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Implementing Biomechanics to Study Motions of Judokas through Kinovea Software for Enhancing their Performance & Maintaining Center of Gravity during Throwing Techniques

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Abstract: ***Judo is world famous game and art of hand-to-hand combating with peaceful mind. There are different techniques of Judo which include different motions of legs & knees, arms, trunks and head to generate required force to perform a technique effectively. Some techniques involve maximum use of limbs when other requires perfect use of head, trunk and limbs in locomotion of Judokas during competition. The winning is dependent on how perfectly the Tori (attacker) applied combination of his muscles power to lift up lever at right position, generate required force to be concentrated on focus to displace the Uke(defender.) Applicability of Biomechanics turned the Judo art into more scientific game that assist in describing the required force by each body motion during fighting. Biomechanical appliances on tradition Judo helps in improving the traditional methods, performing more logically and accurately.The current paper just focus on the throwing techniques of Judo in which whole parts of the Tori 's body work in together to off-balance the Uke's body. The paper highlights how body parts act as lever to shift the maximum force at a particular point while maintaining the center of gravity in throwing the Uke's body without misbalancing itself, avoiding injuries in head, backbone & its lower part near sacrum. Kinovea software is used to study the locomotion of Judokas at different points, track the speed & distance of body motions and path traced during practice that is discussed in the paper.***

Keywords: Biomechanics, Center of Gravity, Judo, Judokas, Kinovea.

I. INTRODUCTION

Judo and ancient Olympic game originated from Japan previously named as Jujitsu. It is stated that in 1532, Jujitsu a martial art system was introduced. Judo is form of wrestling and inherited from Sumo, it is a group of techniques which is a hand-to-hand combat [2]. Judo is not a fighting game, it comprises of practical fighting with a peaceful mind. Judo recognized world widely during men's Judo in 1964 Tokyo Olympics. Women's Judo was started in 1988 in Seoul Olympics. Classification of Judo was considered asKodokan and koizumi classification. Kodokan breaks down in Ko i.e. methods or study, Do i.e. the way and Kan that means a place, means a "place to study the way". Kodokan describe the TeWaza, apply maximum use of hands, arms and shoulders.

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KoshiWazaincorporate hip techniques, AshiWaza comprises hip techniques, SuemiWaza performed on body throw and pushing techniques. Koizumi includes KurumaWaza that comprises Wheel techniques in which body rotate on its axis and role like a wheel. Kodokan classification was done in 1885 that covers the basic & most popular techniques of Judo like UkiWaza, Tai O Toshi, UkiOtoshi etc. [3]. KoshiWaza involves UkiGoshi, Have Goshi,UtsuriGoshi etc. wherasUshiWaza adds Uchi Mata, O Soto Gari, O UchiGari, Ko Soto Gari etc. Ma SutemiWaza includes Tomoe Nage, UraNage, etc. and Yoko SutemiWaza comprises of Yoko Gak, TaniOtoshi, DakiWakarare etc. [2] [3] [9] [10]

Different throwing techniques of Judo are having on principles of forces generated in motionsapplied in particular direction by levers of body as an action of muscles resultant indisplacement of an object in combating. Throwing technique also involves the motion of arms, knees and legs. Motion can be a hoop-shaped (curved) or linear (straight movement) making different angles of incidence. The biomechanical assists in computing the forces, velocity & distance between the points of observations framed during a path generated by a motion. This path may be curved, linear or may be helicoidal (spiral like a snail). [3]

Biomechanics is combination of Sciences like Biology, Mechanics of physics, analytical tools of computer science, behavioral study from psychology and mathematics that helps in study & analysis of judokas and their bodily movements during playing different techniques like throwing in O Soto Gari etc. Biology deals with origin and evolution distribution, transferring, energy generation & its transformation from one object to another as energy cannot be destroyed; it simply transformed the forces against particular object.Therefore biomechanics helps in scientific study and analysis of Judokas, investigating their activities or motions by use of sophisticated biomechanical software. [9] [10] [11]

Kinovea is open source software that is freely available with all documentation and tutorials.The software is downloaded freely from official website of Kinovea. [12] It is biomechanical software that is developed specially to study and analyze different sports graphically, for example videos of games to access and trigger more information about speed, distance, center of gravity and path followed by an object via developing different frames on defined path from a video. Kinovea has many advanced and user friendly tool and can be learned and used effectively. [12]

II. METHODS

A. Techniques Selected

For the purpose of study & analysis, only two throwing techniques of Judoare selected. One is the O Soto Gari and another one is SioNagae, both are throwing techniques and required two Judokas for Combating. [1] [2] [3] [9]

B. Software Applied

Kinovea software is used to observedifferent motions while playing Judo and combating between Judokas along with various options like path tracker, distance and speed options plus multidimensional view of the video. [12]Frames are generated at different points of motion in a single window or two synchronized window. The video is downloaded from YouTube [7] that is cropped just to fit &concentrate on particular technique of throwing. A total of 16 frames are generated automatically by kinovea software of biomechanics as shown in Fig. 1 and Fig.4.

