Stroke Patient Daily Observation System

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Abstract

Stroke is a leading cause of long-term adult disability. Stroke patients can recover through rehabilitation programs prescribed by occupational therapists (OT); however, an individualized rehabilitation program can reduce recovery times compared to traditional ones. We propose a daily activity observation system (DAOS) that uses a Kinect v2 sensor to collect and retrieve motion data. The depth information allows us to perform action recognition, while skeleton data is used to do Range of Motion assessment. Action recognition accuracy is 97% on a multi-class kitchen action dataset. Combining an action and its opposite improves recognition rates. Assessment values are verified with a Vicon system.

Introduction

- 795,000 suffer from a stroke in the U.S. [1]
- The Kinect is a cheap, accurate camera sensor
  - Color camera
  - Depth information
  - Skeleton data
- Daily Activity Observation System (DAOS)
  - Action Recognition
  - Assessment
- **No current system integrates action recognition and assessment!**

Fig. 1. Researcher in the DAOS

Dataset

- We collected an in-house dataset consisting of common kitchen tasks, as in Table 1 and Fig. 2.
- 9 people x 28 actions x 2 = 504 total.

WashSink	WashRinse	PickUpTop	PutDownTop
Wash Dishwasher	PrepCut	PickUpBottom	PutDown Bottom
PrepStir	PrepOpen	OpenTop Cabinet	CloseTop Cabinet
PrepClose	Manipulate Stove	OpenBottom Cabinet	CloseBottom Cabinet
Manipulate Microwave	Manipulate SinkOn	WalkIntoNot Hold	WalkIntoHold
Manipulate Fridge	Manipulate SinkOff	WalkOutNot Hold	WalkOutHold
PickUp Counter	PutDown Counter	WalkAround NotHold	WalkAround Hold

Table 1. Chosen kitchen tasks for our dataset.

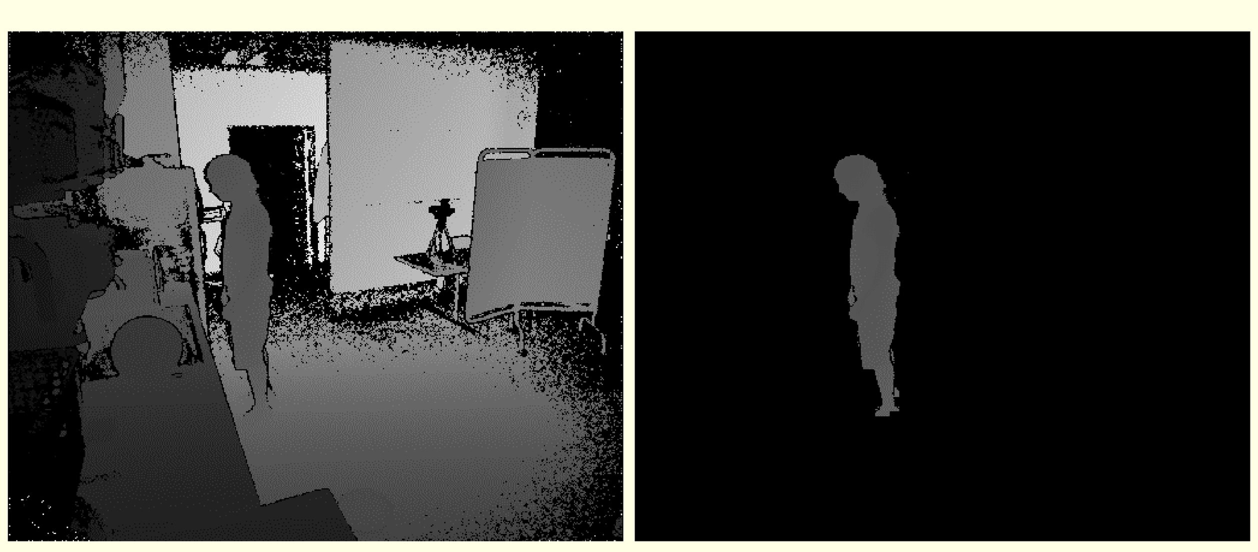

Fig. 2. Unprocessed (left) and processed (right) depth images in data collection kitchen.

