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DETERMINATION OF DYNAMICAL PARAMETERS OF THE HUMAN GAIT USING FORCE PLATE

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Abstract: *This paper aims to identify theoretical and experimental phases of support foot of the ramp take dynamic parameters (moments and reaction forces), specific these phases. In the determination of dynamic parameters specific to walking normally be used an install form of a plate (platform) Kistler, an electrical signal amplifier, two DAQ systems (for analog and digital signal), an interface user program- BioWare, and a system purchased by the data- PC.*
Keywords: *BioWare, force plate, human gait, electrical signal,*

1. INTRODUCTION

Human locomotion may be defined as the action by which the body as a whole moves through aerial, aquatic, or terrestrial space. Locomotion is achieved by coordinated movements of the body segments, taking advantage of an interaction of internal and external forces, and is accomplished through the action of the neuro-musculo-skeletal system. In both healthy and pathological locomotion, the fact that it is possible to take measurements is of great significance [1].

The anatomical substrate of the locomotor system is made up of bones with their surrounding tissues, such as cartilage, muscles, ligaments, the nervous system controlling the motorics, and connective tissue. The skeletal subsystem, supporting the body as a whole, may be called the effector subsystem. The skeletal muscle plant, active force generators with the purpose of realizing movement, may be called the actuator subsystem. Active muscular forces combined with external forces (gravitational, ground reaction), elastic muscle forces, and other inertial forces which arise due to the moving body mass, all determine manifested body kinematics in time and space. The subsystem, called control, which coordinates and controls overall motor activity, is the nervous system.

2. THE HUMAN GAIT

2.1. Periodicity of Gait

The act of walking has two basic requisites:

1. Periodic movement of each foot from one position of support to the next
2. Sufficient ground reaction forces, applied through the feet, to support the body.

These two elements are necessary for any form of bipedal walking to occur, no matter how distorted the pattern may be by underlying pathology [2]. This periodic leg movement is the essence of the cyclic nature of human gait.

2.2 Gait Cycle

Figure 1 illustrates the movement of a wheel from left to right. In the position at which we first see the wheel, the highlighted spoke points vertically down. (The wheel is not stationary here; a.snapshot. has been taken as the spoke passes through the vertical position.) By convention, the beginning of the cycle is referred to as 0%. As the wheel continues to move from left to right, the highlighted spoke rotates in a clockwise direction. At 20% it has rotated through 72^0 (20% x 360^0), and for each additional 20%, it advances another 72^0. When the spoke returns to its original position (pointing vertically downward), the cycle is complete .

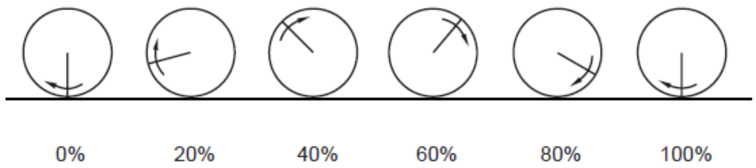


Figure 1: A rotating wheel demonstrates the cyclic nature of forward Progression [3]

2.3 Phases

There are two main phases in the gait cycle: During *stance phase*, the foot is on the ground, whereas in swing phase that same foot is no longer in contact with the ground and the leg is swinging through in preparation for the next foot strike. As seen in Figure 2, the stance phase may be subdivided into three separate phases:

1. First double support, when both feet are in contact with the ground
2. Single limb stance, when the left foot is swinging through and only the right foot is in ground contact
3. Second double support, when both feet are again in ground contact.

2.4 Events

Traditionally the gait cycle has been divided into eight events or periods, five during stance phase and three during swing. The names of these events are self-descriptive and are based on the movement of the foot, as seen in Figure 2.

In the traditional nomenclature, the stance phase events are as follows [3]:

1. ***Heel strike*** initiates the gait cycle and represents the point at which the body's centre of gravity is at its lowest position.
2. Foot-flat is the time when the plantar surface of the foot touches the ground.
3. ***Midstanc***e occurs when the swinging (contralateral) foot passes the stance foot and the body.s centre of gravity is at its highest position.
4. ***Heel-off*** occurs as the heel loses contact with the ground and pushoff is initiated via the triceps surae muscles, which plantar flex the ankle.
5. ***Toe-off*** terminates the stance phase as the foot leaves the ground.

