TRACKING JOINTS WITH ULTRASOUND

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1. Introduction

The overall aim of my research is to develop a novel ultrasound-based system to dynamically describe 3D joint kinematics for musculoskeletal condition diagnosis and therapy monitoring. About 10 million adults and 12,000 children have musculoskeletal conditions in England in 2006 [1]. The pathology of many musculoskeletal problems is likely to be related to abnormal joint kinematics. However, there is currently no effective method to dynamically measure three-dimensional (3D) joint kinematics during routine activities such as walking or squatting due to the constrained measuring volume or time consumption, etc. [3] Traditional 2D freehand ultrasound scanning only describes the morphology characters of the local bony structure. The approach I am developing registers 2D ultrasound data to the 3D position of ultrasound probe so that the bony landmarks imaging with ultrasound can be transformed into 3D space and the resulting ultrasound "signatures" are tracked.

2. Apparatus

The Oxford Motion Analysis (VICON system, Oxford, UK) with UltraSound (Voluson i, GE, UK) (MAUS) system incorporates a 16 infrared camera motion capture system (MCS) to measure the position of retro-reflective markers on bony landmarks (skin-based) and an ultrasound probe as a surrogate to detect and transform the actual position of the underlying bony landmarks.(***Fig.1***)

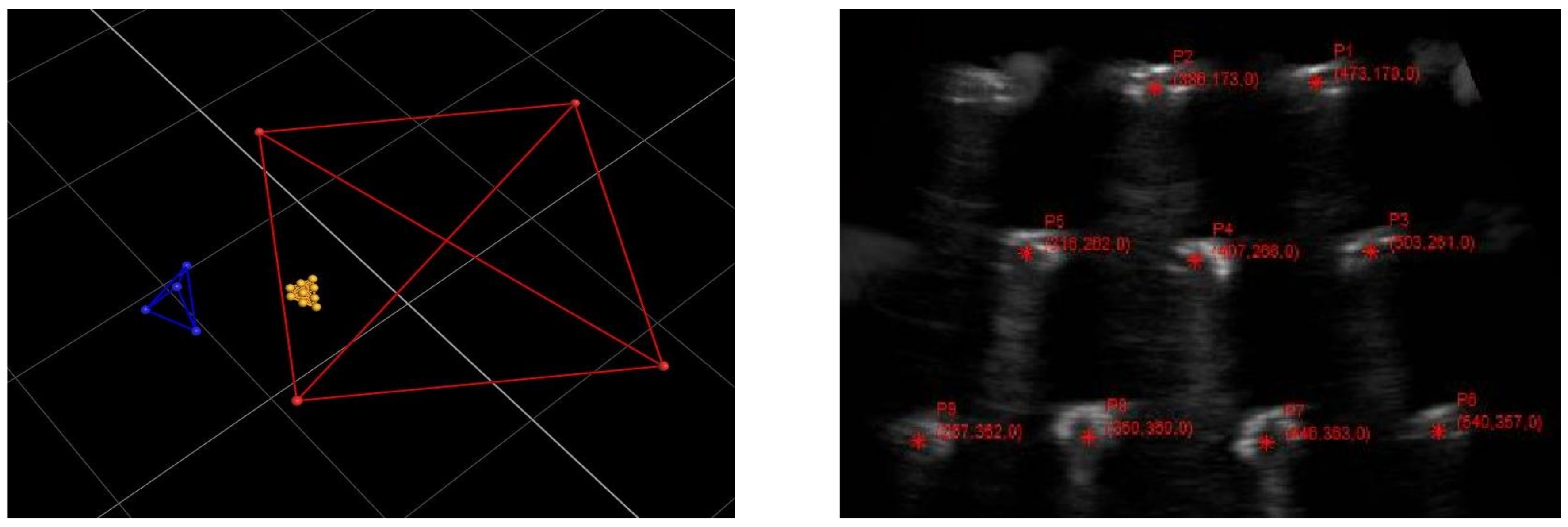
Why not use a Motion Capture System(MCS) alone?
1> soft tissue artefact (STA)
2> unreal bony landmark representation

Why Ultrasound (US)?
1> Real-time
2> portable
3> Cheaper and Safer than MRI,CT or X-Ray

Fig.1 *Experiment set up*

3. Calibration

Nine pins with retro-reflective material on the top, which can both be captured by the MCS when exposed in the air and US when submerged in the water were used to estimate the calibration transformation matrix based on the Euclidean Transformations Algorithm [2]. (***Fig.2***)