Action Recognition

- We use histogram of oriented 4D normals (HON4D) to compute a video descriptor [2].
  - Normals are computed as:

$$\mathbf{n} = \nabla S = \left(\frac{\partial z}{\partial x}, \frac{\partial z}{\partial y}, \frac{\partial z}{\partial t}, -1\right)^T$$

  where $\mathbf{n}$ is then normalized, $\hat{\mathbf{n}}$
  - The bins of the histogram are set as the vertices of a polychoron, $\mathcal{P} = \{\mathbf{p}\}$. Bin contributions are calculated as

$$c(\hat{\mathbf{n}}_j, \mathbf{p}_i) = \max(0, \hat{\mathbf{n}}^T \mathbf{p}_i)$$

- After computation of HON4D descriptors, they are normalized.

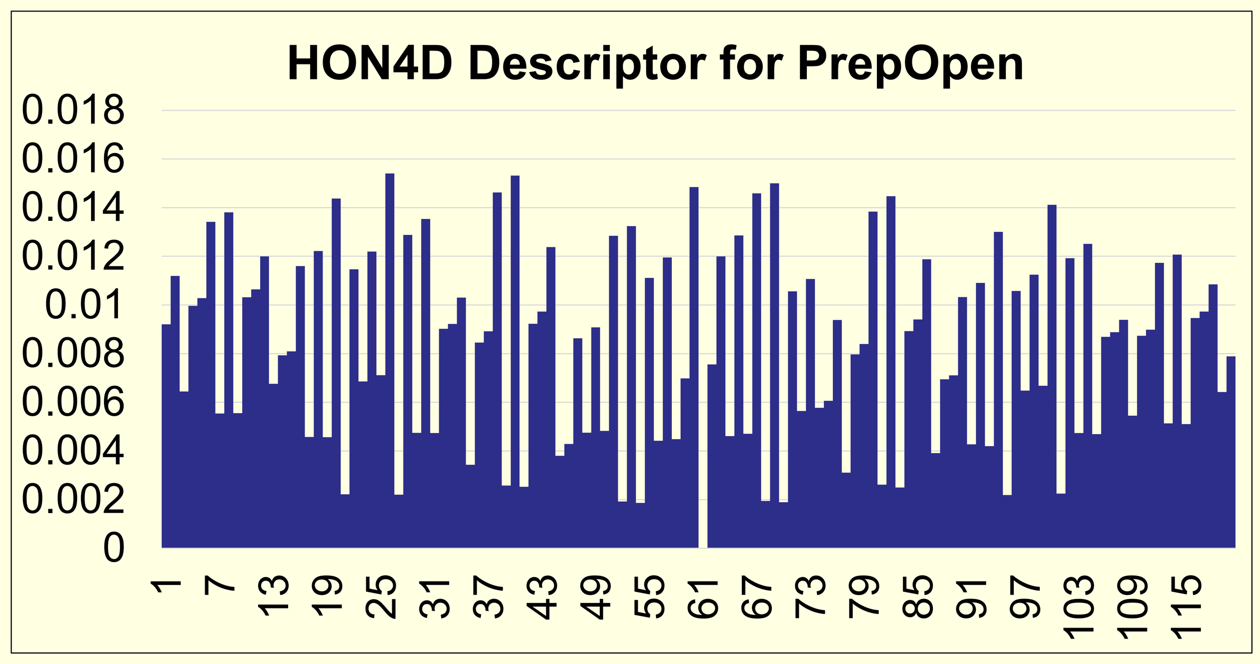

Fig. 2. HON4D Descriptor

Assessment

Major assessment :

- Distance:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

- Speed:

$$r = \frac{d}{t}$$

- Graphs of hand symmetry and chest sway
- To account for occlusion, when any of the upper body joints that are used to perform assessment are inferred or missing, all skeleton data for that instance is set to zero.

Recognition Results

- The in-house dataset in Table 1 was subdivided into smaller datasets as in Table 2.
- SVM with a quadratic kernel to classify the data
- Accuracies are highest on datasets whose actions are different categories. The scores are lower for when an action and its opposite are included, such as opening a jar and closing it.

