Anatomical 2D/3D Shape-Matching in Virtual Reality: A User Interface for Quantifying Joint Kinematics with Radiographic Imaging

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IV/LAB

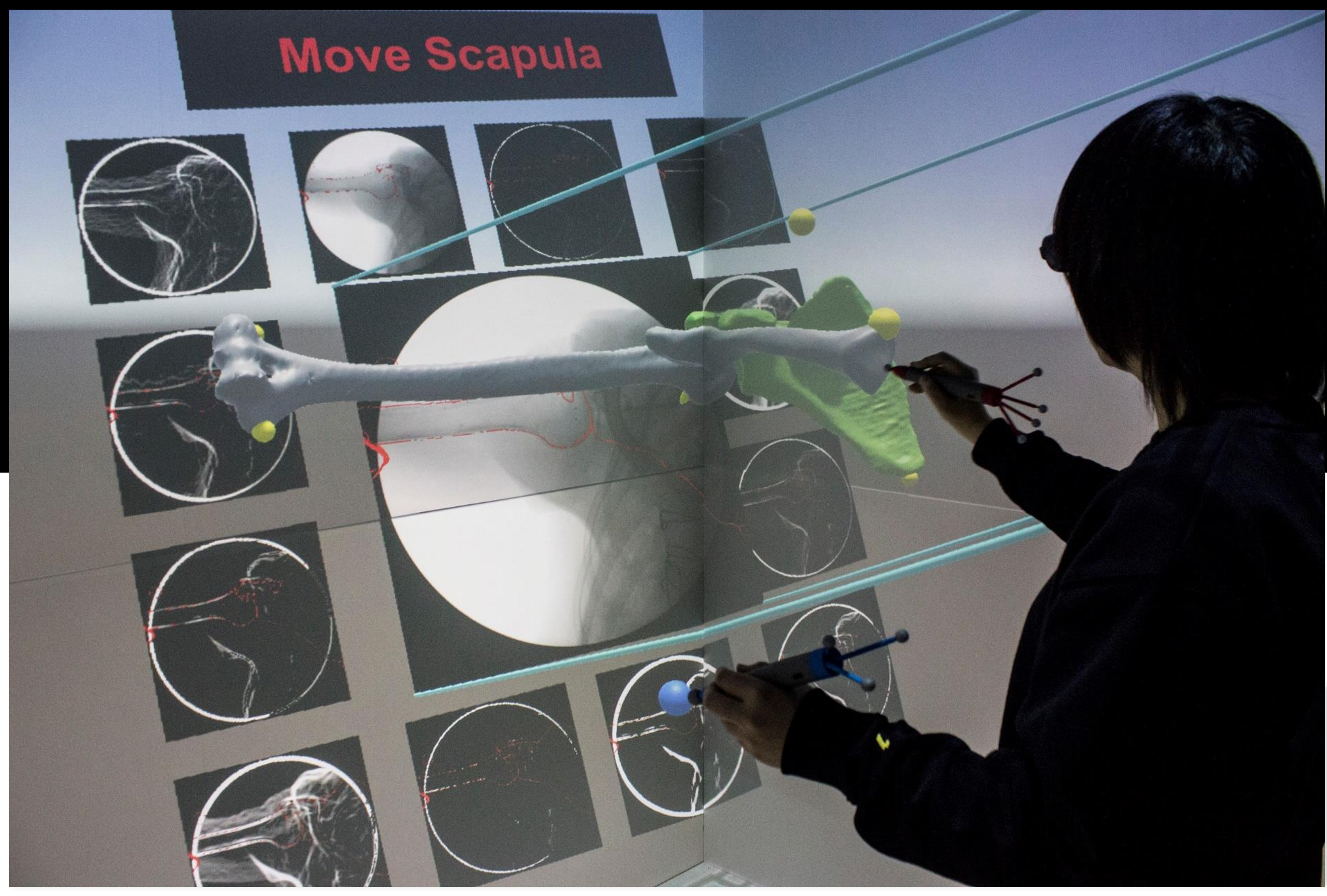


Fig. 2 Users work within a VR environment that is a calibrated virtual reconstruction of the imaging lab, manipulating 3D bone models (here, the scapula, clavicle, and humerus) to make their projections match experimentally collected X-ray imagery.