The swing phase events are as follows:

6. ***Acceleration*** begins as soon as the foot leaves the ground and the subject activates the hip flexor muscles to accelerate the leg forward.
7. ***Midswing*** occurs when the foot passes directly beneath the body, coincidental with midstance for the other foot.
8. ***Deceleration*** describes the action of the muscles as they slow the leg and stabilize the foot in preparation for the next heel strike.

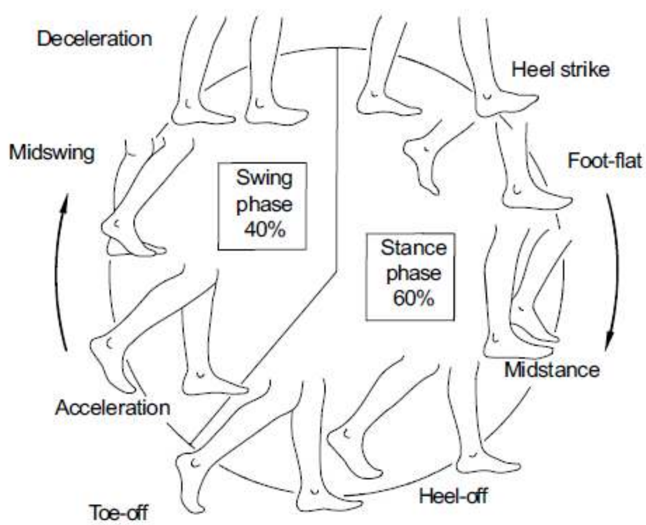


Figure 2: The traditional nomenclature for describing eight main events, emphasising the cyclic nature of human gait [3].

3. FORCE PLATFORM KISTLER

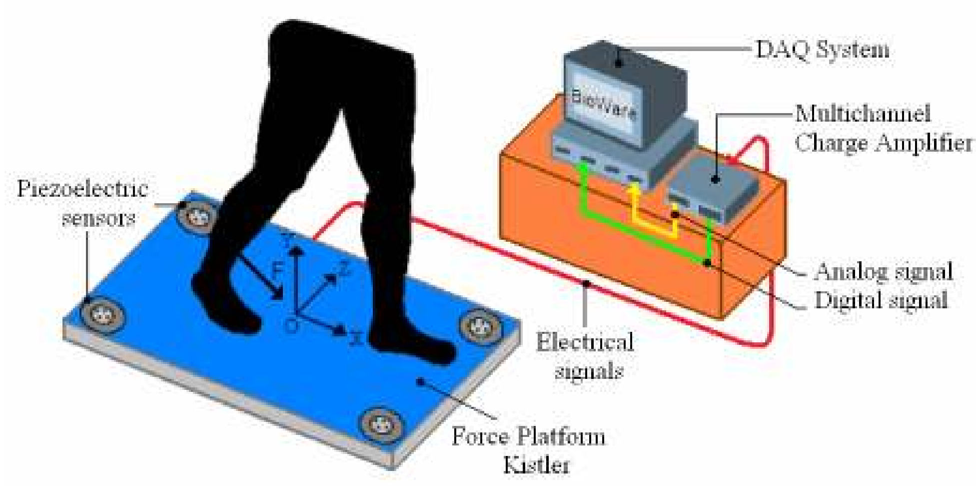


Figure 3: Description of the experimental installation

In the determination of dynamic parameters specific to walking normally be used an install form of a plate (platform) Kistler, an electrical signal amplifier, two DAQ systems (for analog and digital signal), an interface user program- BioWare, and a system purchased by the data (laptop) (Figure 3).

BioWare software is the engine behind the force plate system. It collects data from the force plates, converts the trials into useful information and plots the results. The force plates and charge amplifiers are fully remote controlled by BioWare thus making the system extremely flexible and easy-to-use.

These devices enable measurement of the total force vector ($\boldsymbol{F_m}$) manifested in various locomotor activities during contact between the subject's body (typically the foot) and the surface (floor) in which the device is embedded. Also, the device usually gives the moment of force vector ($\boldsymbol{C_m}$) as well as planar coordinate values $\boldsymbol{x}$ and $\boldsymbol{y}$ of the point of center of pressure $\boldsymbol{R_n}$ as its output. These measurement quantities may be displayed as time curves. As such, the device is generally applicable in locomotion study, healthy or pathological. Besides being used in dynamic phenomena such as gait and running, force platforms (force plates) may also be used in measurements of approximate static body postures since, because body support via the feet is nearly fixed, measurement signals are a consequence of movement of the body's center of mass. This is exploited, for instance, when testing the vestibular apparatus from a neurological and otorhinolaryngological standpoint, in general, when examining postural stability and balance [4].