Dataset Name	Actions	Accuracy
PickPutDataset1	PickUpCounter PutDownCounter PickUpTop PutDownTop PickUpBottom PutDownBottom	37.5%
PickPutDataset2	PickUpCounter & PutDown PickUpTop & Putdown PickUpBottom & PutDown	69.4%
OpenCloseDataset1	OpenTopCabinet CloseTopCabinet OpenBottomCabinet CloseBottomCabinet	54.2%
OpenCloseDataset2	OpenTopCabinet & Close OpenBottomCabinet & Close	75.0%
MixedDataset1	ManipulateFridge CloseBottomCabinet WalkIntoKitchenHold	97.2%
MixedDataset2	WashSink WalkAroundKitchenNotHold PrepStir	97.2%

Table 2. SVM results of datasets.

Assessment Results

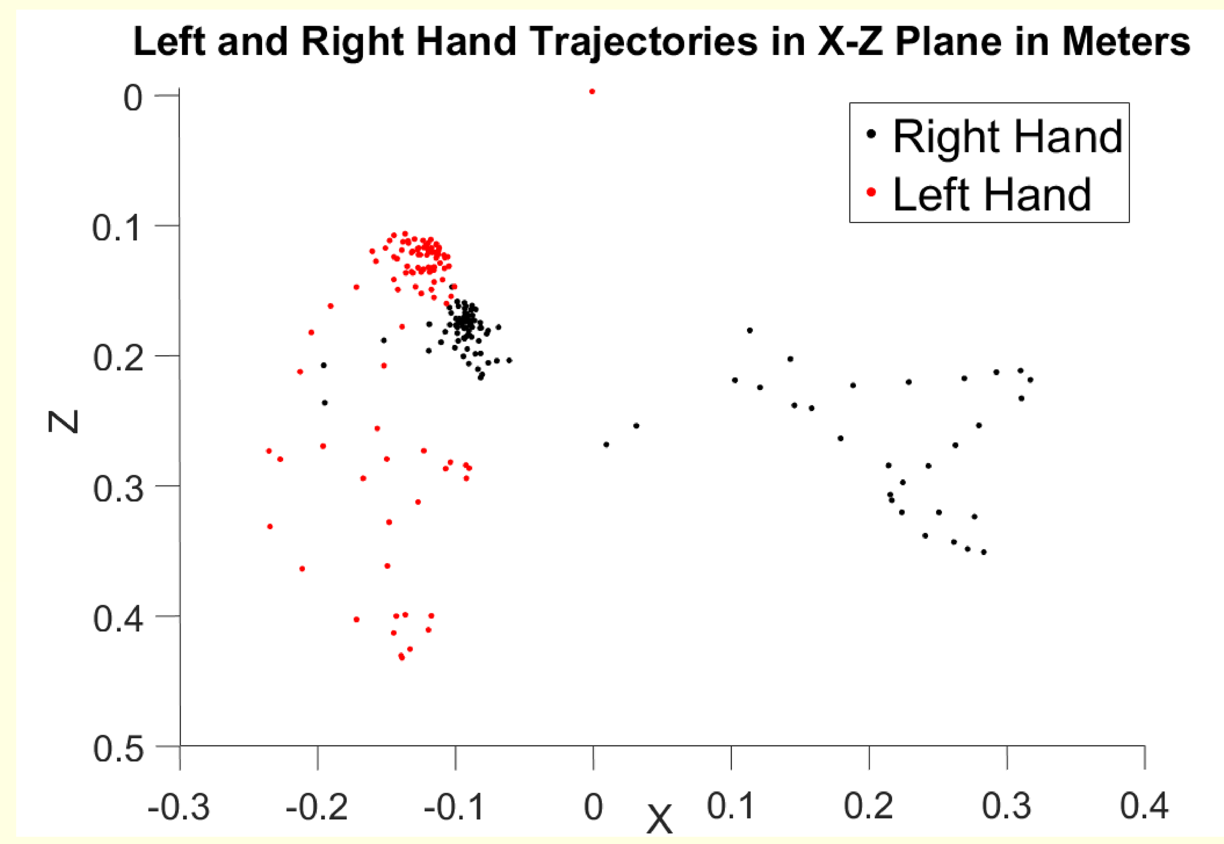

Fig. 3. 2D Hand symmetry for PrepOpen

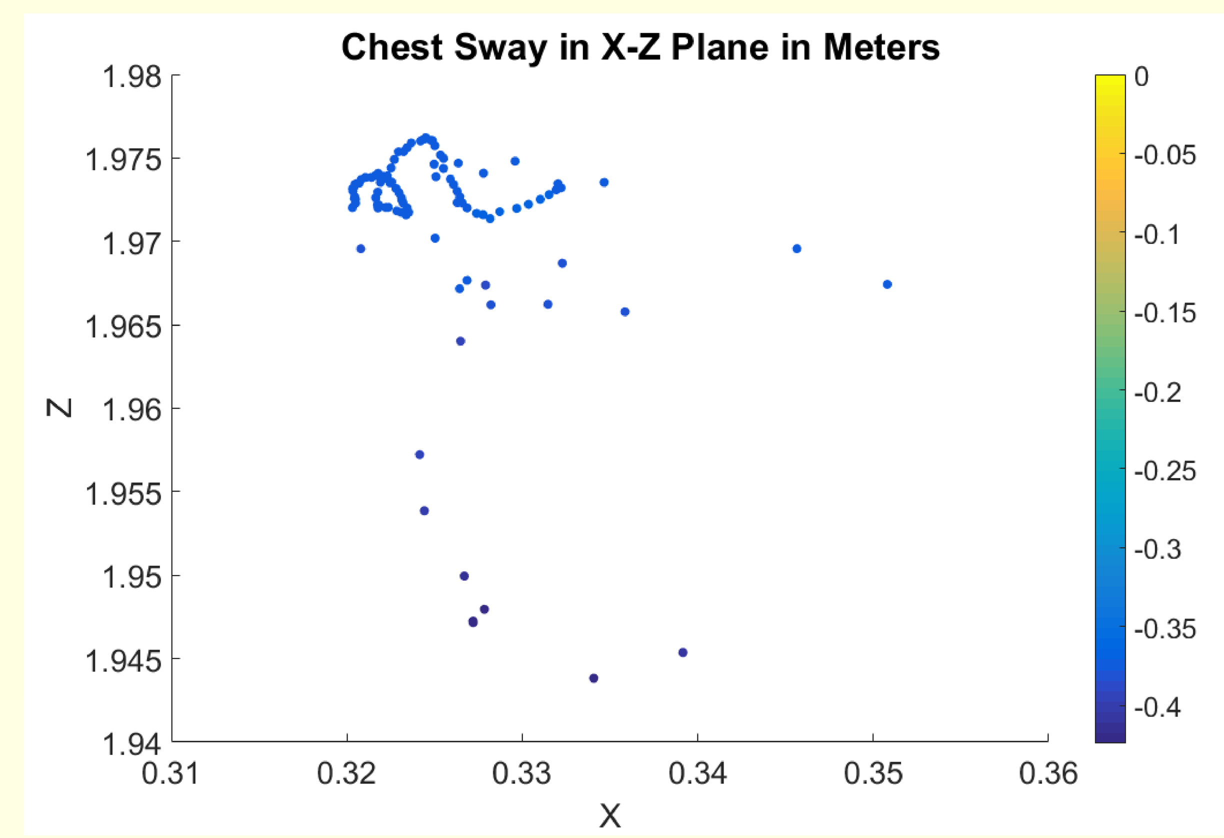

Fig. 4. 2D Chest sway for PrepOpen

Assessment speed accuracy was verified against a Vicon system with average and standard deviation: $\mu = 0.06 \quad \sigma = 7.85$ (inches/second)

	Max Arm Extension, Left	Max Arm Extension, Right	Mean Speed of Hand, Left	Mean Speed of Hand, Right
WashRinse	30.2	25.6	18.3	10.5
PrepOpen	22.4	22.2	8.1	11.6
WIKHold	24.1	21.9	17.3	19.2
MSinkOn	24.9	24.5	12.1	21.1
PUCounter	27.4	22.6	20.3	12.1

Table 3. Max arm extensions and mean speeds.

Conclusions

- We present a novel solution for occupational therapists to create more personalized care for stroke rehabilitation patients.
- Recognizes several actions with a high degree of certainty using HON4D as a global descriptor
- Assessment on critical metrics such as arm extension, mean velocity, and max velocity
- Allows a therapist to easily see problem areas or improvements over time to better provide care for a stroke victim

References

[1] "Rehabilitation therapy after a stroke," Nov 2015. Available: http://www.stroke.org/
[2] O. Oreifej and Z. Liu, "Hon4d: Histogram of oriented 4d normals for activity recognition from depth sequences," in 2013 IEEE Conference on Computer Vision and Pattern Recognition, June 2013, pp. 716–723.

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