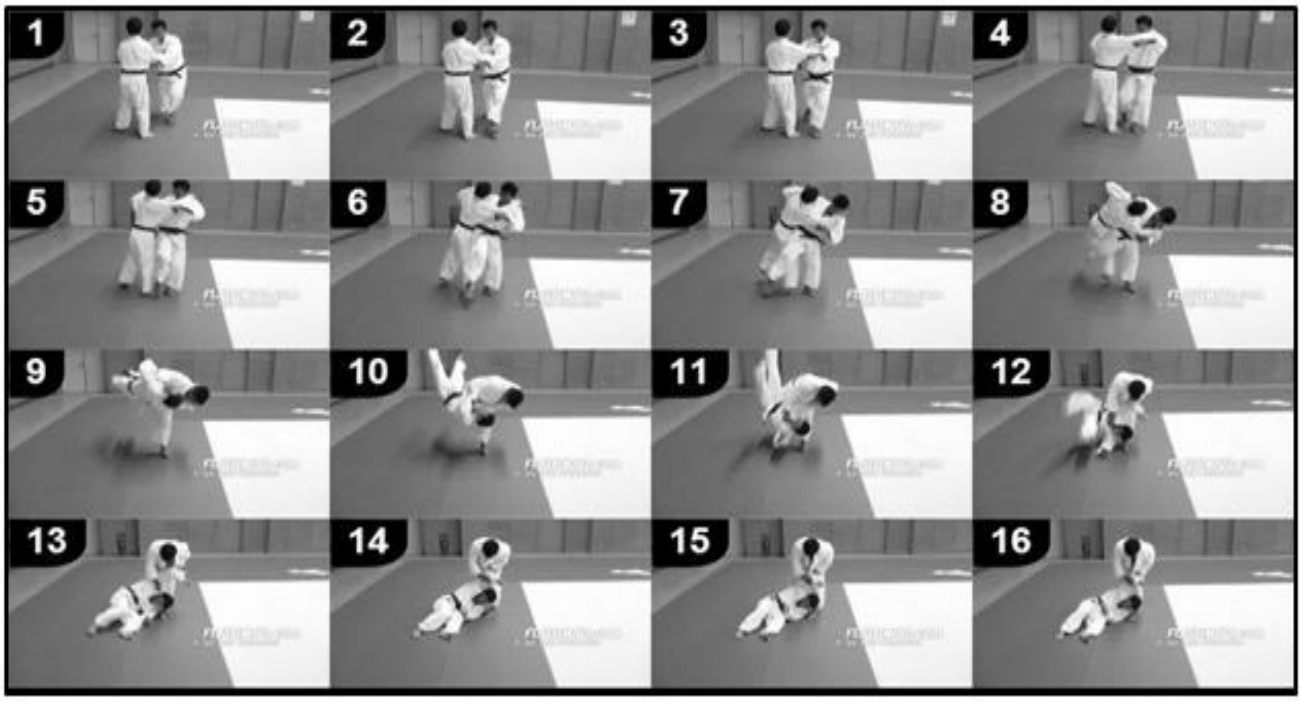

Figure 1: Shows Different Frames Generated by Kinovea Software.

C. Study of Body Locomotion During Combating

In various techniques of Judo, Tori use different bodily motions in combinations of limbs, head & trunk & limbs, trunk & arms or trunk & feet while displacing or throwing Uke. [1] In O Soto Gari [9] and Uchimata [10], Tori use forces at different angles & speed, pushing hips backward and placing center of gravity of his body to imbalance the Uke in throwing. [1] [3] The force can be used any of the category like minimum arm making small arc of hands thus tori used maximum force of hands when holding on Uke's waist, medium arm where fulcrum is under Uke's knees, maximum arm in which fulcrum is under Uke's Malleoli(both sides of ankle and at the lower end of the fibula and tibia) and minimum forced applying when Tori placed lever against the end points of object i.e and fulcrum is just under the waist position of Uke'supto the knees, therefore requires less force to produce energy [3] as shown in Fig. 2.

