Bioinspired head-to-shoulder reference frame transformation for movement-based arm prosthesis control[1]

Bianca Lento, Vincent Lenconte, Lucas Bardisbanian, Emilie Doat, Effie Segas, Aymar de Rugy

Univ. Bordeaux, CNRS, INCIA, UMR 5287, F33000 Bordeaux, France

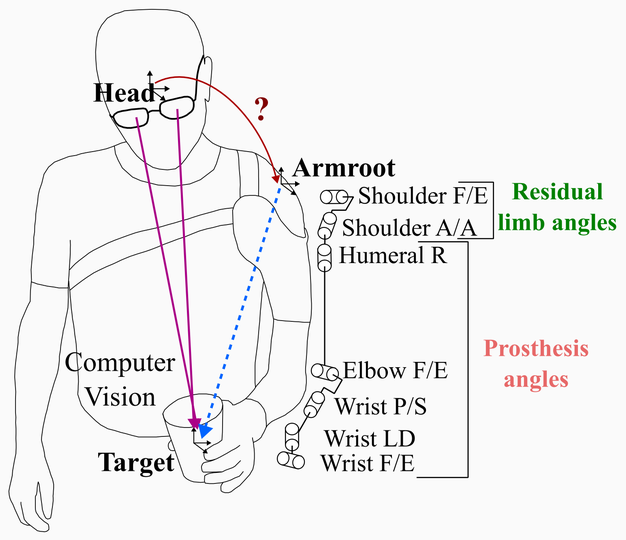
Humanoids 2024
IEEE- RAS International Conference on Humanoid Robots

Introduction

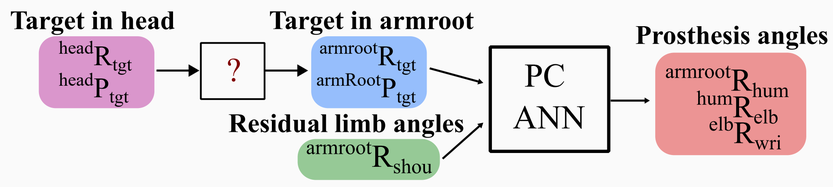
The HYBRID team developed a prosthesis control based on an Artificial Neural Network called Proximo Contextual (**PC**), which predicts distal joints from shoulder motion and movement goals. This control enables individuals with amputation to pick-and-place objects in Virtual Reality (VR) [2, 3].

Real-world scenarios require computer vision with gaze to get movement goal in head reference frame, which must be transformed into the **PC**'s reference frame (armRoot).

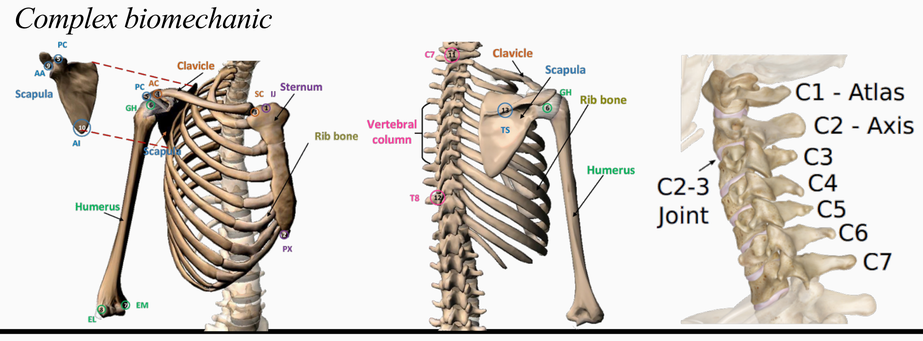
Due to complex neck to shoulder biomechanics and limited sensor data, the **head position involved in this transformation is unknown**. Here, we proposed and tested two solutions to reconstruct it from orientation only data.



