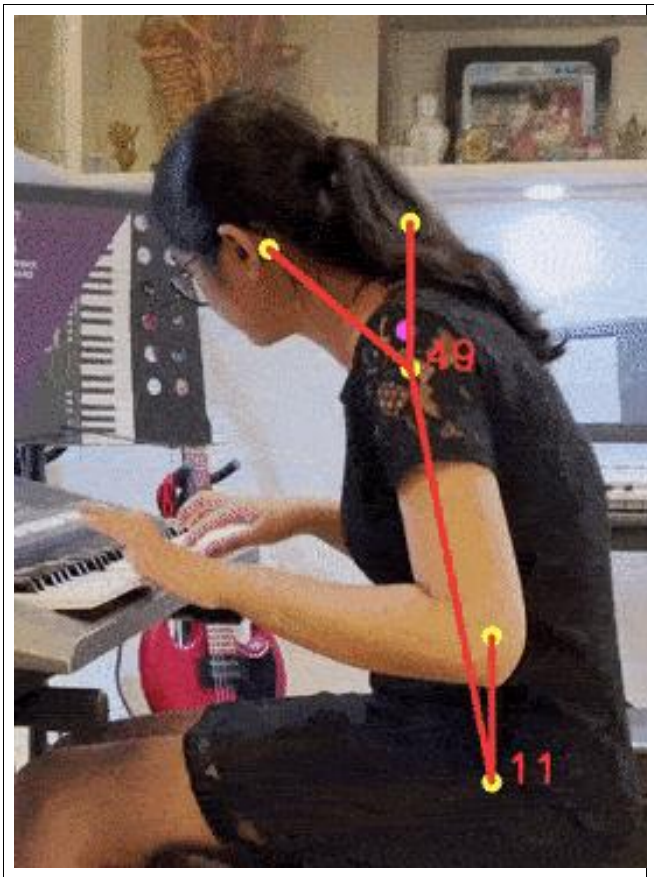


Fig. 2. Bad Posture

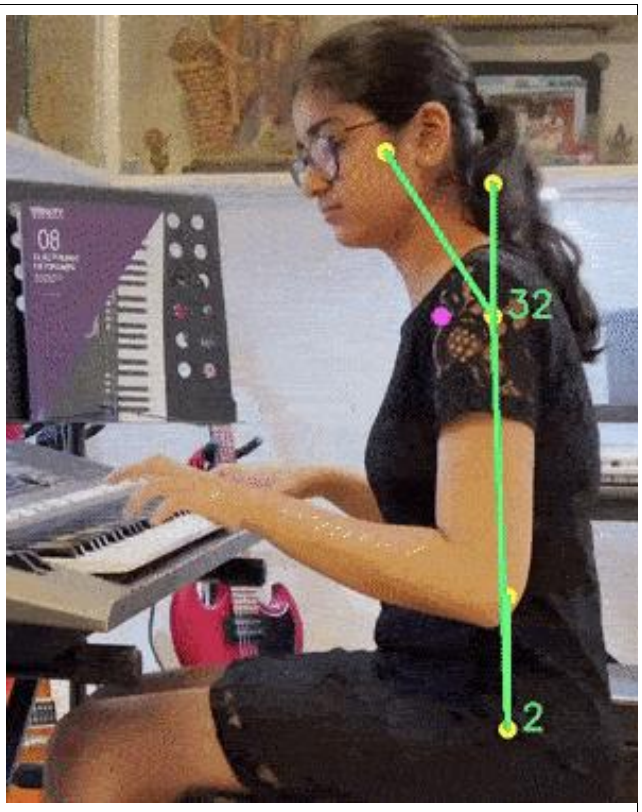


Fig. 3. Good Posture

III.1 Normalizing the coordinate system

When we extract landmarks from an image, their coordinates depend on the location, size, and angle of view of the person in the image. But the posture must be independent of how close or far the camera is, how big or small the person is, etc. Therefore, we need to normalise the coordinate system so that:

- Step 1: The origin of the coordinates is fixed to the body (regardless of the position in the image). In the case of diagnosing sitting posture, the origin is set at the hips.

- Step 2: The size is calculated in “body units” (regardless of image magnification). We normalise the body proportions according to the distance between the shoulders and hips.

III.2 Important angles that describe sitting posture

1. Neck angle

To determine if the student is leaning forward. We check the angle between the nose-shoulder vector and the vertical vector from the middle of the hip to the middle of the shoulder.