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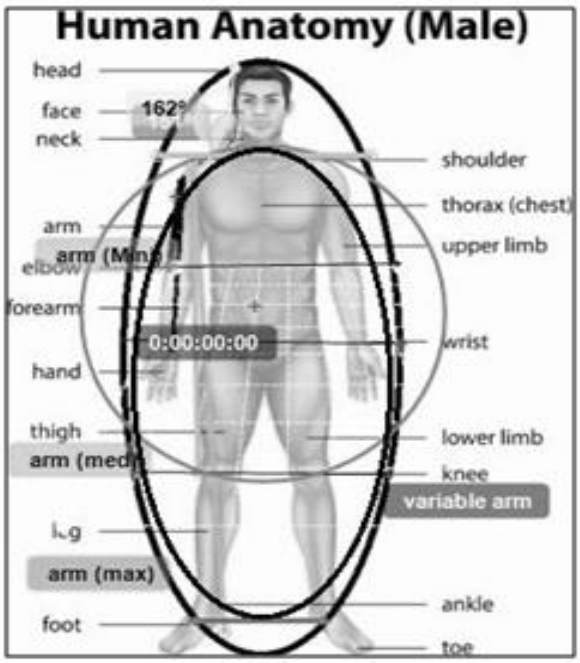

Figure 2: Shows Different Combinations of Body Parts Involves in Combating,

[4] The minimum or maximum energy or force applied depends upon the arc made by the body movements and anatomy of human body. Limbs are the combination of external part of trunk like legs and arms only; trunk is the main body part act as a stem of body having branches limbs and head. Lever is any bone or group of bones associated with joints and act as instrument or machine where force is applied putting the fulcrum (action of limbs) under precompiled location so that can push an object in opposite direction of origin point, thrown or lifted with the power of muscles producing sufficient force to move levers. First class lever has the fulcrum between weight & force, second contain weight between fulcrum and force and third contain force between fulcrum and weight. [5] Thus it is necessary to learn the path and required force at different points over track in order to throwing down the Uke successfully. To compute path taken by Tori with speed, distance during different motions one after another frame vise, Kinovea software is used to generate frames at separate motions from a video as shown in Fig.3 and 4. [9] [12]

Figure 3: Shows Path Travelled and Angle Created in 4 Motions in a Throw

D. Observation of Throwing Techniques During Fighting

In throwing technique Sio Nage [1], Tori hold front grip and side grip, strongly force foot & pull it, making Uke's body closer to the trunk of Tori. Tori moved the leg in curvinear form- first linear then curved toward upstream, bend the body and put the back in front of Uke, pushing hips backward, move head in oppsite direction of gripping, entry action of arm synchronously pushing hip back and arm forward, lifting Tori's body weight forcefully over Uke's, offbalance him and throw Uke's body while balancing own body. This throw comprises the variable movements, maximumarc, balanced center of gravity and lifting off the trunk with muscles generating maximum force of arms and upper body part in throwing.In another technique O Soto Gari [1], the maximum use of limbs is required like gripping with arms and pushing the Uke's legs with movement of lower body parts from waist to movement of knees & ankles by shifting of body weight to Uke's body make him imbalance [9]as shown in Fig. 3 and 4.In Fig. 4, a multi dimensionl view side and front is synchronised, and then different frames generated of both the combined windows,viewing side as well as front extracting more clear information about path travelled in locomotion.