Prosthesis control



Complex biomechanic



Two solutions

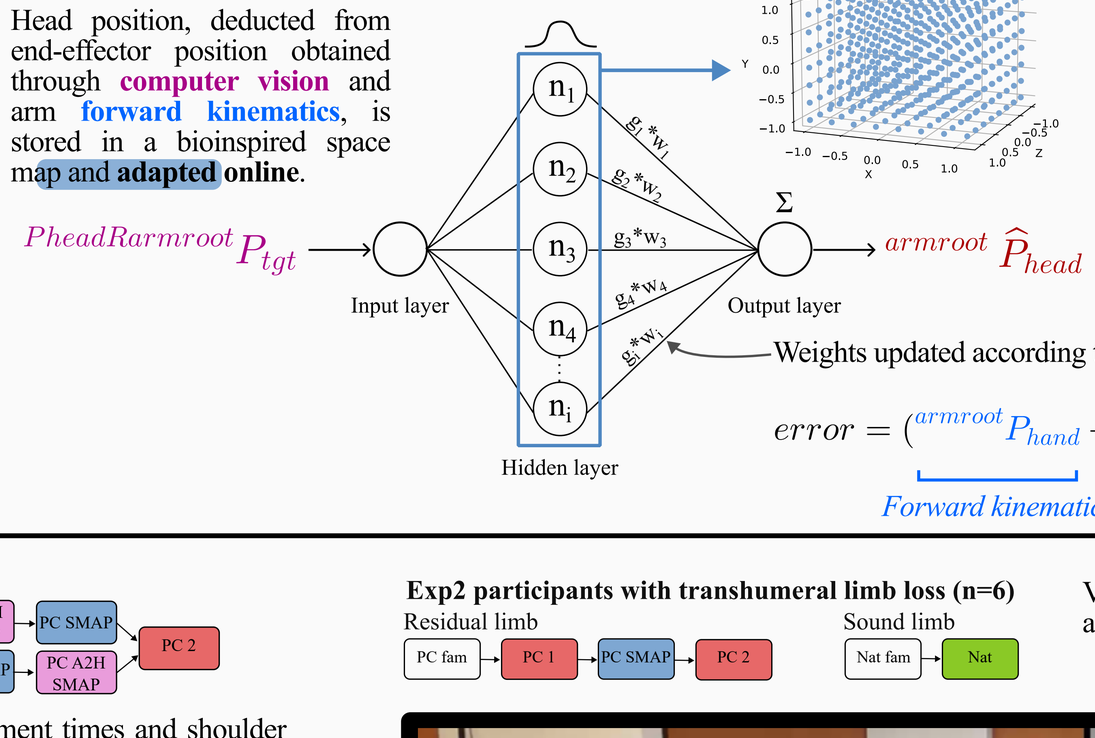
ArmRoot2Head ANN (AR2H)

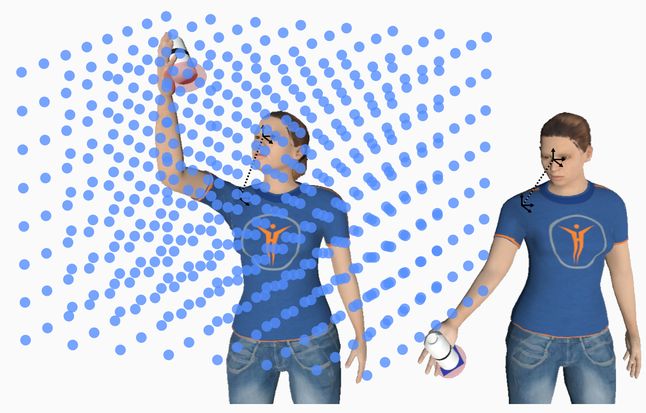
Head position is reconstructed by an ANN based on head and shoulder orientations and the participant's height. The ANN was **trained offline** on a database of natural head and arm movements [4].

$$\left.\begin{matrix} {}^{armroot}R_{head} \\ {}^{armroot}R_{shoulder} \\ Participant\ height \end{matrix}\right] \rightarrow \boxed{AR2H} \rightarrow \left[{}^{armroot}\widehat{P}_{head} \right.$$

Space Map (SMAP)

Head position, deducted from end-effector position obtained through **computer vision** and arm **forward kinematics**, is stored in a bioinspired space map and **adapted online**.





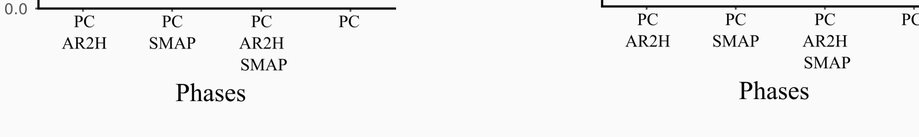
Weights updated according to: $w_i(t+1) = w_i(t) + a \cdot g_i \cdot error$

$$error = ({}^{armroot}P_{hand} - {}^{PheadRarmroot}P_{hand}) - \sum_{i}^{N} g_i \cdot w_i$$

Forward kinematics — *Computer vision* — ${}^{armroot}\widehat{P}_{head}$

VR Experiments

Exp1 participants with intact-limbs (n=12)



