Comments and Corrections

Corrections to "A Sub-Pixel Accurate Quantification of Joint Space Narrowing Progression in Rheumatoid Arthritis"

Yafei Ou, *Member, IEEE*, Prasoon Ambalathankandy, *Member, IEEE*, Ryunosuke Furuya, Seiya Kawada, Tianyu Zeng, Yujie An, Tamotsu Kamishima, Kenichi Tamura, and Masayuki Ikebe, *Member, IEEE*

Rheumatoid arthritis (RA) is an autoimmune disease that poses significant diagnostic and monitoring challenges. Our previous work [1] contributed to this field by focusing on the role of radiography in detecting and monitoring joint space narrowing (JSN), a critical marker of RA progression. However, during our investigation, we inadvertently misquoted data in Table V and Table VII, a key component of our findings.

This paper primarily addresses a correction of our previous work [1]. We aim to clarify the mistaken reference numbers, ensuring that our findings and conclusions are accurately represented. This is essential not only for the integrity of our work but also for the broader scientific discourse surrounding RA.

In this correction, we not only rectify the reference indexing error, and provide the revised Tables, ensuring the correctness of the data presented. Additionally, we include an updated version of Section IV-B-1) and Section IV-B-3) of our previous paper [1]. This section is particularly significant as it discusses the implications of our findings and their relevance in the context of RA research and clinical practice.

IV. Experiments and Discussion

B. JSN Progression Quantification

1) Phantom Study: Phantom images with ground truth were used in this experiment to calculate the absolute error of Partial Image Phase Only Correlation (PIPOC), and to compare it with manual measurements. Our manual measurement experiments were performed by one radiologist and one radiological technologist after substantial training. They did not know the ground truth of the random phantom images. They were asked to determine the center of the proximal phalanx bone phantom by drawing straight lines horizontally connecting both ends of the phantom base, then a straight line was drawn from the center vertically, and the Joint Space width (JSW) overlapping the straight line was measured.

Fig. 10 and Table V presents the measurement result of phantom study. The manual measurement result of the radiologist and the radiological technologist showed high similarity in terms of mean error and Root-Mean-Square Deviation (RMSD) in multiple phantom data sets. The mean error of manual measurements is about 0.0555 mm (0.37 pixel) in low noise environment (air sets), and 0.1036 mm (0.69 pixel) in high noise environment (water sets) in radiographic phantom studies. For tomosynthesis datasets, the mean error is 0.1780 mm (0.68 pixel) in low noise environment, and 0.1969 mm (0.76 pixel) in high noise environment. This shows that visual measurement also can be greatly affected by the noise. On the other hand, this also indicates the manually annotated data have sub-pixel level mean error. Hence, the manually annotated ground truth may result in sub-pixel level deviation in algorithm evaluation of other works.

In paper [2], only one phantom dataset (environment: air, JSW range: 1.20 mm–2.20 mm, increment step size: 0.10 mm) is used in experiment. The mean error of Full Image Phase Only Correlation (FIPOC) is slightly lower than manual measurement. When compared to FIPOC, PIPOC can further improve the accuracy and robustness in JSN progression quantification, by eliminating the impact of image in-painting algorithm. As show in Table V, our work only has a 11.9% to 35.0% mean error, and a 11.7% to 32.0% RMSD when compared to manual measurement in radiographic phantom study. For the tomosynthesis datasets, our work only has 6.0% to 15.6% mean error, and a 6.0% to 16.1% RMSD in comparison to manual measurement. This illustrates the improved performance of JSN progression quantification when using phantom datasets. Considering the spatial resolution of radiography (0.15 mm/pixel) and tomosynthesis (0.26mm/pixel), we can notice that PIPOC performs better on tomosynthesis images when compared in pixels. We regard this difference is due to the sharper edge information of the tomosynthesis. Thus, we recommend using PIPOC in tomosynthesis preferentially with same spatial resolution.

3) Comparison With Related Works: Table VII compares our work with previous JSW/JSN quantification works. In paper [3], they only used RMSD instead of mean error to evaluate the accuracy of their work, so we standardized the error metric accordingly. Considering that the error should conform to a Gaussian distribution, the mean error and

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Yafei Ou, Prasoon Ambalathankandy, Ryunosuke Furuya, and Seiya Kawada are with the Research Center for Integrated Quantum Electronics, Hokkaido University, Sapporo 060-0813, Japan, and also with the Graduate School of Information Science and Technology, Hokkaido University, Sapporo 060-0814, Japan (e-mail: oygrallen@gmail.com; prasoon.ak@ist.hokudai.ac.jp; huruya@rciqe.hokudai.ac.jp; kawada@rciqe.hokudai.ac.jp).

Tianyu Zeng and Yujie An are with the Graduate School of Health Sciences, Hokkaido University, Sapporo 060-0812, Japan (e-mail: zengtianyu1223@yahoo.co.jp; anyujie19960922@kamiken.net).

Tamotsu Kamishima is with the Faculty of Health Sciences, Hokkaido University, Sapporo 060-0812, Japan (e-mail: ktamotamo2@hs.hokudai.ac.jp).