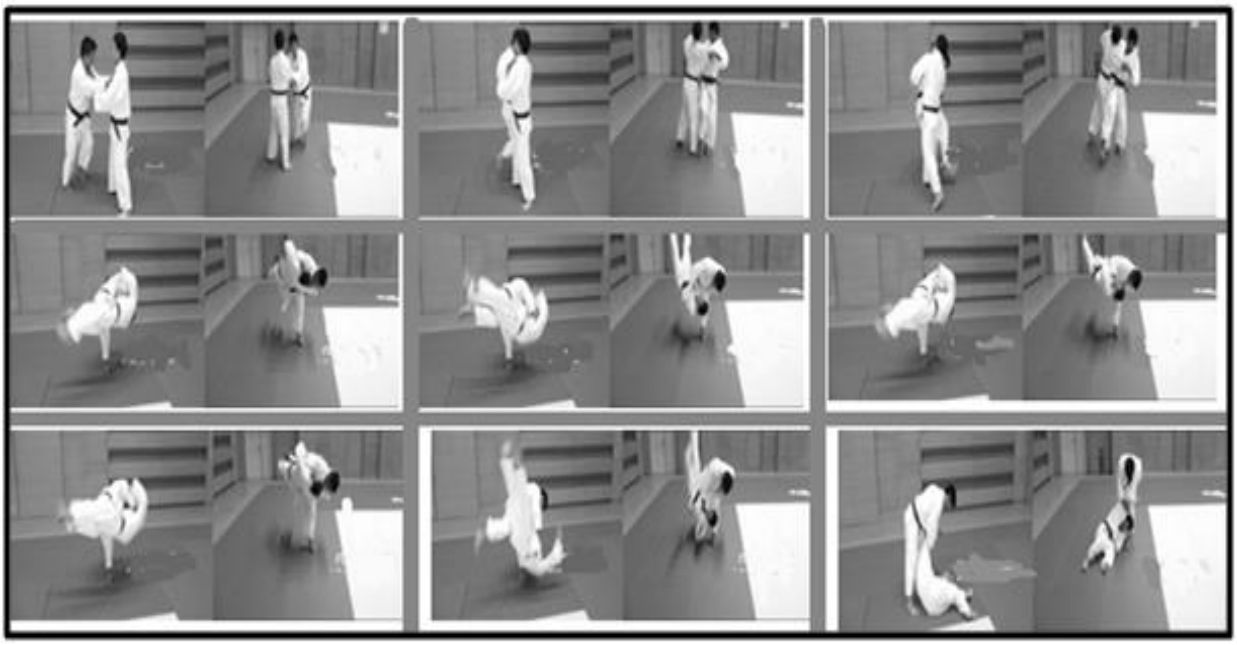

Figure4: Shwos the double window frame to show side and front view of throw syncronously.

In O Soto Gari, applying center of gravity (balanced weight of body) of Tori to pressure & generate equal weight on Uke's body, thus transferring weight of one object to another in equilibrium. [1] [9] Center of gravity is the point where combined mass of body is concentrated. [8] It is anterior to second sacral vertebra, changed its location with change in position of trunk and limbs. The direction is towards the earth thus to maintain balance, reaction is needed to remain in the base of support. Otherwise due to change in position and line of gravity, gravity comes outside of base of support and person become imbalanced or instable. Base of support means object to which a body contact to get its support for balance like by feet while walking, standing on hands sitting on chair etc. [6] Therefore for maintain balance in a body, center of gravity is to be controlled in different bodily motions as shown in Fig. 5

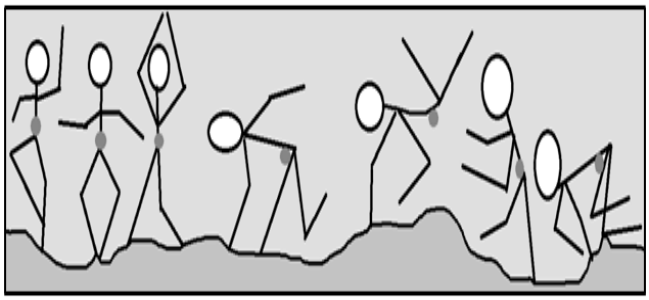

Figure 5: Shows Center of Gravity in Different Body Locomotion.

III.RESULTS AND DISCUSSIONS

In O Soto Gari technique of throwing, the body weight equilibrium is maintained while shifted the weight from Tori to Uke, misbalancing Uke's body with the variable use of limbs, trunk and head to move force at center of gravity. It is important to note that in order to make Uke's body off-balance, Tori's center of gravity must move outside the body base point.

