Relative Velocity

Introduction:

Relative velocity is generally associated with an object moving through a fluid – a fluid being defined as any substance that tends to flow or continuously deform when acted on by a shear force. However, relative velocity can also be calculated between two bodies. The relative velocity of a body is the velocity as it approaches or recedes another body, where one or both of the bodies are in motion. As velocity is a vector quantity, it is both magnitude and direction sensitive. The sign attached to the relative velocity indicates the direction of the relative velocity with respect to reference direction. Relative velocity refers to two moving bodies; it is not just the difference in the velocities.

Magnitude of the relative velocity of bodies moving in opposite directions to each other, i.e. moving closer together → ← or further apart ← →, is calculated as the algebraic sum of the speeds of the two bodies, remembering that they are direction aware and that in this case at least one of the values is travelling in a negative direction. Magnitude of the relative velocity of bodies moving in the same direction → → is the difference in the speeds of body A and body B. If two bodies are moving in the same direction at the same velocity, then the relative velocity will be zero.

The equation for relative velocity is as follows:

$$V_{AB} = V_A - V_B$$

Where:

V_{AB} = is the velocity of body A as observed by body B

V_A = velocity of body A

V_B = velocity of body B

(alternatively, this can be switched around to find V_{BA}, which is the velocity of body B relative to body A. This will result in the same value as V_{AB} but in the opposite direction).

Objectives:

- To define relative velocity with reference to sports specific situations using the Quintic software
- To calculate the relative velocity of two bodies during a rugby tackle.

Method:

- The video has been digitised and calibrated using the Quintic software.
- Data has been exported to an excel file where it was used to calculate the velocity of the two bodies during the rugby tackle. Graphs have been prepared using this information.
- Still images have been captured from videos to outline different stages of the exercise

Functions of the Quintic Biomechanics and Quintic Coaching Software used:

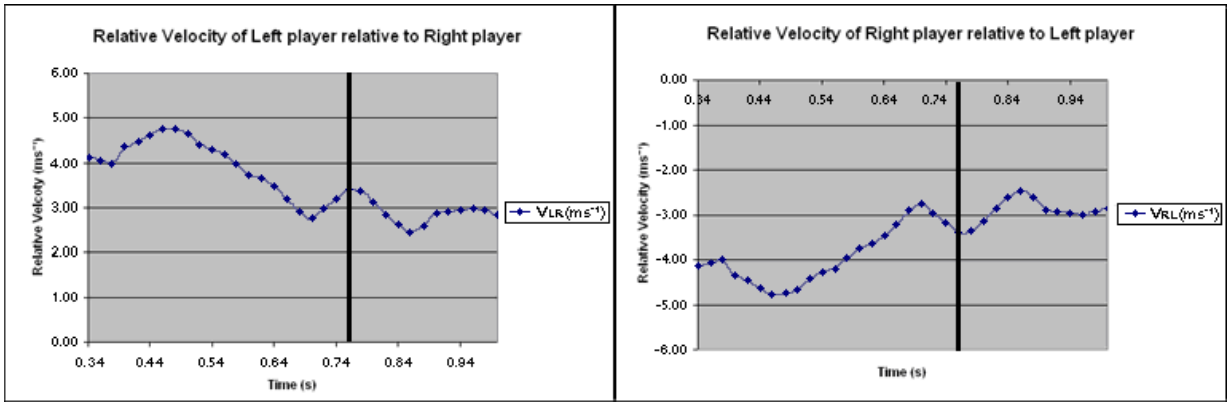
- *1 Point Digitisation Module*
- *Calibration*
- *Interactive Graph and Data displays*
- *Export Data*
- *Multi-Image Capture*

Results:

Relative velocity of the rugby tackle was calculated from frame 17. A single point digitisation model was created using the hips of the players as a reference point. The players were digitised through until frame 50, where contact has just been made.

