RGB+D skeletal data error analysis and correction

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RGB+D skeletal measurement accuracy and its relevance

Cheap RGB+D revolutionized research in biometrics

24 mln copies of Kinect sold

Multiple new devices appearing

Applications: robotics, security, biometrics, rehabilitation.

Even small improvement in accuracy may have a great impact on dozens of algorithms and countless users

Has to be: simple, reference-less, fast

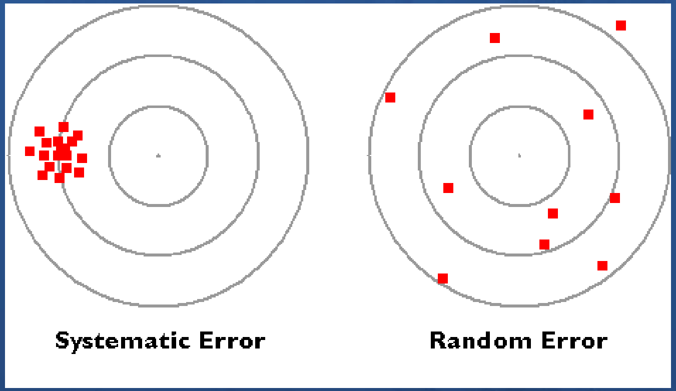
RGB+D measurements and possible error types

