

Depth Energy Image for Gait Symmetry Quantification

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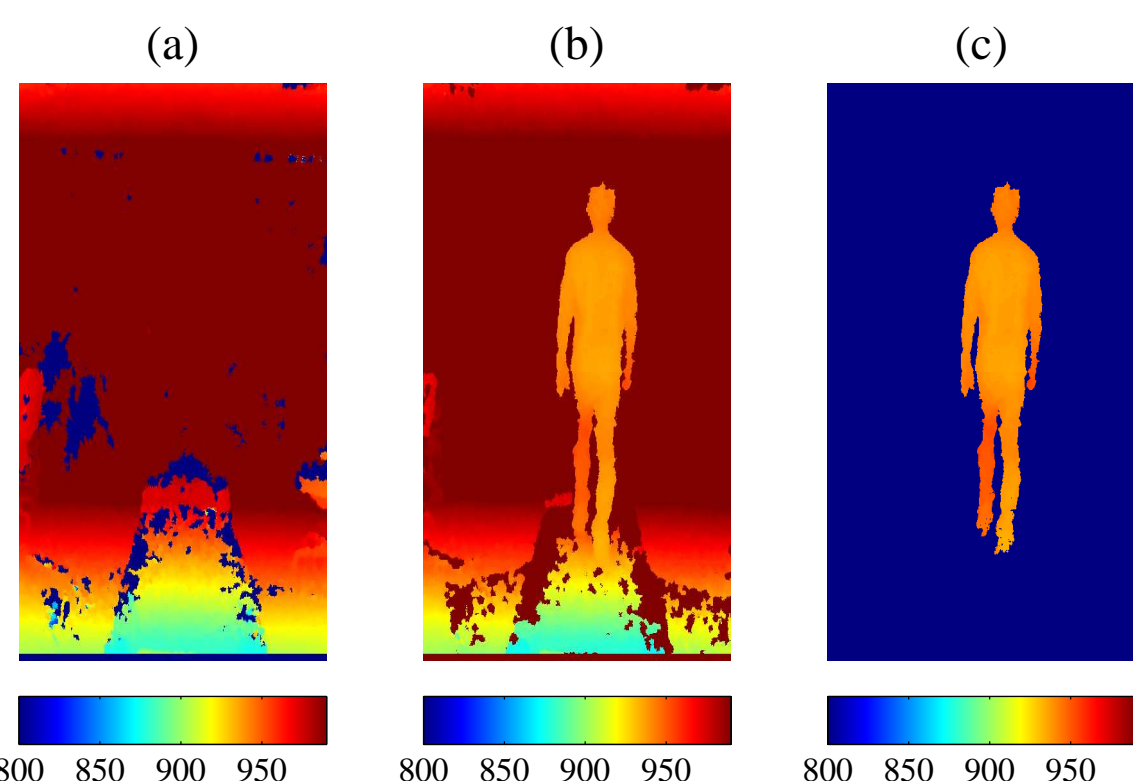
Abstract This paper introduces a new quantification method for gait symmetry based on depth information acquired from a structured light system. First, the new concept of Depth Energy Image is introduced to better visualize gait asymmetry problems. Then a simple index is computed from this map to quantify motion symmetry. Results are presented for six subjects with and without gait problems. Since the method is markerless and cheap, it could be a very promising solution in the future for gait clinics.

Introduction

- **Gait analysis:** to help diagnostic of abnormal gait patterns
- **Usually with motion capture (MOCAP)** [1, 2]
 - **Problems:** very expensive, complex to implement
- **Our gait analysis solution**
 - **Cheap depth sensor**, placed at the back of a treadmill
 - **Advantages:** No markers required, low cost price, well adapted for clinical use

Depth Energy Image (DEI)