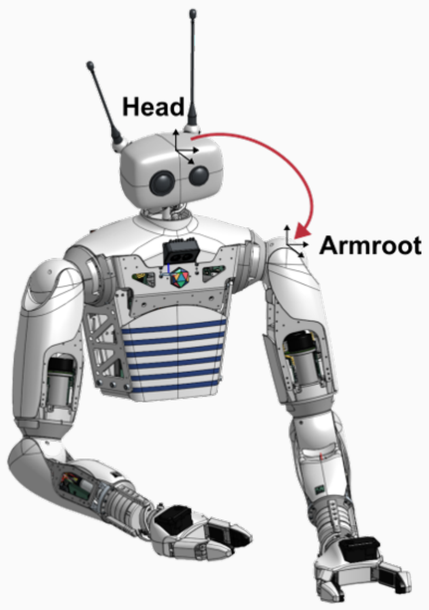
Exp2 participants with transhumeral limb loss (n=6)

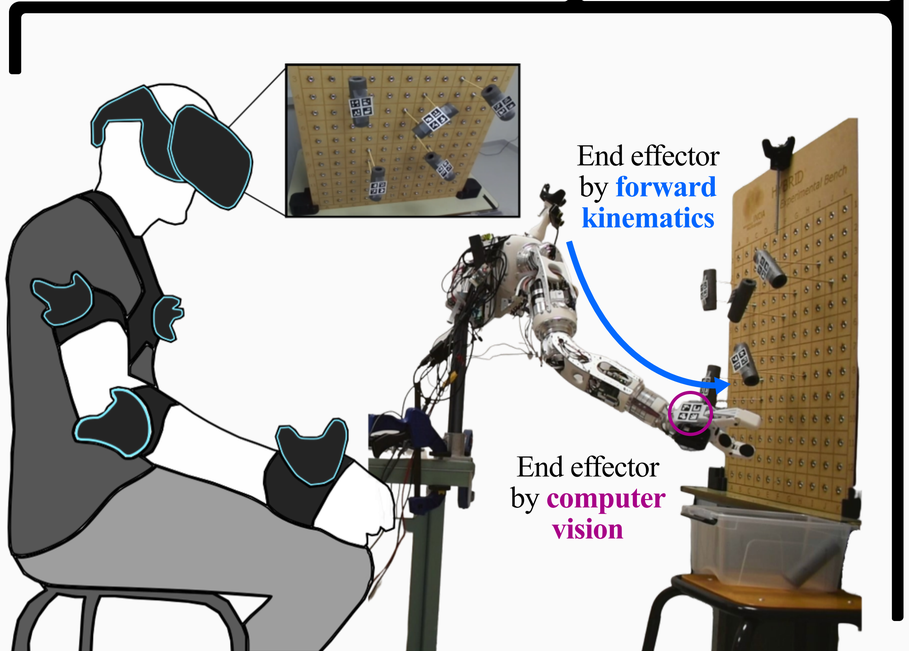
Due to imperfect predictions, **AR2H** led to increased movement times and shoulder compensations.
SMAP exhibited performance close to the ideal case (**PC**), demonstrating its effectiveness in rectifying inaccuracies.

Validation in VR on 6 transhumeral amputees. Videos available through the QR Code.

Robotic Validation

Proof of concept on a robotic platform (Reachy 2) with simplified computer vision (ArUco Markers). Videos available through the QR Code.





References

[1] B. Lento, V. Leconte, L. Bardisbanian, E. Doat, E. Segas and A. de Rugy, "Bioinspired Head-to-Shoulder Reference Frame Transformation for Movement-Based Arm Prosthesis Control," in IEEE Robotics and Automation Letters, vol. 9, no. 9, pp. 7875-7882, Sept. 2024

[2] S. Mick, E. Segas, L. Dure, C. Halgand, J. Benois-Pineau, G. E. Loeb, D. Cattaert, and A. De Rugy, "Shoulder kinematics plus contextual target information enable control of multiple distal joints of a simulated prosthetic arm and hand," Journal of NeuroEngineering and Rehabilitation, vol. 18, no. 1, p. 3, Dec. 2021.

[3] E. Segas, S. Mick, V. Leconte, O. Dubois, R. Klotz, D. Cattaert, and A. De Rugy, "Intuitive movement-based prosthesis control enables arm amputees to reach naturally in virtual reality," eLife, vol. 12, p. RP87317, Oct. 2023.

[4] B. Lento, E. Segas, V. Leconte, E. Doat, F. Danion, R. Peteri, J. Benois-Pineau, and A. De Rugy, "3D-ARM-Gaze: a public dataset of 3D Arm Reaching Movements with Gaze informaion in virtual reality," Scienific Data, vol. 11, no. 1, p. 951, Aug. 2024

This project is supported by a DGA funded PhD scholarship

INNOVATION DÉFENSE LAB