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In this way, gravity works directly in downwards direction forcing Uke's body fall.In Sio Nage, synchronization of head, hips and upper body part is must to avoid head injury and damage in sacrum. To trace the throw motions, video of O SotoGari is cropped to fit in to desired working zone with the help of left and right cutters. Speed is minimized to 19 % to get the slow motion of actions and mark the right arm movement with line tool one after another creating different frames for marks. It is noted that movement of Tori's right foot from one position to another is 129px, then 48px in 3rd step. After that, Tori's leg moves linearly 369px towards Uke's body. At this position, Tori's leg start moving in curved with least helicoidal shape to shift center of gravity downwards and off-balance the Uke's body. Cross marker tool in Kinovea software is opted to measure the path tracked by legs and arms of Tori. After selection of cross marker tools, right clicked to select track path option from dialogue box. Two rectangles are shown by the tracker tool, first rectangle indicates the location of object and second rectangle is used as search area for traversing path in locomotion. Location of right foot and right hand from the side view that is more visible is tracked between points and is corrected manually too. Cross marker is put at co-ordinates {822;-548}px and track path option is selected after on. Uplifting of right leg of Tori from {822;-588}px co-ordinate position to {316;-316}px, move back with same fixed position of foot at 48px, then stop at 129px making center of gravity at same point and maintain own balance after displacing Uke. In similar way, movement of Tori's arm has also been tracked by cross marker on right palm at {413;-424}px in the beginning. Tracker shows the time count in movement i.e. 1:44s, 1:92s, 2:32s and 2:96s in Kinovea format showing time taken in throw. In configuration of Cross Marker tool, distance and speed is selected to compute distance covered by Judokas during throw by limbs of Tori. It was found that distance travelled is 2268 px by arm and 1180 by leg approximately. Fig.6 shows the speed of hand movement from one position to another.

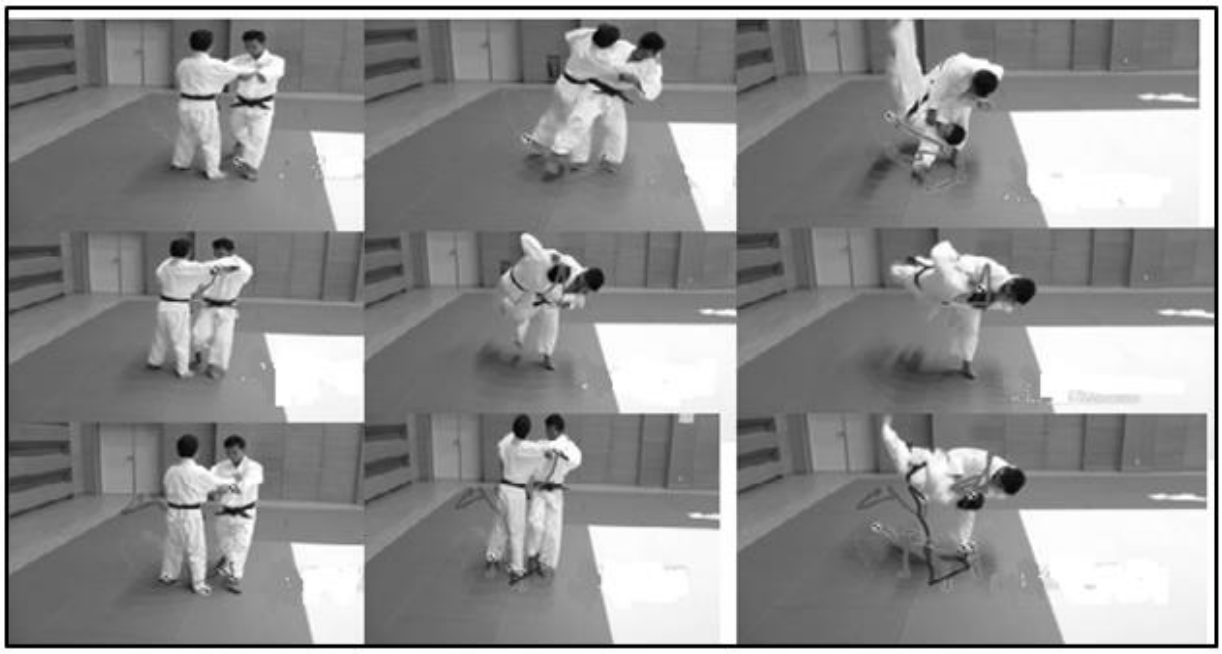

Figure 6: Shows Cross marker's Path Tracker Positions of Legs and Hands.