Frame	*Time (s)*	$V_R\ (ms^{-1})$	$V_L\ (ms^{-1})$	$V_{LR}\ (ms^{-1})$	$V_{RL}\ (ms^{-1})$
17	0.34	0.73	3.41	-4.14	4.14
18	0.36	0.64	3.43	-4.07	4.07
19	0.38	0.54	3.46	-3.99	3.99
20	0.40	0.81	3.55	-4.36	4.36
21	0.42	0.97	3.49	-4.46	4.46
22	0.44	1.14	3.49	-4.63	4.63
23	0.46	1.33	3.44	-4.77	4.77
24	0.48	1.46	3.30	-4.76	4.76
25	0.50	1.38	3.28	-4.66	4.66
26	0.52	1.28	3.14	-4.42	4.42
27	0.54	1.33	2.96	-4.29	4.29
28	0.56	1.27	2.91	-4.18	4.18
29	0.58	1.17	2.79	-3.97	3.97
30	0.60	1.14	2.59	-3.73	3.73
31	0.62	1.11	2.55	-3.65	3.65
32	0.64	1.02	2.46	-3.48	3.48
33	0.66	0.95	2.26	-3.21	3.21
34	0.68	0.80	2.10	-2.90	2.90
35	0.70	0.63	2.12	-2.75	2.75
36	0.72	0.61	2.36	-2.97	2.97
37	0.74	0.62	2.57	-3.19	3.19
38	0.76	0.66	2.74	-3.40	3.40
39	0.78	0.68	2.69	-3.37	3.37
40	0.80	0.62	2.52	-3.14	3.14
41	0.82	0.59	2.27	-2.86	2.86
42	0.84	0.62	2.00	-2.62	2.62
43	0.86	0.69	1.78	-2.46	2.46
44	0.88	0.84	1.76	-2.60	2.60
45	0.90	1.10	1.78	-2.87	2.87
46	0.92	1.29	1.62	-2.92	2.92
47	0.94	1.39	1.56	-2.95	2.95
48	0.96	1.40	1.59	-2.99	2.99
49	0.98	1.35	1.57	-2.92	2.92
50	1.00	1.29	1.56	-2.86	2.86

Table 1: Velocity and Relative Velocity of rugby tackle



Graph 1 and 2: Relative Velocity of players (V_{LR} & V_{RL})

Graph 1 and 2 shows the calculated relative velocity of left player as observed by the right player (V_{LR}) and right player as observed by the left player (V_{RL}) respectively. The black vertical lines in the graphs represent the point of contact at frame 38, after 0.76sec. Graph 2 is a mirror image of graph 1, as the players moving towards each other and the right player is the one travelling in a negative direction, this results in V_{RL} to have negative values.

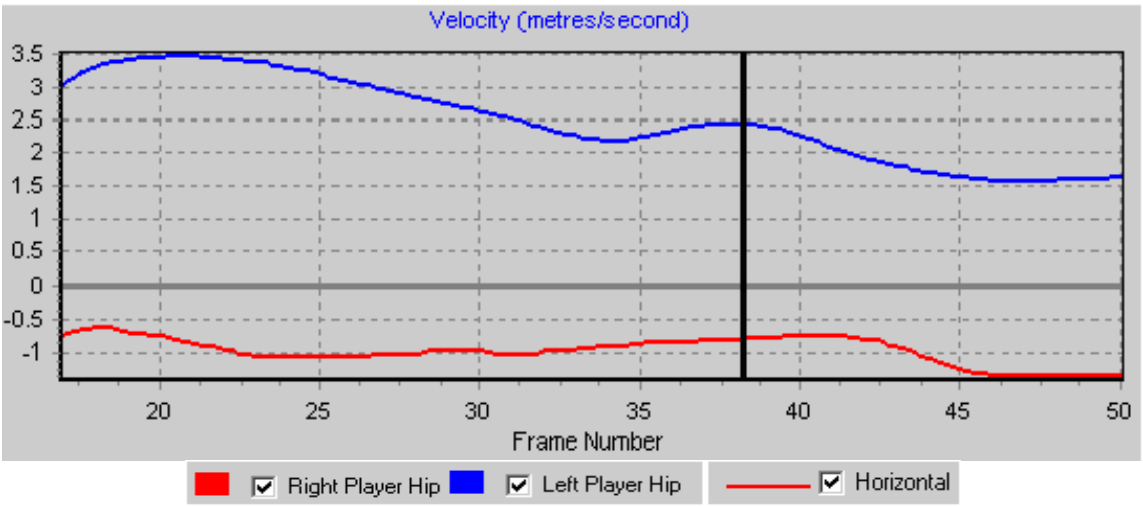
Relative velocity is continuously altering going from a max value of (-)4.77ms^{-1} at the start of the move down to (-)2.75 ms^{-1} just before the point of contact. This decrease is a result of both players reducing their velocity in preparation for contact. For the last few frames before contact the relative velocity slightly increases to (-)3.40ms^{-1}, as both players push their bodies forward. After contact has been made, relative velocity decreases to (-)2.46 ms^{-1}.