Kenichi Tamura is with the Department of Mechanical Engineering, College of Engineering, Nihon University, Koriyama 963-8642, Japan (e-mail: tamura.kennichi@nihon-u.ac.jp).

Masayuki Ikebe is with the Research Center For Integrated Quantum Electronics, Hokkaido University, Sapporo 060-0813, Japan (e-mail: ikebe@ist.hokudai.ac.jp).

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TABLE V
PERFORMANCE ANALYSIS IN MILLIMETER FOR PIPOC AND MANUAL MEASUREMENT WHEN USING PHANTOM IMAGES

	Mean Error						Root-Mean-Square Deviation					
	Air			Water			Air			Water		
Radiography	Fig.10(a)	Fig.10(b)	Average	Fig.10(c)	Fig.10(d)	Average	Fig.10(a)	Fig.10(b)	Average	Fig.10(c)	Fig.10(d)	Average
Radiologist (Manual)	0.0509	0.0620	0.0565	0.0727	0.1196	0.0961	0.0665	0.0758	0.0711	0.0923	0.1450	0.1186
Technologist (Manual)*	0.0595	0.0497	0.0546	0.1186	0.1034	0.1110	0.0709	0.0632	0.0671	0.1440	0.1237	0.1339
Mean of Manual	0.0552	0.0559	0.0555	0.0957	0.1115	0.1036	0.0687	0.0695	0.0691	0.1182	0.1343	0.1263
PIPOC (Ours)	**0.0193**	**0.0066**	**0.0130**	**0.0251**	**0.0200**	**0.0226**	**0.0220**	**0.0081**	**0.0150**	**0.0303**	**0.0245**	**0.0274**
FIPOC [2]	0.0400	-	0.0400	-	-	-	-	-	-	-	-	-
Tomosynthesis	Fig.10(e)	Fig.10(f)	Average	Fig.10(g)	Fig.10(h)	Average	Fig.10(e)	Fig.10(f)	Average	Fig.10(g)	Fig.10(h)	Average
Radiologist (Manual)	0.0815	0.1477	0.1146	0.2009	0.1316	0.1662	0.1000	0.1835	0.1418	0.2365	0.1603	0.1984
Technologist (Manual)*	0.2155	0.2671	0.2413	0.2210	0.2342	0.2276	0.2616	0.3307	0.2962	0.2678	0.2800	0.2739
Mean of Manual	0.1485	0.2074	0.1780	0.2110	0.1829	0.1969	0.1808	0.2571	0.2190	0.2521	0.2201	0.2361
PIPOC (Ours)	**0.0180**	**0.0124**	**0.0152**	**0.0329**	**0.0243**	**0.0286**	**0.0220**	**0.0154**	**0.0187**	**0.0407**	**0.0292**	**0.0349**

* Measured manually by a radiological technologist.

TABLE VII
COMPARISON WITH RELATED WORKS

		Dataset	Resolution	Mean Error				Standard Deviation			
		(Radiographs)	(mm/pixel)	DIP	PIP	MCP	Overall	DIP	PIP	MCP	Overall
Neural Network [3]	'00	54	0.1	0.118	0.071	0.091	0.093	-	-	-	-
Active Shape Models [4]	TMI'08	160 MCP*	0.0846	-	-	0.283(16.1%)	-	-	-	0.080(5.4%)	-
Edge Detection [5]	TBME'15	104	0.1	(5.8%)	(7.2%)	(7.1%)	(6.8%)	(4.8%)	(5.3%)	(4.4%)	(4.8%)
PIPOC (Ours)	**-**	**549**	**0.175**	**-**	**-**	**-**	**-**	**0.044**	**0.053**	**0.050**	**0.049**
FIPOC [2]	ISBI'19	Phantom	0.15	-	-	0.040	-	-	-	-	-
Manual Measurement	-	Phantom	0.15	-	-	0.056	-	-	-	-	-
PIPOC(Ours)	**-**	**Phantom**	**0.15**	**-**	**-**	**0.013**	**-**	**-**	**-**	**0.007**	**-**

* The dataset in [4] contains 160 MCP joint radiographs. Considering that each hand radiograph contains 5 MCP joints, this dataset can be equivalent to 32 hand radiographs. Mean error and standard deviation in millimeter. Numbers in braces indicate the corresponding percentage of the ground truth value for the respective joint.