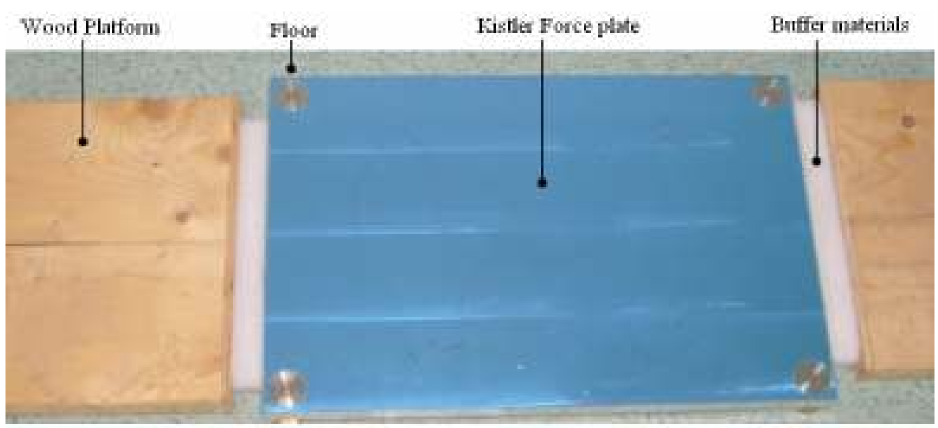


Figure 4: Experimental installation

The instrument's contact area is a rectangular plate usually 760 x 360 x 35 mm in size (various other special designs of larger platforms are also possible) embedded in a firm, substantial base (Figure 4). The platform's surface must be at ground level, possibly covered by carpeting to enable truly noninvasive measurements (so the subject is not aware of having stepped onto the platform). The measurement room must be well equipped. There must be a track about 10 m in length for gait measurements and an even larger corresponding space for measurement of running, take-offs, etc. The two most widely applied measurement instruments, the strain gage-based platform and the platform with piezoelectric transducers.

A strain gage transducer-based platform usually has four rectangularly arranged load transducers separating two plates. A certain loading pattern will induce reactions in all four transducers. In order to obtain output for each respective channel of the total device output (forces will be denoted with Fx, Fy, Fz, and moments will be denoted with Mx, My, Mz), outputs of each transducer are added together and principles of summation and superposition are used as previously described [4]. In this way, each output channel represents a direct measure of corresponding force, i.e.,
moment. Besides strain gage-based platforms, another kind of instrument is also used for measuring locomotion. It is based on another physical principle of measuring forces and moments: the piezoelectric effect. It is a kind of active transducer, since the transduction of mechanical into electrical energy occurs without an external energy source. A device by the Swiss firm Kistler, based on this type of measurement sensors has widespread application and may be said to be a standard in biomechanical locomotion measurements. Usually, four identical force transducers are used, each positioned in one corner of the platform (Figure 4). Moment values are deduced from the forces measured and from the relative positions of transducers in the platform, which is why there are eight output channels . Twelve of the outputs from the four transducers are connected so that there are finally eight outputs.

The Kistler platform provides measurement of the total vertical force and horizontal components of the force applied with an accuracy better than 1%, nonlinearity and hysteresis less than 1%, and sensitivity up to 0.05 Pa, in a working range typically 200 kPa for the vertical and ± 50 kPa for the horizontal force component.

4. RESULTS

Walking and running, the most natural human locomotion, have often been the subject of ground reaction force measurements. The solution proposed is based on determining the specific dynamic parameters of human gait, that forces the action side of the ground on foot F_x, F_y, F_z and reactive moments M_x, M_y, M_z , on the three directions O_x, O_y, O_z ,during phases support of the foot on board force. To understanding the phenomenon will present how the pursuit of a experiment, after were obtained dynamic parameters specific normal walking in case of human subjects.

The experiment was carried bad in three successive stages as follows [5]:

1. initially setting the Kistler system;
2. acquisition of dynamic parameters;
3. processing and interpretation of results.