ABSTRACT

We introduce a virtual reality 3D user interface (3DUI) for anatomical 2D/3D shape-matching, a challenging task that is part of medical imaging processes required by biomechanics researchers. Manual shape-matching can be thought of as a nuanced version of classic 6 degree-of-freedom docking tasks studied in the 3DUI research community. Our solution combines dynamic gain for precise translation and rotation from 6 degree-of-freedom tracker input, constraints based on both 2D and 3D data, and immersive visualization and visual feedback.

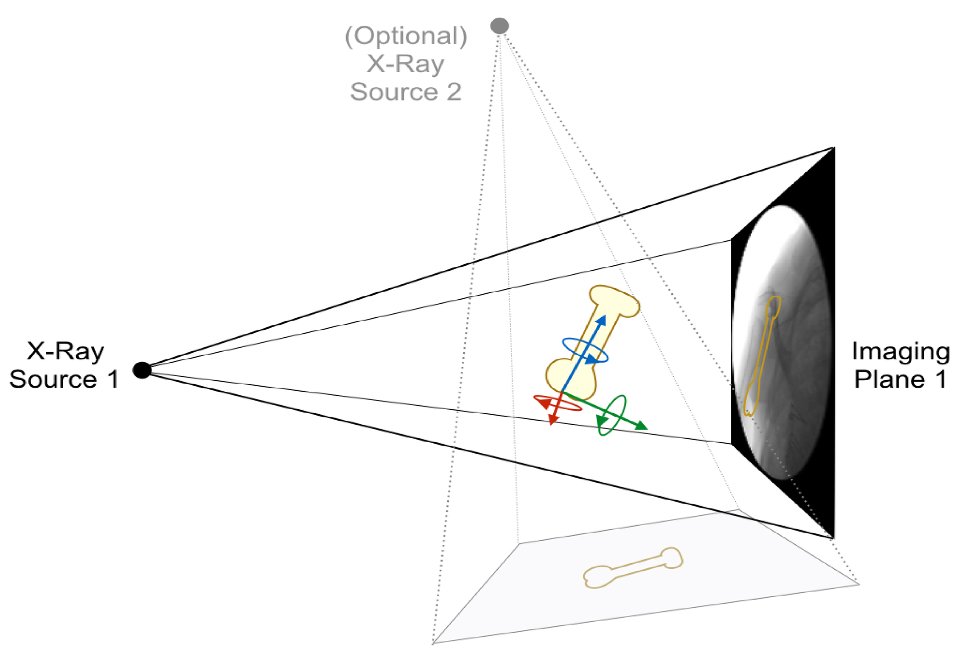
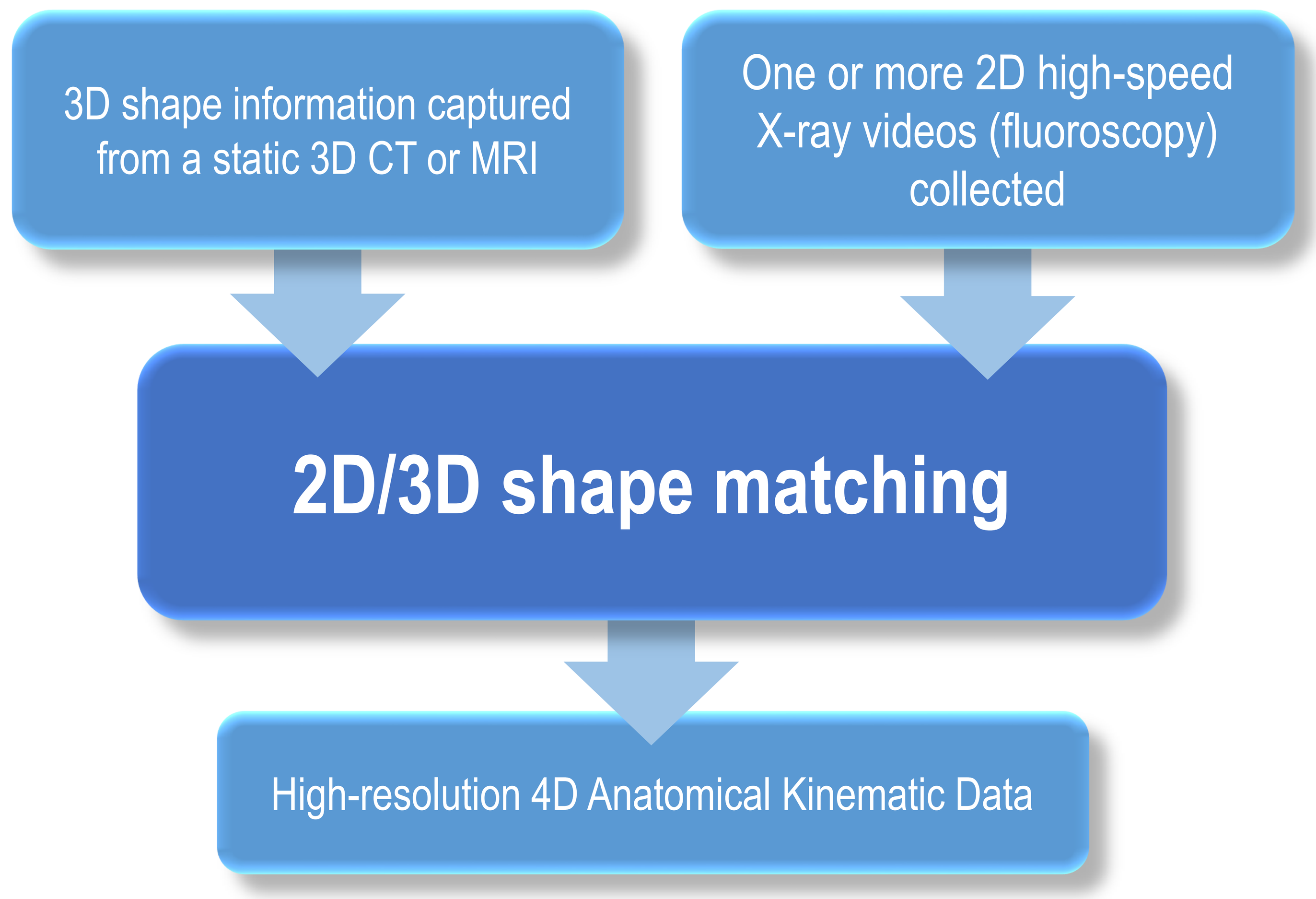