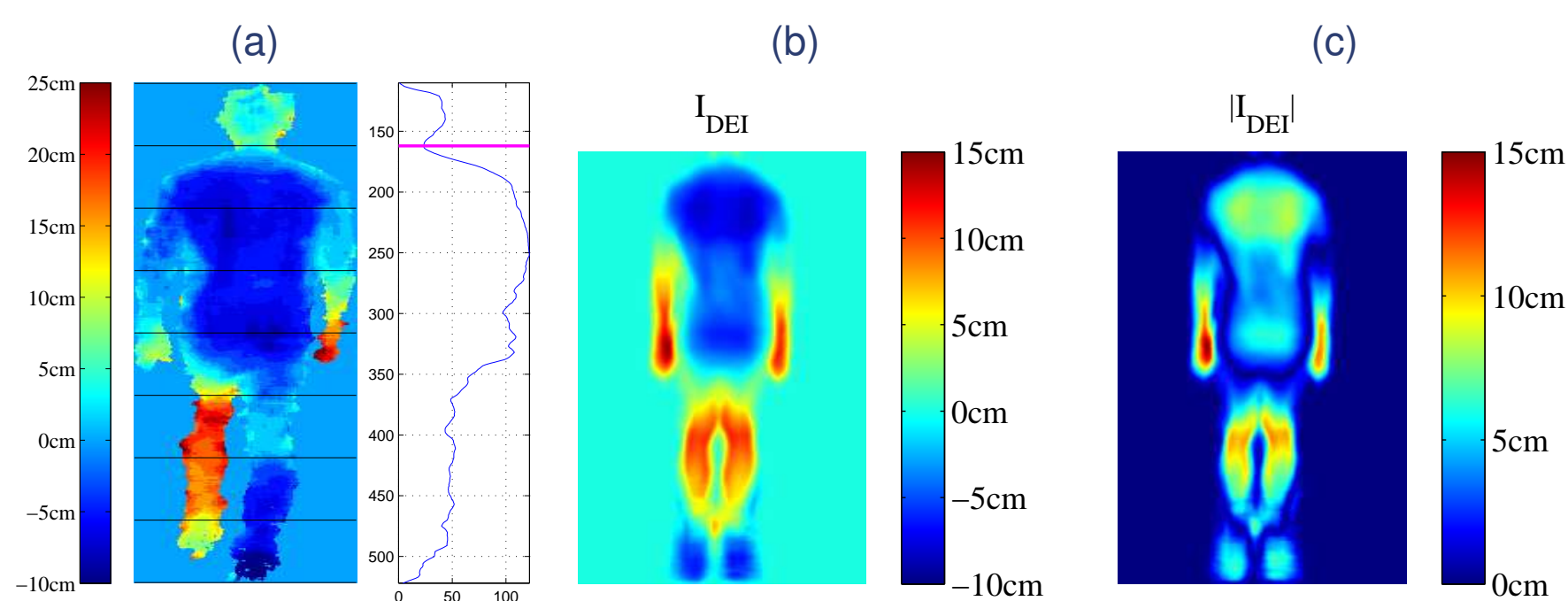
- **Kinect depth sensor [3]:** depth map 640x480 pixels at 30 fps
 - Infrared structured light (IR dots) projected in the scene and observed with an infrared camera → disparity map
- **Depth conversion** $Depth = 1/(-0.0032936 \cdot Disparity + 3.5463)$
- **Depth silhouette image** obtained from depth background



(a) Background and (b) current disparity images, and (c) resulting disparity silhouette

Depth Energy Image (DEI)