We call:

$$\vec{v_1} = P_n - P_s, \quad \vec{v_2} = P_s - P_h$$

We have the angle between head and back:

$$\theta_{\text{neck}} = \cos^{-1}\left(\frac{\vec{v_1}\cdot\vec{v_2}}{\|\vec{v_1}\|\|\vec{v_2}\|}\right)$$

- If $\theta_{neck} \approx 180^{\circ}$: This is a straight head-back position. So this is a good posture.
- Nếu $\theta_{neck} < 150^{\circ}$: This is a posture with the head bent forward. So this is a bad posture.

```python
# Calculate angle.
def findAngle(x1, y1, x2, y2):
    theta = m.acos( (y2 -y1)*(-y1) / (m.sqrt(
        (x2 - x1)**2 + (y2 - y1)**2 ) * y1) )
    degree = int(180/m.pi)*theta
    return degree
```

This is the code to calculate the angle between two vectors

2. Torso angle

To measure the tilt of the upper body relative to the vertical axis, we measure the angle between the back vector and the vertical reference vector (0,−1,0). This angle is called θ_{torso}.

- If $\theta_{torso} < 10^{\circ}$: This is a straight back posture. So it is a good posture.
- If $\theta_{torso} > 20^{\circ}$: The person is bent forward or backward. So it is a bad posture.

3. Pelvic tilt

To measure hip tilt, which is often associated with leaning to one side when sitting, we check whether the shoulders and hips are parallel to each other. If they are not parallel, we calculate the tilt angle called θ_{tilt}. If $|\theta_{tilt}| > 10^{\circ}$ then the student leaned to one side.

IV. Warning threshold for incorrect sitting posture

This is a summary table of reference thresholds for the indices. When these thresholds are exceeded, sitting posture is considered unhealthy. For better control, the time limit of a bad posture should also be considered. For example, if there is a bad sitting posture for more than 10 minutes, there will be an alert.

Metric	Threshold (reference)	Meaning of “Bad posture”

θ_neck	<150°	The head is bowed
θ_torso	>20°	The person bent down
θ_tilt	>10°	The sitting posture is off to one side

V. Pipeline for coding

To detect a correct sitting posture recognition program through the camera, the first step is to align the camera, extract frames, normalise the image coordinate system, and extract landmarks. Then we calculate the main vector axes and angles. Based on the given threshold, we will consider whether the tilt angles and metrics exceed the threshold or not. If there is a bad posture, the program can issue visual and audio warnings for the child can adjust his posture.

This is the pipeline of 4 main steps:

Fig. 4 Pipeline for coding

V.1 Camera frame preprocessing

The goal of this step to keep slow oscillations (real human motion) and remove fast oscillations (camera noise). The algorithm is Butter worth filter to reduce noise due to jitter or lost frames.

Input: X_raw[t,j], window_size k
Output: X_smooth[t,j]
Algorithm:

For each joint j:
For each coordinate axis (x,y,z):
$X\_smooth[t,j,axis] \leftarrow (1/k) * \Sigma_{\tau=t-k+1 \rightarrow t} X\_raw[\tau,j,axis]$

V.2 Calculate the postural metrics at time t

The goal of this step: from smooth coordinates X_smooth[t], we calculate geometric feature vectors and angles.

Input: X_smooth[t]
Output: F_t = [θ_{neck}, θ_{torso}, θ_{tilt}]
Algorithm:

We use the formulas in section III.2 to calculate vectors and angles.

V.3 Frame-by-frame pose classification based on 3D rules

The goal of this step is to classify posture as good or bad.

Input: F_t = [θ_{neck}, θ_{torso}, θ_{tilt}]
Output: y_t is " Bad" or "Good"?
Algorithm:

If $\theta neck < 150°$ or $\theta torso > 20°$ or $|\theta tilt| > 10°$:

```
    y_t ← "Bad"
Else:
    y_t ← "Good"
```

V.4 Detect and maintain alerts

The goal of this step is to trigger the alert only if the incorrect posture persists. If error persists for more than 5 seconds, a warning is issued; reset after each warning.

Input: $\hat{y}$_t with these parameters T_alert = 10 minutes and fps = 30.
Output: Raise_Alert()
Algorithm:

```
counter_bad ← 0

For each frame t:
   If ŷ_t == "Bad":
      counter_bad ← counter_bad + 1
   Else:
      counter_bad ← 0

   If counter_bad > T_alert * fps:
      Raise_Alert()
      counter_bad ← 0  # reset sau cảnh báo
```

VI. CONCLUSION

The study has just introduced a model to recognise the correct sitting posture to help students prevent scoliosis. We also introduced the sequential steps to be able to develop the recognition software. The study introduces from the theoretical aspect to the application.

With the formulas to calculate the tilt angle on the 3D image, we can understand the problem clearly and can develop different models to recognise different postures.

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