Fig. 1 Anatomical 2D/3D shape-matching requires adjusting the position and orientation of an accurate 3D bone model such that its projection onto one (or more) imaging plane(s) matches as closely as possible with 2D X-ray imagery collected in the lab.

HIGH LEVEL PROCESS



OUR GOALs

- To create an intuitive and efficient user interface for 3D shape-matching that can both work as an effective stand alone tool and serve as a more effective front end for automated shape matching algorithms.
- To create a **fluid interface** that avoids unnecessary menus, selections, explicit mode switches, and other distractions while keeping the user's focus on the challenging task at hand.

USER DRIVEN DESIGN INSIGHTS

- **No gain situation**: An important observation during initial development was that there was simply too much muscular and tracker jitter in our system to support the type of small-scale adjustments to the bones that are needed.
- **Immersive visualization**: One of the great advantages of having immersive visualization over desktop-based interfaces is that user has the ability to see 2D and 3D together by moving one's head to get a better perspective view of the scene. This allows users to first align the bones in the 3D scene then refine with a focus on the 2D projection.

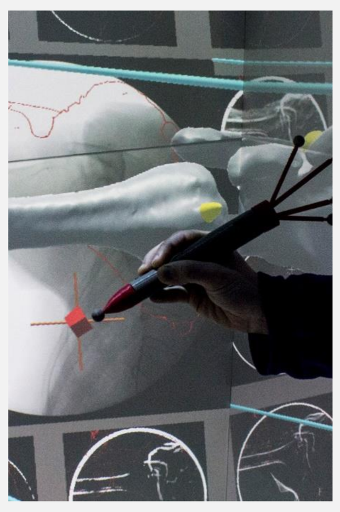
ANATOMICAL 2D/3D SHAPE-MATCHING IN VR

DYNAMIC GAIN

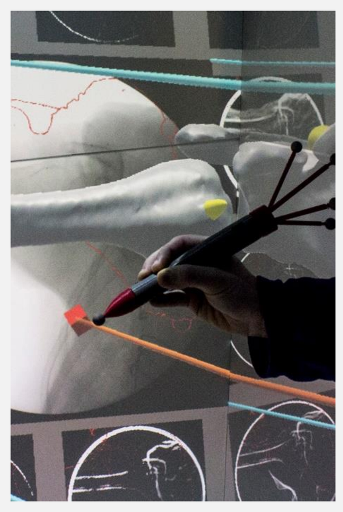
This operation is applied to the currently selected bone(s) when the button on the primary input device is clicked and held. This is the situation where low-gain is needed for precise control but can be annoying to users when large translations or rotations are required to move bones into initial rough placements. Rather than adding explicit widgets or modes for setting the desired gain, our approach is to **adjust the gain dynamically in response to the velocity of the movement of the input device**. Translation and rotation are handled separately. Translational and rotational velocities are measured by averaging over a sliding time window of 1 second, and a linear model is used to dynamically adjust the gain for each style of movement with fast motions triggering gains close to 1.0 and slow motions reducing the gain.

2D & 3D DATA-DRIVEN CONSTRAINTS

1. Based upon the **2D X-ray imaging plane:** See (a), (b). When the primary input device is positioned close to this plane and the button is pressed and held, then translational movements are constrained relative to the plane. If the user moves primarily along the normal of the plane, then the normal constraint is activated. An orange guideline is displayed as visual feedback, and the proxy corresponding bone movement is limited to pure translation along this axis.

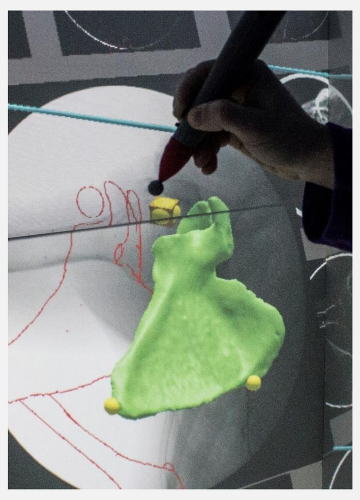


(a)



(b)

2. Based upon **anatomical landmarks in the 3D data** : See (c). When the proxy is moved close to one of these points, it snaps to it, and if the button is pressed and held at that point, a rotational constraint is applied so that the proxy and corresponding bone movement is limited to rotation about the anatomical landmark only.



(c)

VISUALIZATION & VISUAL FEEDBACK

1. **Virtual reconstruction of the imaging lab (See Fig. 2)**
2. **Automatic bone selection:** Visual feedback for bone selections is implemented as a color change in the bone models.
3. **Gallery view:** Our implementation includes both Sobel and Canny edge detection. Both edge detection algorithms are implemented as GPU shaders, and both take parameters (e.g., delta, intensity, threshold). The X-ray image plane is surrounded by a gallery of 12 preview images to capture a variety of useful edge detection filters and parameter settings. Users swap between different filters and parameters simply by hovering over a preview image.

ACKNOWLEDGEMENTS

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