Subject 1- man/34 years/ 98.75 Kg /1.70 m

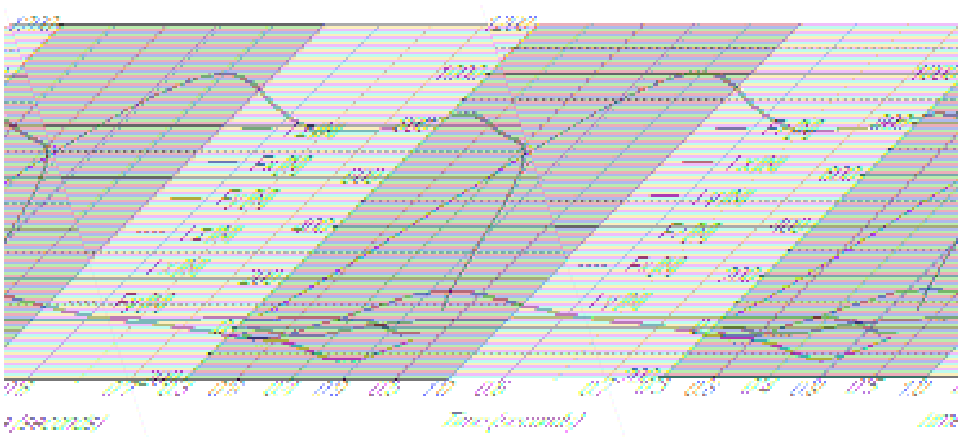


Figure 5: Ground Reaction Forces (GRF) after applying the statistical filter

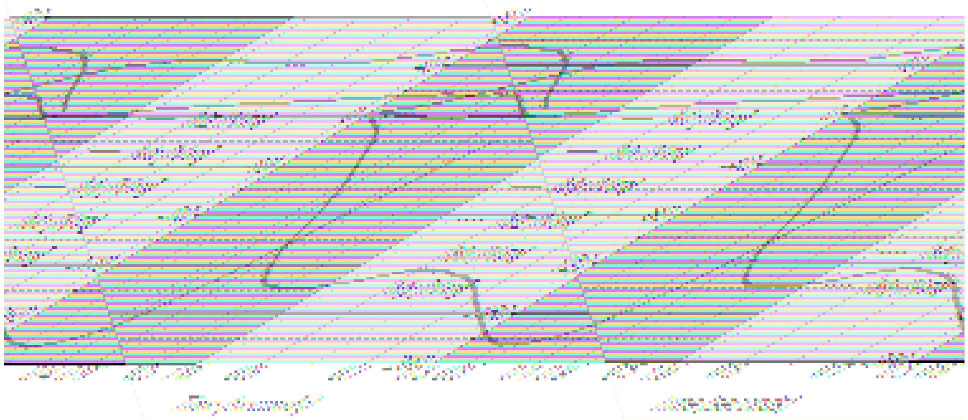


Figure 7: Reactive moments M_x, M_y, M_z after applying the statistical filter

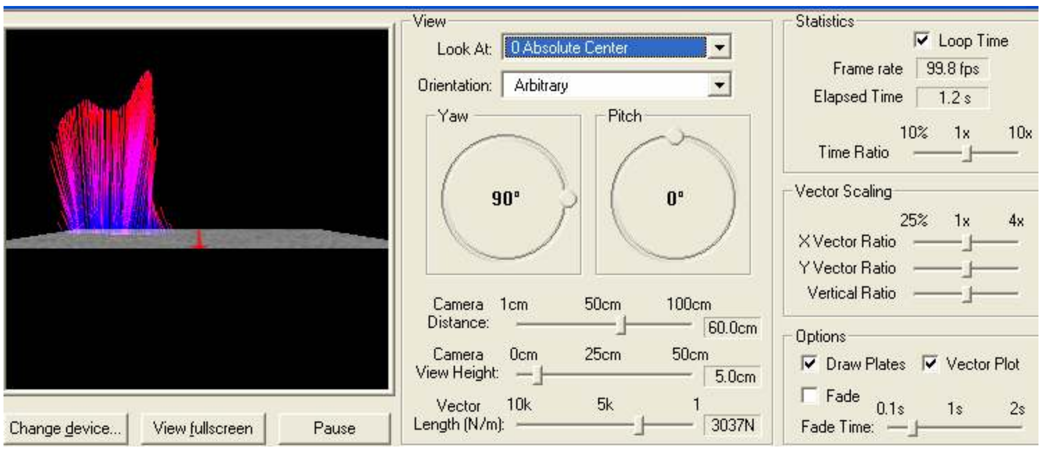
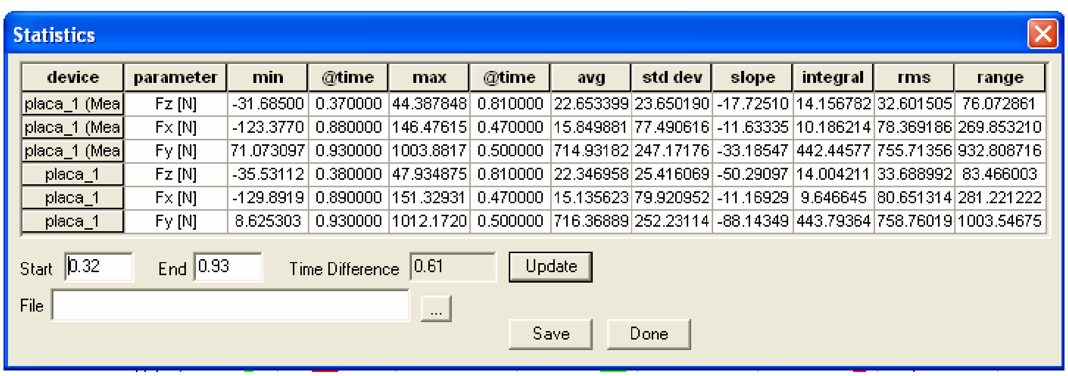