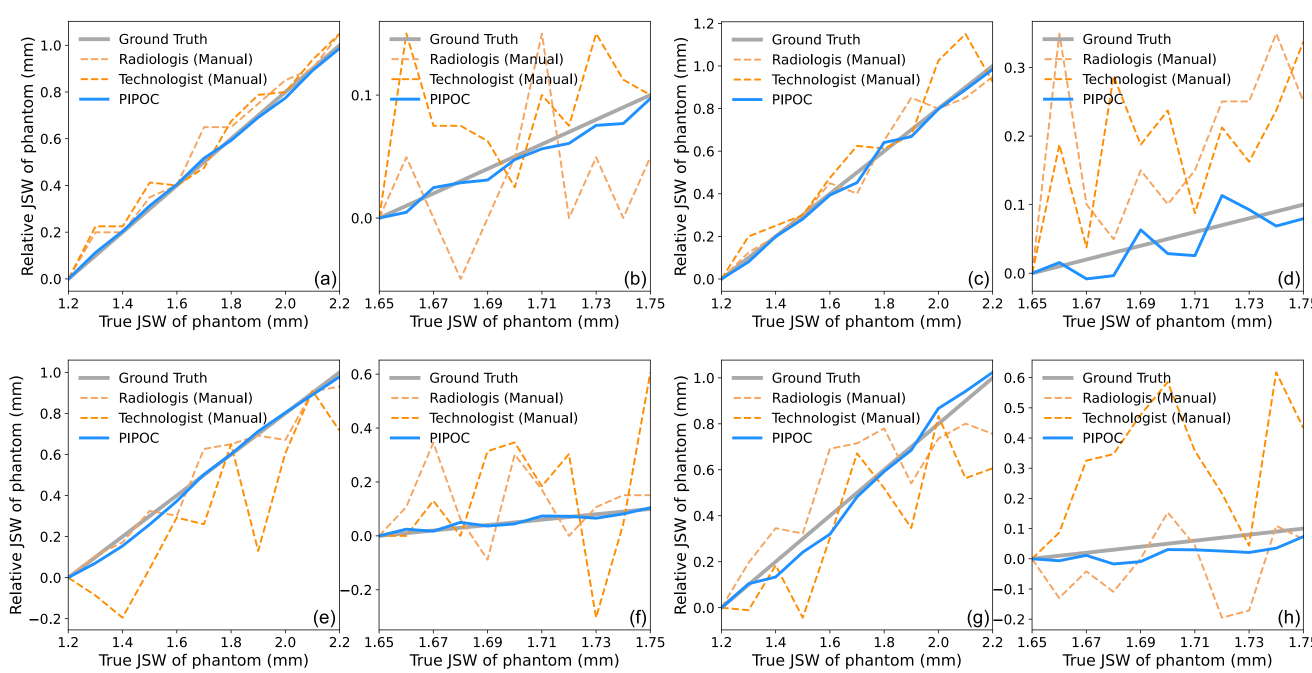

Fig. 10. Measurement result of PIPOC and manual in phantom study. Blue lines are the relative JSW of each image to the first image obtained by PIPOC. Orange dot lines are the difference of manually measured JSW between every image and the first image. We preformed two imaging techniques in our phantom study, radiography: (a)∼(d), Tomosynthesis: (e)∼(h). The phantom of sub-figure (a), (b), (e) and (f) is placed in air. The phantom of sub-figure (c), (d), (g) and (h) is placed in distilled water. The true JSW of phantom is from 1.20 mm to 2.20 mm at increments of 0.10 mm in sub-figure (a), (c), (e) and (g). And it is from 1.65 mm to 1.75 mm at increments of 0.01 mm in sub-figure (b), (d), (f) and (h).

RMSD can be transformed by (15).

$$E = \int_{-\infty}^{+\infty} |x| \cdot \frac{1}{\sqrt{2\pi} \cdot \mathrm{RMSD}} e^{-\frac{x^2}{2 \cdot \mathrm{RMSD}^2}} dx = \sqrt{\frac{2}{\pi}} \cdot \mathrm{RMSD} \tag{15}$$

In paper [5], authors only give the corresponding percentage of the error to the ground truth. Considering the JSW of metacarpophalangeal (MCP) joint is around 1.70 mm, the mean error of MCP joint in millimeter is around 0.121. It is noteworthy that, papers [3], [4], [5] used manual measurement results as ground truth. As discussed above and in Table VII, manual measurement has an error about 0.056 mm (low noise) / 0.104 mm (high noise) when using phantom data (spatial resolution: 0.15 mm/pixel). Although this value can decrease with higher spatial resolution, it is undeniable that in these works which employ manual measurement as the ground truth, the mean error may have a deviation.

The calculation procedure of standard deviation in paper [4] is different from ours. They measured JSW of each joint 10 times with varying clipping of the entire radiograph. The standard deviation quantified the uncertainty of measuring a radiograph. In our work, an intermediate radiograph is introduced in standard deviation calculation. The JSN progression between the two radiographs and the intermediate image is calculated respectively, thus, the standard deviation can be obtained by changing the intermediate image. When using the standard deviation calculation method given in paper [4], we measured a lower standard deviation (Distal interphalangeal joint (DIP): 0.0099 mm, Proximal interphalangeal joint (PIP): 0.0095 mm, MCP: 0.0061 mm. These standard deviations do not include mismatched data).

Compared to the method which combines FIPOC, spatial domain segmentation, and image in-painting algorithm [2], this work has a lower mean error in phantom study, and faster processing speed (on our clinical dataset, PIPOC (Ours): 0.0121 sec/time, FIPOC [2]: 0.0358 sec/time). These improvements are due to the removal of the in-painting algorithm.

We can observe from Table VII that even though the spatial resolution of our work is poorer than those in the related works, our mean error and the standard deviation are significantly lower.

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