

CONTROLLING TWO INDEPENDENT JOINT MOTIONS WITH THE ACROMION

T. Walley Williams, III
Liberating Technologies, Inc., Holliston, MA

INTRODUCTION

Recently two groups reported excellent results having subjects control two degrees of freedom (DOF) by sampling the motion of the acromion. They use a cap placed over the acromion to move a joy stick. Since joy sticks are difficult to use clinically, we built an X-frame socket to use as a test bed to try other approaches to recording this motion. This test socket can use cables to activate a linear transducer for continuously recording the motion of protraction-retraction independent of motion in elevation-depression. A second transducer can record changes in elevation. By using cables, the inputs can be separated better than with a joy stick, and furthermore better feedback can be provided to the user.

A socket interface for free motion of the acromion

Traditional X-frame sockets encapsulate the entire lateral aspect of the remaining shoulder. This constraint makes the location of stable myoelectrode sites easy, but it severely limits independent motion of the acromion. Any attempt to move the tip of the shoulder forward results in forward rotation of the entire socket. To capture this motion prosthetists have used elastic webbing in the cross-back harness. Typically a user protracting the shoulder will cause a rotation of the socket with respect to the contralateral side of 15 to 30mm at the acromion. Compare this to the motion of the free acromion with respect to the thorax as reported by Williams and Lipschutz. [1, 2] They measure two to three times as much displacement. Losier et al also report using the acromion to control two degrees of freedom. [3]

Designing a socket where the acromion is free

The author had colleagues make a series of photos without a socket followed by another series with a socket designed for study. (Note while viewing these photos that my right shoulder is lower than the left when relaxed.) Photos were made from directly ahead of a white board with a horizontal line on it, and the camera position was kept the same throughout. In Figure 1, a mark has been placed over the sternoclavicular joint with a second over the acromioclavicular joint. The clavicle is also outlined. A careful measurement was made between the tips of my glasses and this measurement was used to quantify changes when I moved. In figure 1, the mark on the acromion moves up 17mm and medially 6mm. The angular motion of the clavicle is 19.4° which is no surprise, since the tip of the

acromion is constrained to move about the center of the sternoclavicular joint. In the test bed socket elevation-depression will be motion in a plane tilted 19.4° from the vertical. Figures 1 and 2 show relaxed to max elevation.

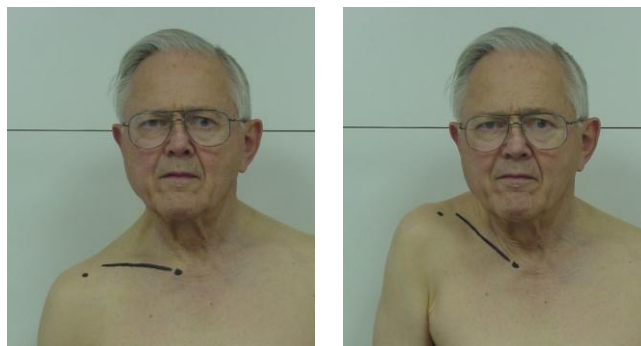


Figure 1: Clavicle, acromion, sternoclavicular joint are marked



Figure 2: Shoulder relaxed then elevated; acromion is marked

To optimize the socket you need to know which parts of the anatomy move and which do not. For this we marked areas which showed no motion to palpation when the acromion was moved to all four maximum displacements. Figure 3 shows the result. Unfortunately the frame in Figure 4 was trimmed out before these marks were made or it would have covered more of the area in the back.

Lessons learned from the test frame

The shoulder cap in Figure 4 was made directly on the subject using a low-melting-point plastic. (The first cap, made from the cast for the frame, was too loose.) To make the cap a separate cast should be taken with the prosthetist pushing down around the area which will be the edge of the cap as the plaster sets. Note the four elastic bands holding