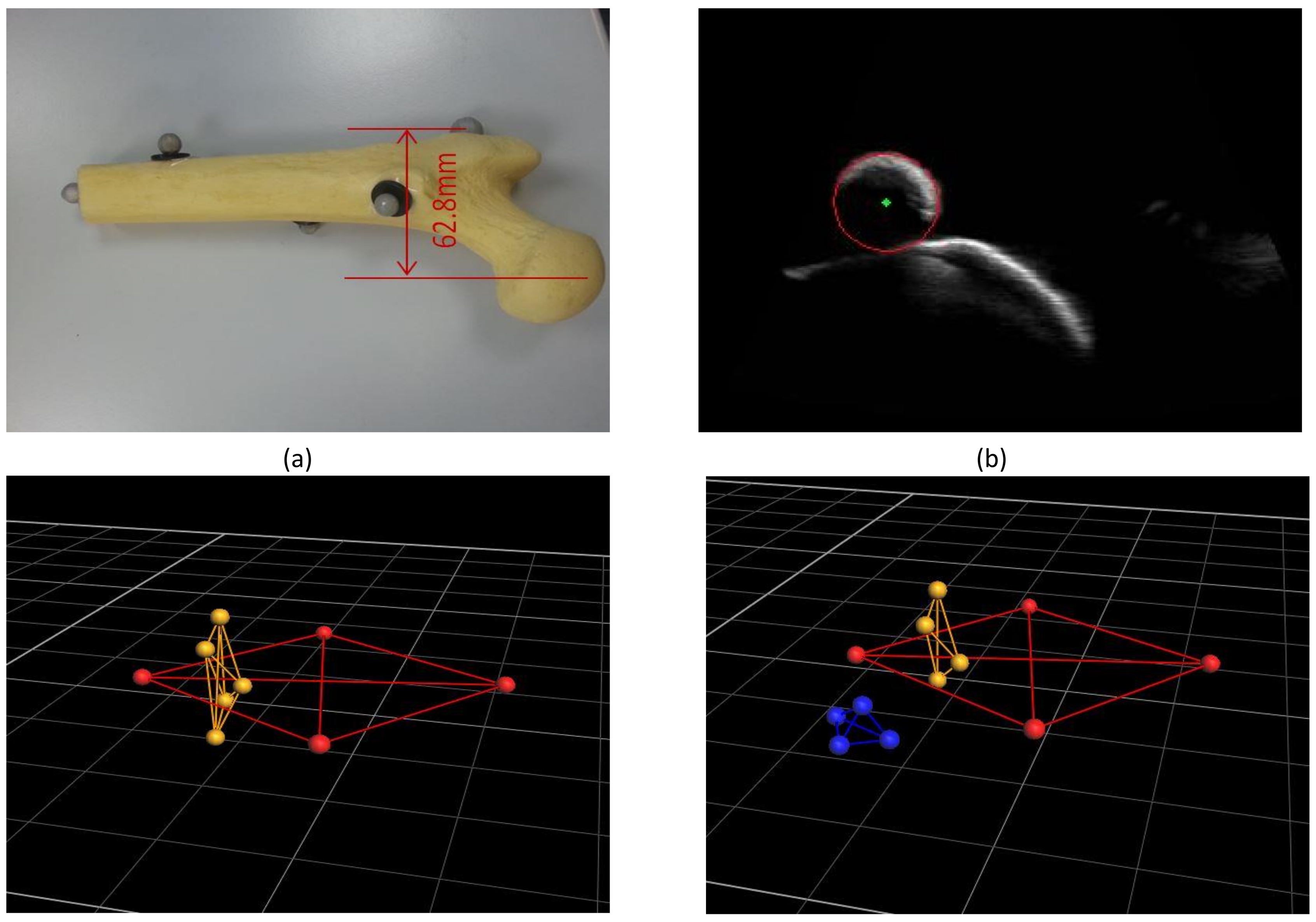


(a) ***(b)***

Fig.2 *Nine pins* ***(a)*** *Markers on box, pins and probe captured by MCS* ***(b)*** *Nine pins in Ultrasound*

4. Femur Phantom Experiment:

A femur model with five markers (non co-planar) was manually rotated around one axis. First, these five markers were captured by the MSC. Then the bottom marker was submerged in (degassed) water. The other four markers on the femur and four on the probe were captured by the MCS and the bottom marker captured by US. The positions of the bottom marker in the US Local Coordinate System (LCS) were transformed to the Global Coordinate System (GCS). (***Fig.3***)



(a) (b) (c) (d)

Fig.3 (a)*Femur model* ***(b)*** *Bottom marker on in US* ***(c)*** *Five markers in MCS* ***(d)*** *Four makers on femur and four on probe in MCS*

5. Result

Data analysis was carried out using Matlab. Three trials were collected to reduce observer error. One dimension rotation trajectories of the bottom marker on the femur model were transformed from the US LCS to GCS (***Fig. 4***) .