Speed of hand is 2px/f, 15px/f, 0px/f, 3px/f, 7px/f, 10 px/f,47px/f,1px/f,17 px/f, 78 px/f, 9 px/f, 27 px/f, 62 px/f and coming down to 1px/f and 0px/f. Speed is computed per frame that generated automatically by the speed configuration of Cross Marker's Path Tracker. Likewise speed of right leg is quick and move faster from 0px/f to 34px/f, 47px/f and 51px/f where speed of arm is just at 12px/f at this position, jumped to 99px/f in leg position. After that sudden jump is noticed from 51px/f to 102px/f then 177px/f. then comes down suddenly at 6px/f, 7px/f. From 7px/f, there was an immediate increase to 330px/f and after it coming down to 8px/f unexpectedly. Important point of concern is that at this position, speed of leg and hand is same at 8px/f showing the balance of Tori's body. both are decreasing at same point however motion of leg is stopped at 0px/f where the speed of arm is still at 1px/f. both in ratio of 1px/f and 0px/f to 0px/f and 1px/f between leg and arm as shown through Fig. 6, Fig. 7 shows time taken in occurrences through start and stop option of stopwatch.

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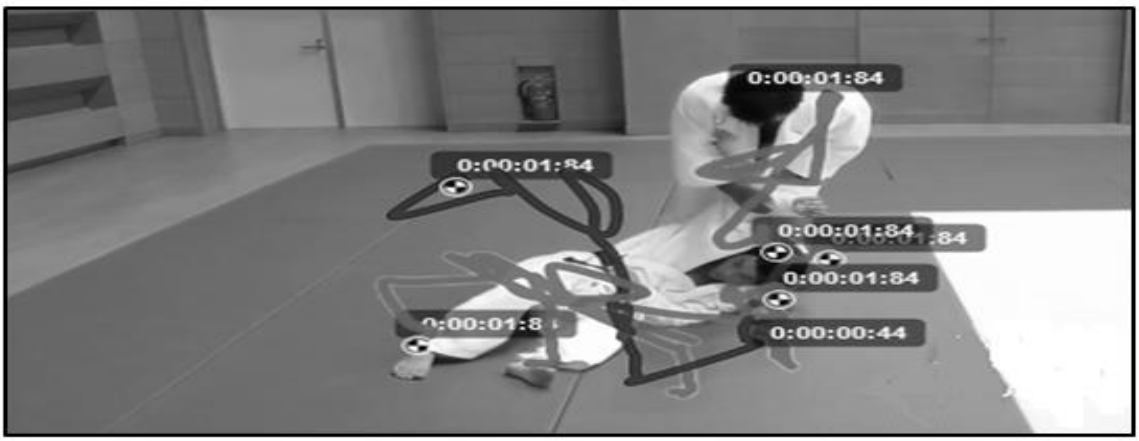

Figure7: Time Taken Between Two Positions Measured by Stopwatch in Kinovea.

The resultant data is exported to XML spreadsheet as given in Fig. 8 due to long table; a snapshot of the tables is taken. The output of all the analytical process is shown in Fig.8. Charts developed from the data exported to XMLtables are shown in Fig. 9.

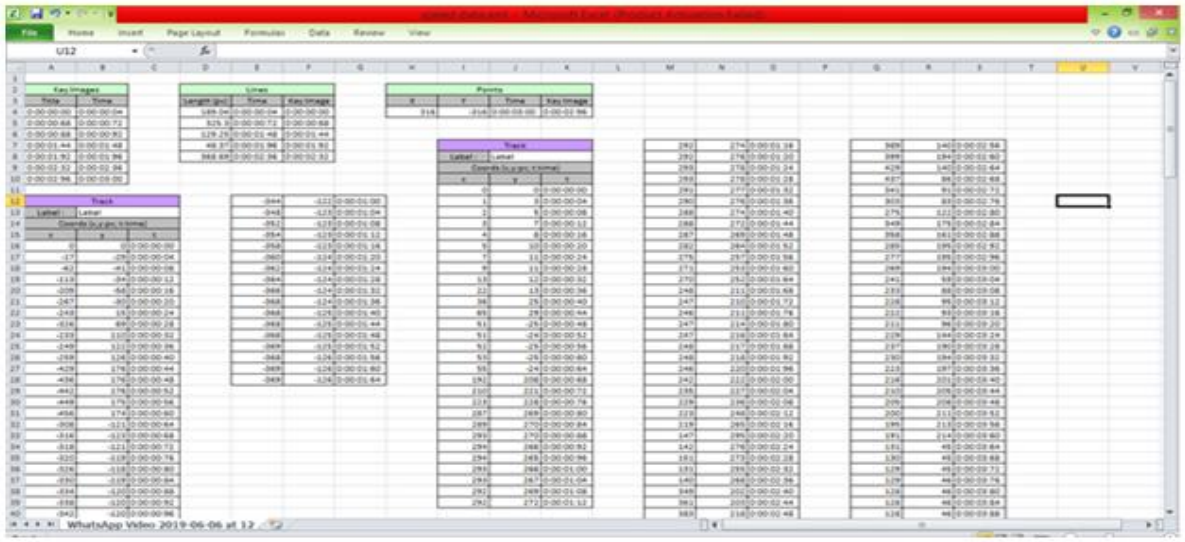

Figure 8: Shows speed and distance data exported to XML spreadsheet.