Figure 3: Areas not moving with the acromion are marked

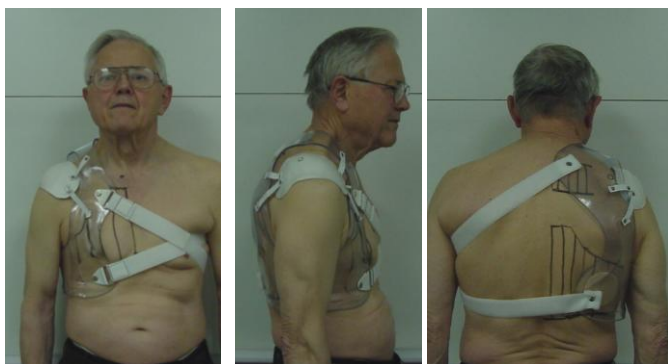


Figure 4: Subject wearing test frame over marked areas

the cap against the subject. Their angular location, length, and pre-stretch determine the force vectors holding the cap. These forces must remain active as the subject positions the shoulder tip. In addition the bands must not interfere with the control mechanisms added later. Typically in a finished prosthesis the elastics would exit from between two thin layers comprising the cap.

Where should we measure motion?

Lipschutz et al measured motion of the acromion with a joy stick at the highest point on their test frame near the user's neck. Attached to the stick was a rod passing through a ring on the shoulder cap to accommodate the change in distance with elevation and depression. The joy stick had two potentiometers, one recording forward-back angular motion and a second recording up-down. This arrangement produced good data, but having a joy stick here is too uncosmetic in a definitive prosthesis. This paper explores an alternate scheme for collecting the same data.

A simple cord pulling a linear transducer is good for detecting changes in the distance between two points. We analyzed over 35 photos which showed linear displacements of about 100mm. The LTI Linear Transducer has too short a range to record this, since it can only detect motions of 0-12 or 0-25mm. Thus a different type of transducer is needed. A good solution to would be a thin capstan about 35mm in diameter above a thin coaxial potentiometer. These parts can fit within a disc 40mm in diameter and only 6mm thick. The

cord goes around the capstan which has a spring to maintain some tension in the cord. To record protraction-retraction, the cord needs to pass from the cap medially almost to the center of the back where a small pulley can redirect the cord to a convenient transducer mount under the scapula.

While protraction-retraction seems to move the acromion forward and back, the actual motion is more complex. Study Figure 5 which is a horizontal cross section through the frame at the height of the sternoclavicular joint with the cap in its neutral position. The joint center is marked with a black dot in the upper right. A second mark has been placed at the other end of the clavicle where it is constrained to move on the magenta arc. The plastic frame is indicated by heavy black lines and the cap by a thin blue arc. Two possible cord locations are indicated. The location on the subject's back is on the left in green and the front location is on the right in brown. A black bar shows how far the center of the cap moves left-right when photographing the frame from the side. The cord on the back is almost tangent to the arcuate motion of the cap which will result in maximal motion, while the front cord is almost radial and parallel to the dashed line resulting in little motion. Thus we need only place a transducer and cord in the back.

To locate the pulley attachment, we studied the photos to locate the center of rotation during elevation-depression. It is below the upper harness-strap rivet in Figure 4 and a little below the frame edge. The frame needs to be larger so a small pulley can be placed here. This location minimizes cross talk between the front-back and up-down motions.

To record elevation-depression a cord can be run from a fixed point below the cap in front and then over the cap in a Bowden sheath to a second transducer in back.

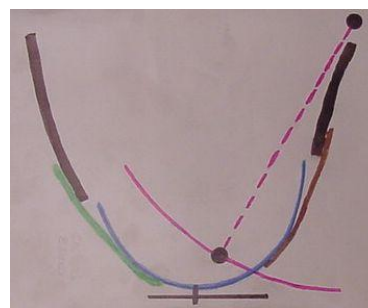


Figure 5: Horizontal plane at height of the sternoclavicular joint

REFERENCES

- [1] T. W. Williams, "Electric control using relative body motion," *Proceedings of the MEC '94 Myoelectric Controls Symposium*, Fredericton, NB, Canada: p 60-75. 1994
- [2] R. Lipschutz, B. Lock, J. Sensinger, A. Schultz, and T. Kuiken, "Use of two-axis joystick for control of externally powered shoulder disarticulation prostheses," *J Rehabil Res Dev*, vol. 48(6). 2011
- [3] Y. Losier, K. Englehart, and B. Hudgins, "An evaluation of shoulder complex motion based input for endpoint prosthetic limb control using a dual task paradigm," *J Rehabil Res Dev*, vol. 48(6) 2011.