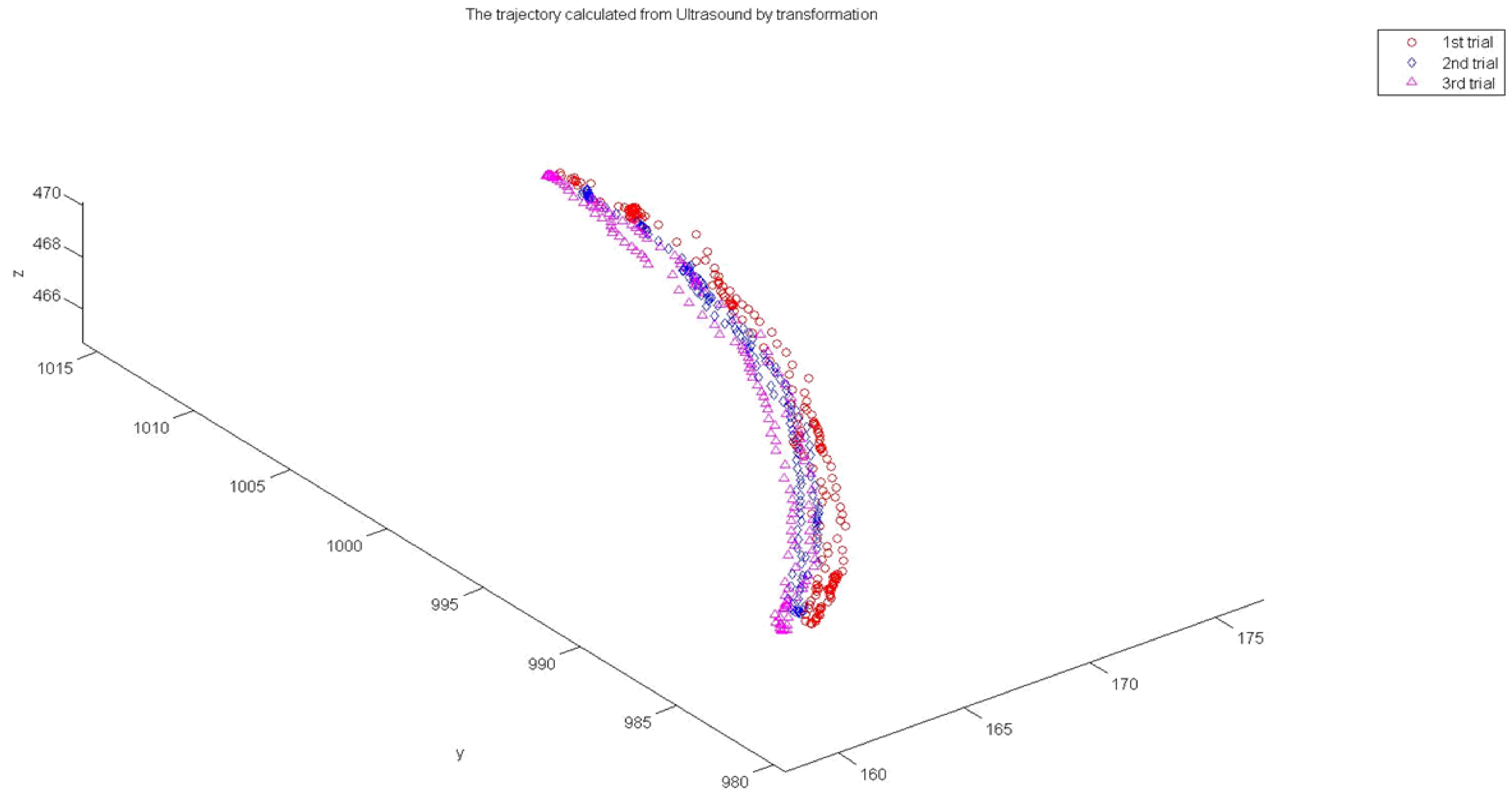


Fig.4 *Rotation trajectories of the bottom marker on the femur transformed from US to GCS*

The radii of the trajectories were plotted in ***Fig.5***.