Figure 8: Force vector- 3D representation


Statistics

device	parameter	min	@time	max	@time	avg	std dev	slope	integral	rms	range
placa_1 (Mea	Fz [N]	-31.68500	0.370000	44.387848	0.810000	22.653399	23.650190	-17.72510	14.156782	32.601505	76.072861
placa_1 (Mea	Fx [N]	-123.3770	0.880000	146.47615	0.470000	15.849881	77.490616	-11.63335	10.186214	78.369186	269.853210
placa_1 (Mea	Fy [N]	71.073097	0.930000	1003.8817	0.500000	714.93182	247.17176	-33.18547	442.44577	755.71356	932.808716
placa_1	Fz [N]	-35.53112	0.380000	47.934875	0.810000	22.346958	25.416069	-50.29097	14.004211	33.688992	83.466003
placa_1	Fx [N]	-129.8919	0.890000	151.32931	0.470000	15.135623	79.920952	-11.16929	9.646645	80.651314	281.221222
placa_1	Fy [N]	8.625303	0.930000	1012.1720	0.500000	716.36889	252.23114	-88.14349	443.79364	758.76019	1003.54675

Start 0.32 End 0.93 Time Difference 0.61 Update

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Subject 2: women/27 years/74.46 Kg/ 1.69 m

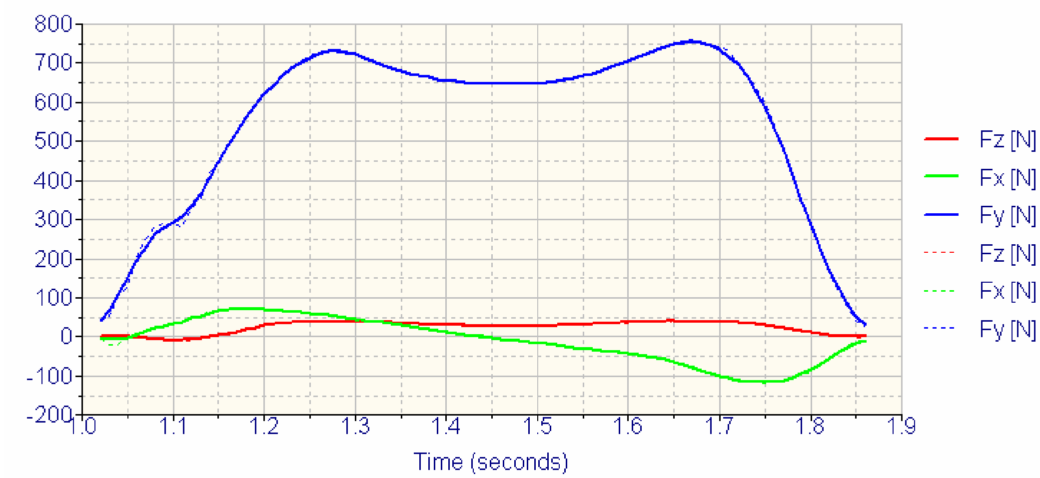
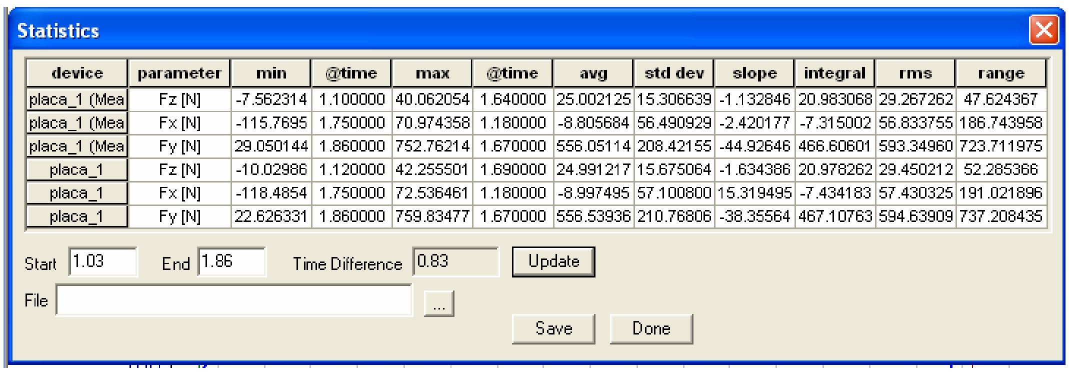