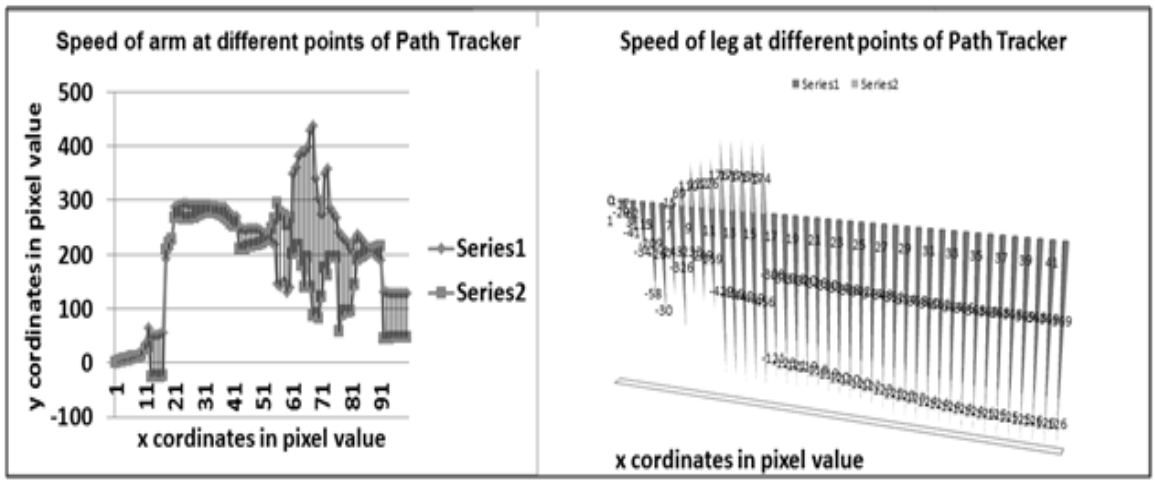

Figure 9: Shows the arm and leg coordinate values of Path Tracker of Cross marker in Excel Charts.

IV. CONCLUSIONS

Biomechanically representation in multidimensional view of speed and distance in throwing techniques of Judo is useful for making a good balance between the movements of limbs, trunk and head in order

to transform energy on focus through the force applied on lever. Results got from the observation by kinovea software states that perfection can be attained by maintaining centre of gravity in different actions during combatting. It is found that accurate selection of body posture, level and direction of energy toward focus point while throwing Uke's body enhance the speed of throwing and more refined in repetitive actions. The measurements of actions even in repetitions minimize the gap between outcomes and expected through back propagation. The measurement of speed, velocity of force and distance travelled in motion by arms and legs can avoid damage in joints and head specially backbone of Tori as well as Uke and sacrum points. It is concluded that the proper combination of lever and position of fulcrum helpful in effective outcome while minimizing the chance of injuries in locomotion. With this reason, Judo techniques can be divided biomechanically, however, this classification of techniques into various combinations of body parts like trunk and hands, trunk and legs, head, trunk & arms and trunk, arms & legs etc., are dependent on the experience of coach, his training methods, physical characteristics of Judoka like height, weight and speed in maintaining balance through center of gravity. Therefore applicability of biomechanics is just aids coaches or Judokas for better performance and can't replace the traditional methods of combating. Further with certain divisions, techniques can also be divided biomechanically in static or dynamic. In Judo, during completion, there is always maximum use of head, arms and legs or trunk while static temporarily to control the balance of body. So optimization of dynamic motions can mold the fighting style of Judokas to perform a technique more effectively by the use of sophisticated software tools in practice. Tori can change his position of arms and legs, forcing lever to lift over a particular position on Uke's body with maximum concentrated power benefit him rapidly perform the throwingtechniques. The methods can be learned from beginning by the entry point Judokas.

V. TERMS USED:

px-pixel, s-second, f –frame

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