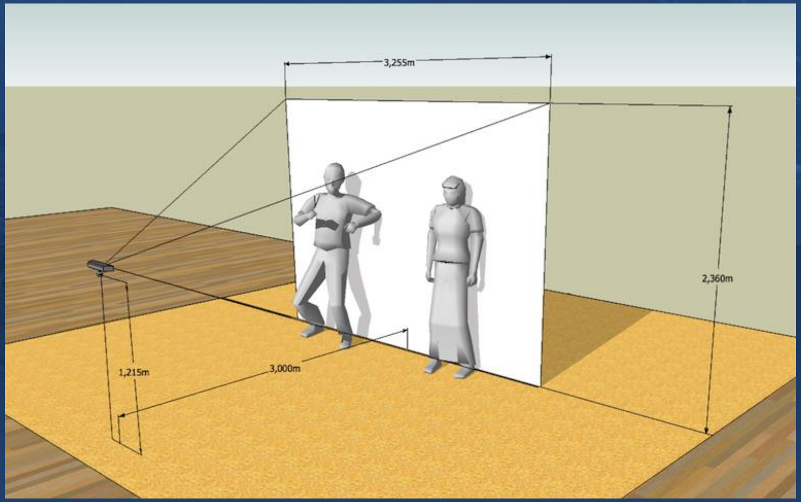
Random error

Systematic error

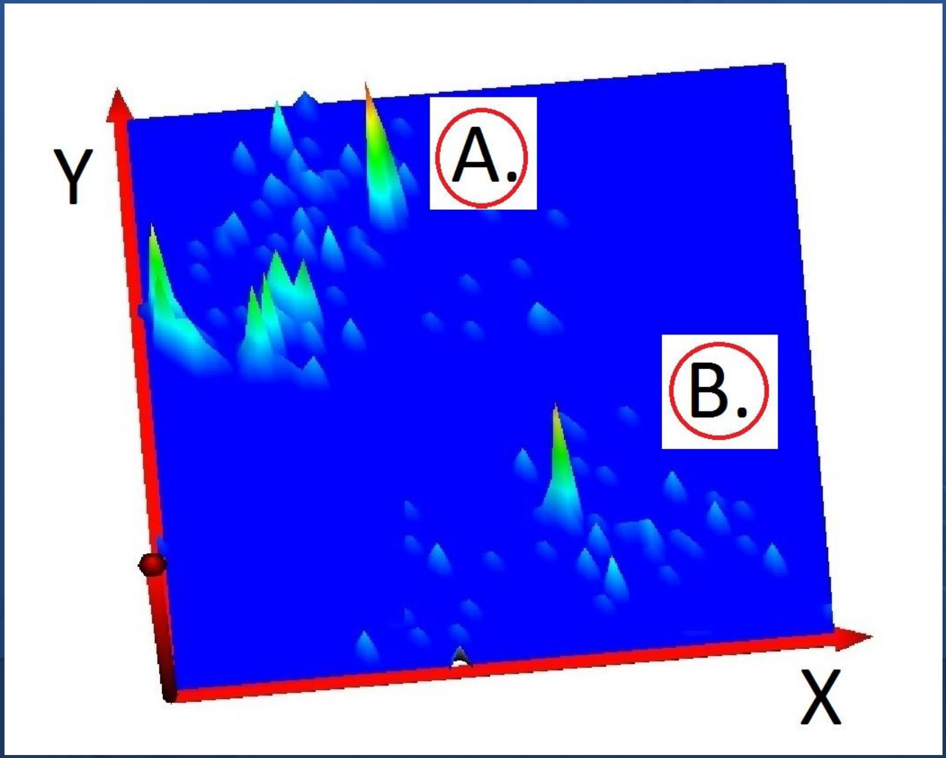
Catastrophic error

This work: only random and systematic errors





But.. how big is Kinect's systematic error??



Literature review

In general, errors of Kinect 1&2 are extensively investigated.

Major object's of investigation

1. Depth measurement precision
   - Khoshelman and Elbernik: "Accuracy and resolution of Kinect depth data for indoor mapping applications,"
   - Smisek et al. : "3D with Kinect"

2. Specific pose/motion measurement precision based
   - Wang et. Al. "Evaluation of Pose Tracking Accuracy in the First and Second Generations of Microsoft Kinect"
   - Obrzalek et. al. "Accuracy and robustness of kinect pose estimation in the context of coaching of elderly"

3. Quality of Kinect based specific biometric solutions

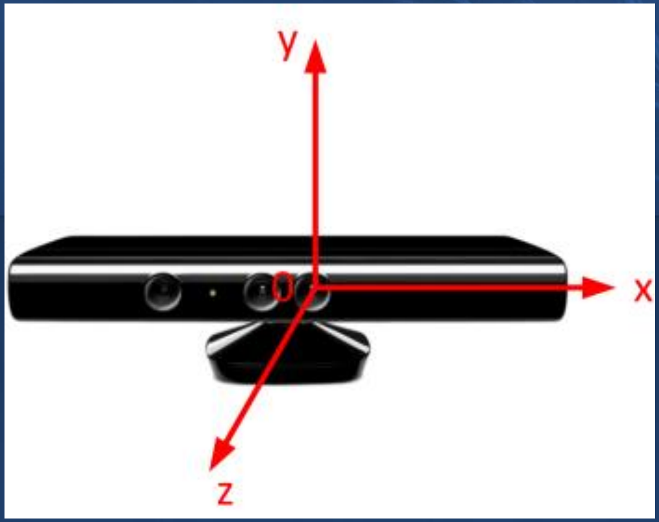
<u>No research on general systematic error of Kinect skeletal data.</u>

General model of improvement

1. Problem:
   a) is our how reliable is limb length data in a RGB+D frame?
   b) is it probably under or over estimated?

2. Reference-less system
   a) no actual limb length available.
   b) an average of multiple measurements = point of reference

3. QUESTION. Can we predict:
(Rx, Ry, Rz) - > dist. from the average?



First approach – linear classifier and angle-to-error correlation

Does the error change linearly with distance from the optimal angle?

Yes. To a degree. For some joints.

ID	N	R_x	R_y	R_z	limb Name
1.	1801	0.16	0.31	0.41	Lshoulder
2.	1699	-0.38	0.50	0.31	Rshoulder
3.	1703	-0.01	-0.82	-0.47	LeftArm
4.	1574	-0.07	-0.93	-0.39	RightArm
5.	1653	0.11	-0.83	0.32	Lforearm
6.	1611	-0.01	-0.34	0.42	Rforearm
7.	2141	0.12	0.20	-0.21	LeftHip
8.	2141	-0.18	0.00	-0.07	RightHip
9.	1901	0.05	-0.55	-0.48	LeftThigh
10.	1930	-0.04	-0.45	-0.30	RightThigh
11.	1820	0.00	-0.67	-0.44	LeftSheen
12.	1790	0.03	-0.64	-0.45	RightSheen

Some improvement of the results. Unstable for various users.

Can a more sophisticated approach work better?