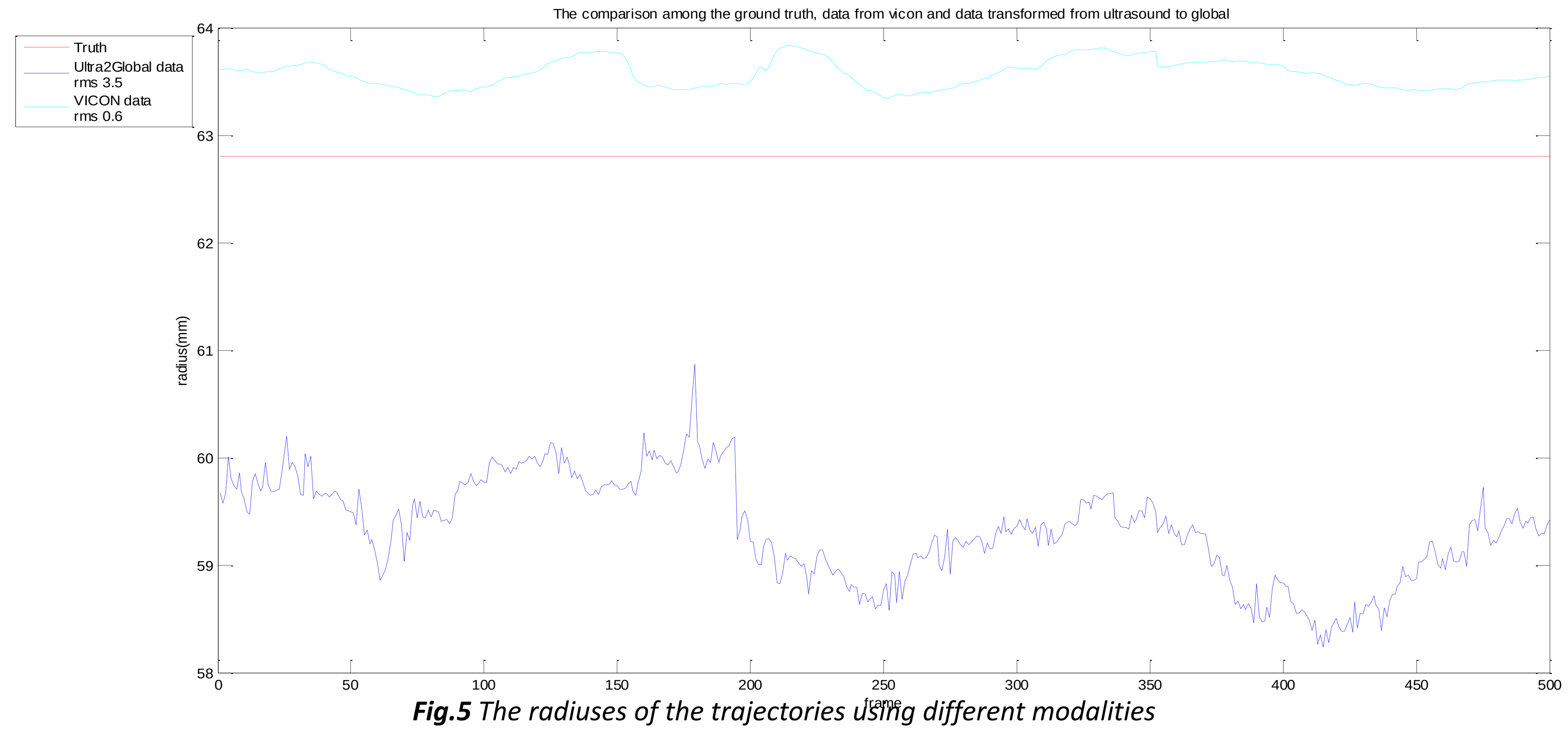


Fig.5 *The radiuses of the trajectories using different modalities*

The root mean square (r.m.s) errors of the different methods were calculated (***Chart.1***). STA problem was also compared (***Chart.1***). It is reported that the STA can caused the error up to 50 mm[4].

	TRUTH	MCS	US	MCS STA
r.m.s.(mm)	0	0.57	3.48	Up to 50mm

Chart.1 *r.m.s errors of different methods*

6. Discussion

- MCS provides the most accurate results, but when used *in vivo,* it causes a huge error because of STA.
- We have developed MAUS which can detect deep bony landmarks under skin using ultrasound, and tracked its movement by transforming the movement in US into GCS.

References:

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