Figure 9: GRF- after applying the statistical filter (subject 2)



Statistics

device	parameter	min	@time	max	@time	avg	std dev	slope	integral	rms	range
placa_1 (Mea	Fz [N]	-7.562314	1.100000	40.062054	1.640000	25.002125	15.306639	-1.132846	20.983068	29.267262	47.624367
placa_1 (Mea	Fx [N]	-115.7695	1.750000	70.974358	1.180000	-8.805684	56.490929	-2.420177	-7.315002	56.833755	186.743958
placa_1 (Mea	Fy [N]	29.050144	1.860000	752.76214	1.670000	556.05114	208.42155	-44.92646	466.60601	593.34960	723.711975
placa_1	Fz [N]	-10.02986	1.120000	42.255501	1.690000	24.991217	15.675064	-1.634386	20.978262	29.450212	52.285366
placa_1	Fx [N]	-118.4854	1.750000	72.536461	1.180000	-8.997495	57.100800	15.319495	-7.434183	57.430325	191.021896
placa_1	Fy [N]	22.626331	1.860000	759.83477	1.670000	556.53936	210.76806	-38.35564	467.10763	594.63909	737.208435

Start 1.03 End 1.86 Time Difference 0.83 Update

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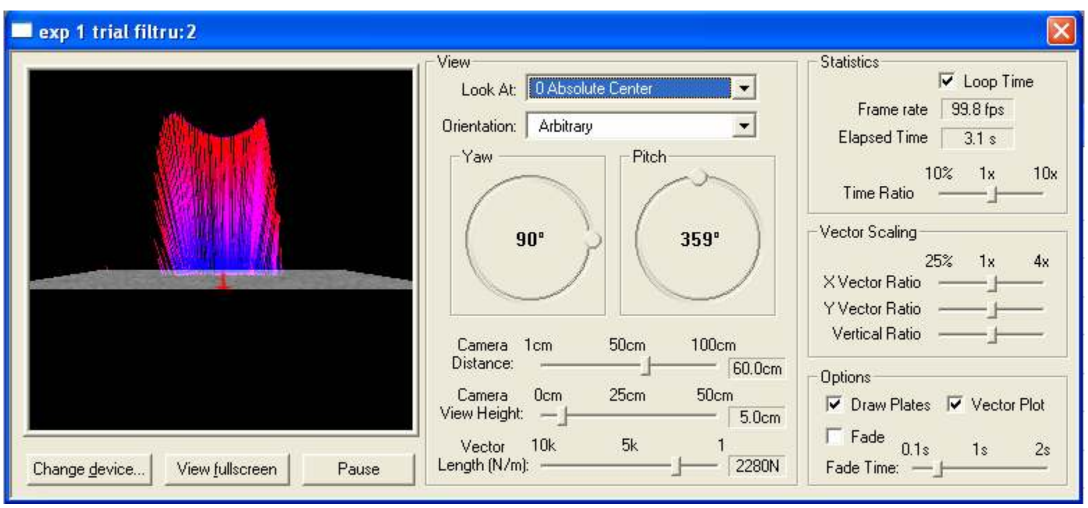

Figure 10: Force vector- 3D (subject 2)

5. ACKNOWLEGDEMENTS

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