- Mean depth silhouette over several gait cycles



(a) Centered depth silhouette, (b) resulting DEI and (c) absolute value of DEI

- Gait asymmetry problems [1, 2] detected with the DEI image

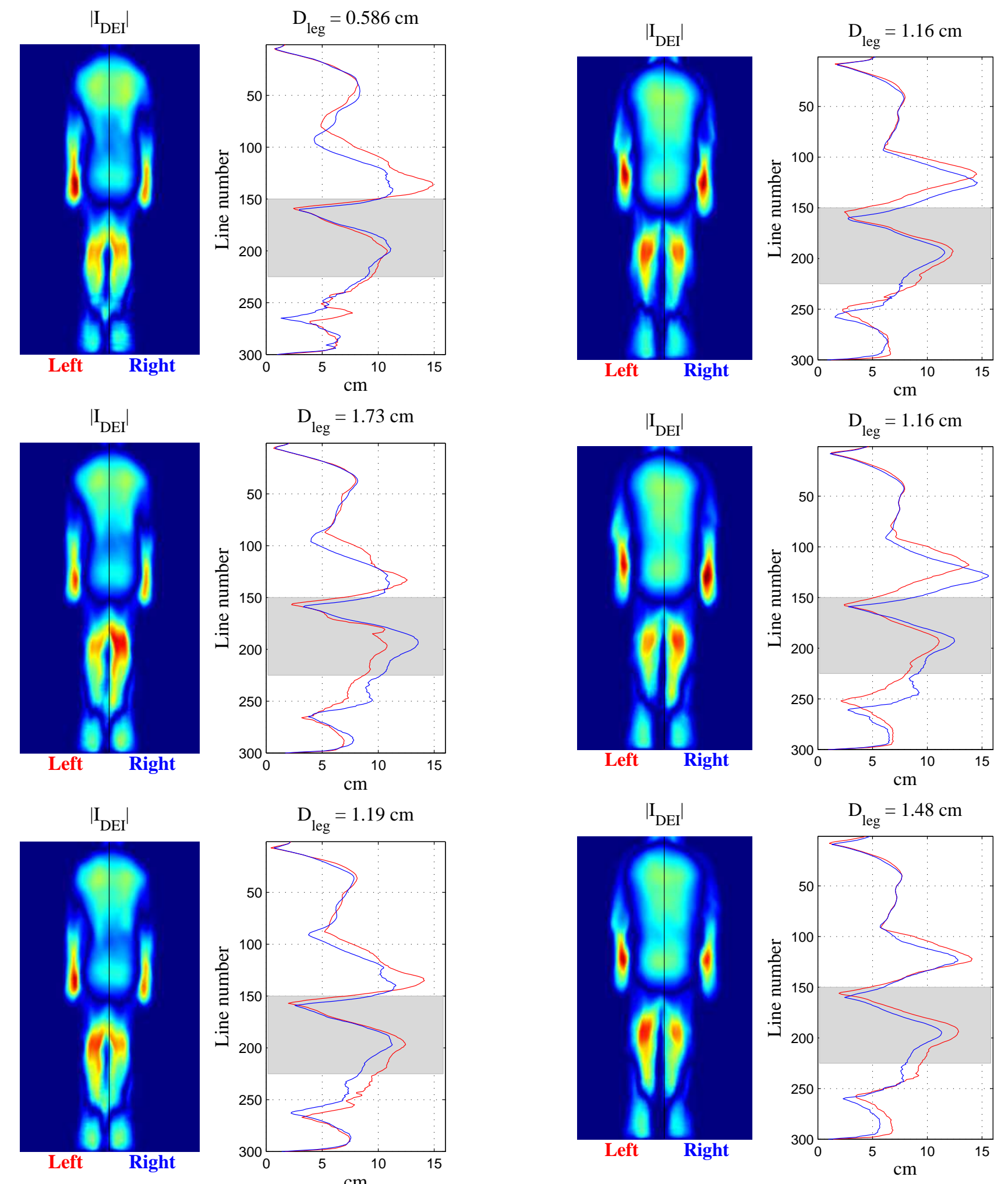
Experimental protocol

- Six young male adults, treadmill (Life Fitness F3)
- Limping walk with heel cup (height of 2.5cm)
 - ⇒ unbalanced gait with asymmetric characteristics
- Ethical approbation obtained from the research ethics board (REB) of our university
- **Several tests:** 2-3 min habituation period, 3 min video recorded
 - **Normal walk** = reference.
 - **Right leg problem** with heel cup placed inside the right shoe
 - **Left leg problem** with heel cup placed inside the left shoe

Experimental results

- Curves of maximum absolute DEI value computed for each leg
- D_{leg} = mean absolute distance value between the two legs
- Symmetry leg motion index $D_{leg} \leq 0.6cm \Rightarrow symmetric walk$

Red = left side curve, blue = right side curve



Subject S2

Subject S6

- D_{leg} and D_{arm} distances for our six subjects

Distance	Subject	Normal walk			Asymmetric normal walk		
		S1	S2	S3	S4	S5	S6
D_{leg} (cm)	Normal walk	0.55	0.59	0.57	1.52	0.74	1.16
	Right leg problem	1.72	1.73	1.56	1.17	0.71	1.16
	Left leg problem	1.21	1.19	1.81	2.31	2.18	1.48
D_{arm} (cm)	Normal walk	1.16	2.14	3.3	1.79	2.74	1.64
	Right leg problem	1.06	1.36	3.48	1.4	2.42	2.4
	Left leg problem	0.7	1.53	3.27	1.48	2.15	0.83

Conclusion

- **Depth Energy Image (DEI)** directly readable tool for clinician to analyze gait characteristics
- **Gait asymmetry** can be efficiently detected from back-viewed depth images
- **Future works** with more subjects, other gait indexes, other depth camera positioning (e.g. side view)
- **Acknowledgment** This work was supported by the Fonds de Recherche Nature et Technologies du Québec.

References

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- [2] A. Sant'Anna and N. Wickström, "A Symbol-Based Approach to Gait Analysis From Acceleration Signals: Identification and Detection of Gait Events and a New Measure of Gait Symmetry", *IEEE Transactions on Information Technology in Biomedicine*, vol. 14, no. 5, 2010, pp. 1180-1187.
- [3] Kinect, 3D-sensing technology <http://www.primesense.com>