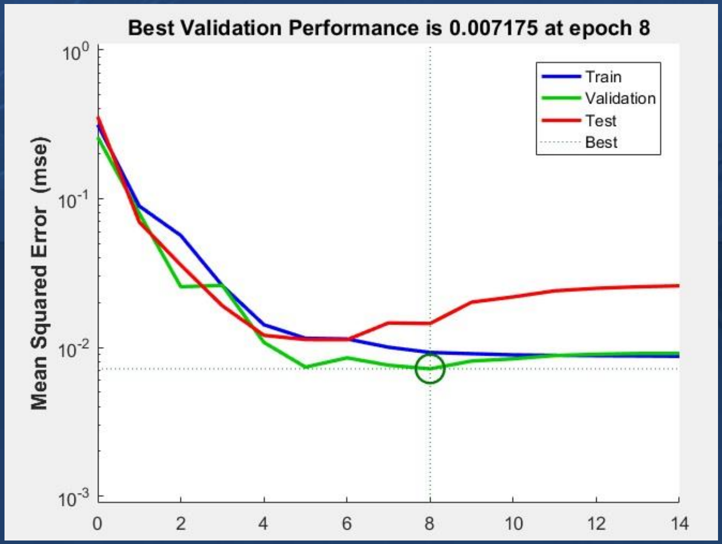
Better approach

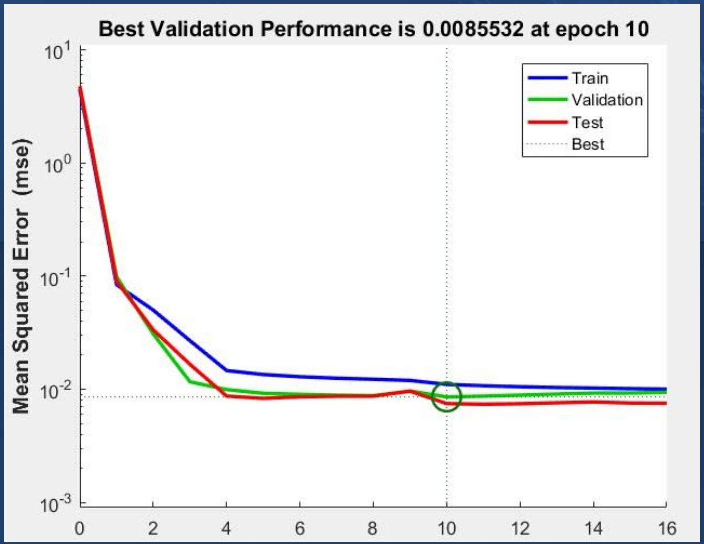
1. Sets of 3000+ samples per limb, for 12 people

2. Per person normalization of measurements (1.0 = set average)

3. Per joint approach

4. NN supervised learning: (Rx, Ry, Rz) - > distortion from average





Better approach(2)

5. 10-25 classifiers trained.

6. Best one is chosen (based on the validation data).

Corrected_limb_length = Kinect_limb_length/NN (Rx, Ry, Rz)

Base_error = Σ(Kinect_limb_length– average)^2/n

Corrected_error = Σ(Corrected_limb_length – average)^2/n

Correction_rate = Base_error/Corrected_error

Validation

Several scenarios. Training, Testing and Validation on...:

... the same subjects and actions, various repetitions

... the same subjects, various actions

… different subjects

Results, known subjects, actions

Average results:

- NN-Fit and correction ratio equal for training and testing

- Correction ratio on average > 1.6

- Correction ratio varies consistently per limb

Limb 1	NN Fit	Base Error	Correction Ratio.
Training	0.01424	0.0993	1.53735
Validation	0.01121	0.00769	1. 33123
Testing	0.01231	0.00819	1. 63484

Limb 7	NN Fit	Base Error	Correction Ratio.
Training	0.00775	0.01611	2.90218
Validation	0.00617	0.00821	2. 90994
Testing	0.00494	0.00607	2.10068

Results, unknown users, actions

Average results:

- NN-Fit and correction ratio vary for training and testing
- Correction ratio on average > 1.1 for unknown subjects, sometimes below 1.0
- Correction ratio for the known subjects remains high (1.5+)
- Correction ratio varies consistently per limb

Limb 1	NN Fit	Base Error	Correction Ratio.
Training	0.01953	0.02493	1.33735
Validation	0.00585	0.00769	1.45719
Testing	0.01013	0.00819	1.10706

Limb 7	NN Fit	Base Error	Correction Ratio.
Training	0.00775	0.02281	2.84912
Validation	0.00617	0.00611	1.01281
Testing	0.00494	0.00470	0.98068

Summary

- Presented simple method of improvement of skeletal data based limb length estimation
- It allow an significant average error reduction for known users by 1.7 ratio.
- Unknown users are unaffected on average
- Interesting findings:
  - Kinect systematic error is limb specific
  - Kinect systematic error is person specific

Thank you!