Figure 1

Figure 1 shows the frames approaching the point of contact, frames 26-35. The blue and red lines represent the distance travelled throughout these frames only by both players. During these ten frames, there is very little movement from either player as both are preparing for the point of contact. Velocity decreases as a result of this thus causing the decrease in relative velocity also.

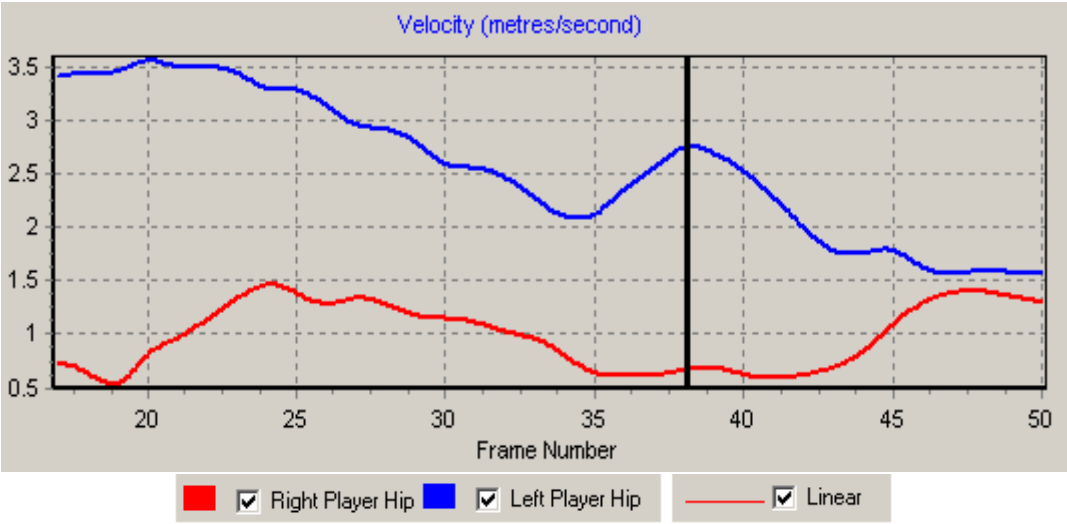
Figure 2

Figure 2 shows the immediate frames before contact, as well as the frame of actual contact, where relative velocity increases as both players are stepping into the tackle. During these frames the feet of both players remain in somewhat the same position but as the hips are moving forward, this causes the increase in relative velocity to (-)3.40ms^{-1}. Once contact has been made, the relative velocity decreases and it would be expected that eventually the relative velocity would return t o zero as both bodies would be moving in the same direction at the same speed.



Graph 3: Horizontal Velocity

Graph 3 shows the horizontal velocity of both players. The vertical black line in the graph represents the point of contact of the players at frame 38. Graph 3 shows a similar trend to the relative velocity graph. The horizontal velocity of the left player increases initially but decreases as the player nears the point of contact. Just before the point of contact, the horizontal velocity of the left player increases as he pushes his body forward, moving into the tackle. A similar trend can be seen for the right player also. As the right player is travelling in a negative direction, his velocity is constantly negative. To begin with, horizontal velocity is increasing but closer to the point of contact horizontal velocity decreases and continues to decrease after contact is made. After contact, velocity of the left player decreases while horizontal velocity of the right player decreases momentarily but then increases and towards the end becomes relatively constant.



Graph 4: Linear Velocity

Graph 4 shows the linear velocity of both players. This graph has similar trends as the other graphs, velocity decreases nearing the point of contact, but in the final couple of frames before contact, velocity of left player increases while the velocity of the right player levels off with only minor increases. After contact, velocity of the left player immediately decreases while the velocity of the right player slowly begins to increase. Towards the end of the tackle, both players are nearing the same velocity value, which would result in zero relative velocity once both bodies are moving in the same direction

Conclusion:

Relative velocity of two bodies refers to the velocity of body A in accordance with body B or vice versa. Relative velocity can also be used to calculate the velocity of an object through a fluid i.e. swimming, rowing. In these cases, the velocity would be calculated of the swimmer relative to the velocity of the water, or the velocity of the oar relative to the water. Relative velocity can also be calculated with reference to air when the wind speed and direction is known. This can be used in outdoor sports such as javelin throw or shot put by measuring the relative velocity of the javelin or shot put with reference to the wind.