

SONIC DIGITIZING: A NEW METHOD FOR KINEMATIC ANALYSIS OF HIGHLY PRECISE SPORTS AND MOVEMENTS -AIR RIFLE AND PISTOL SHOOTING

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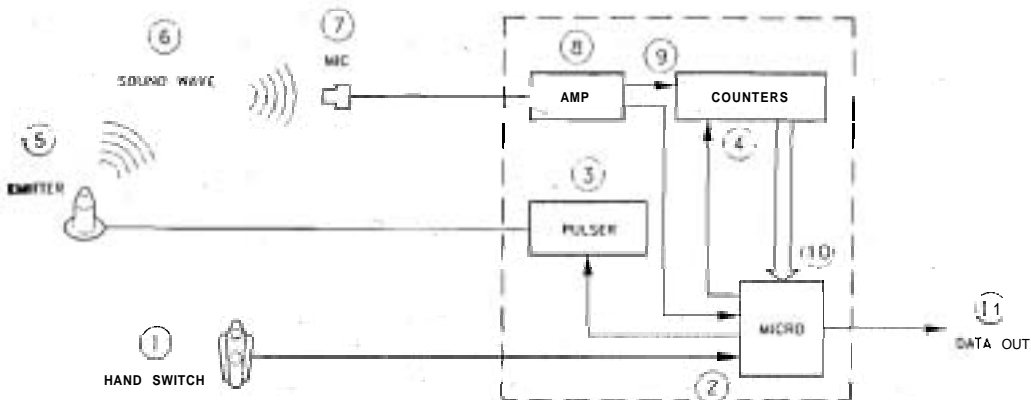
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INTRODUCTION

Body segments stabilization is the most important factor in sport shooting technique. After the original study of the pioneers W. Braune and O. Fischer in their book "On the center of gravity of human body as related to the equipment of the German infantry soldier", many researchers have used different instrumentation chains, looking for relationships among various Biomechanical and Physiological variables and performance. (Nickel, 1981; Niinimaa, 1983; Myllyla, 1986; Gajewski et al. 1986; Iskra et al. 1988; Larue et al. 1989; Mason et al. 1990; Zatsiorsky, 1990). So far as we know, none of the methods which they have proposed describes the time history of the 3-dimensional coordinates of the anatomical joints of the Shooter during the aiming process. Sonic Digitizing does permit us to quantify the relative position of the body segments of the shooter, his or her Posture, as well as the spatial orientation of the Rifle at every instant. It seems to be very interesting given that from a Mechanical point of view, the shooter with the rifle form an Oscillating System around a Static Position and according to an important principle of General Systems Theory, the behavior of a system emerges from the Dynamic Interactions of its parts. Therefore, a complete Kinematic Analysis can and must be done measuring the dependence of the Geometry of the whole Kinematic Chain upon the oscillations of the aiming line.

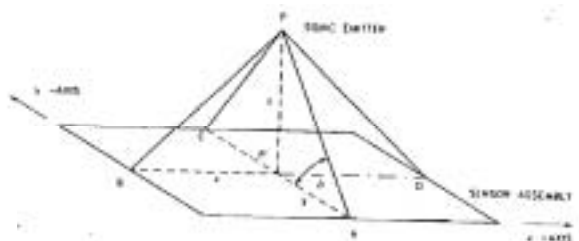
METHOD

SONIC DIGITIZING is the process of converting information of position in three dimensions to digital values, in a form suitable for data transmission storage and processing, based on the properties of ultrasounds. The hardware of our presently configured system consists of the GP8-3D Sonic Digitizer, manufactured by Science Accesories Corporation. It includes 16 Sound Emitters which can be fixed on the shooters anatomical joints and on the barrel of the gun, 4 Microphone\Sensors supported on a rigid frame, which define our system of reference, the Multiplexer Unit and the Control Unit which communicates with a Personal Computer, via Parallel Interface Card (PIO12) for high data rate throughput. The Sampling Rate is 35-37 Hz using 2-16 emitters. Therefore the Sampling Rate for every emitter is equal to $36 \text{ Hz/Number of emitters}$, in an active volume of 2 meters side cube. Nominal System's Resolution is 0.1 mm and the calculated Standard Deviation (Precision) in the bilateral direction OY was 0.15 mm (in the other two directions vertical OZ and anteroposterior OX the precision was better). The system works using impulses generated at the tip of the emitter to calculate its position in the working volume (fig. 1). Cognizant of the distances between the microphones on the reference system AC, BD (fig. 2) previously calibrated and the speed of sound in still air (343.8 m/sec 20°C), the times required for the sound wave to reach the microphone\sensors are converted into X, Y, Z coordinates. The software designed for our purposes includes: A). the program for Kinematic Analysis in time and frequency domain. B). 3 modules for calibration (reference system, emitters climbed on the gun which define the aiming line and the coordinates of the center of the target). C). The module for the transformation of the distance of the aiming line from the center of the target to an acustical feedback signal of variable frequency.



1-HANDSWITCH 2-TELLS MICRO 3-TO FIRE PULSER CAND START COUNTERS 5-PULSER TRIGGERS SPARK AT EMITTER 6-CAUSING SOUND WAVE 7-WHICH IS RECEIVED BY MIC 8-SIGNAL PASSES THROUGH AMP 9-STOPPING COUNTERS 10-AND TELLING MICRO 11-TO READ COUNTERS AND TRANSMIT DATA.

Fig 1. GP8-3D Function Block Diagram



$$(PC)^2 = (PA)^2 + (CA)^2 - 2(PA)(CA)\cos\theta$$

$$y = (PA)\cos\theta$$

$$(PC)^2 = (PA)^2 + (CA)^2 - 2(CA)y$$

$$y = [(PA)^2 + (CA)^2 - (PC)^2] / (2(CA))$$

$$z = \sqrt{PC^2 - (PA)^2 - y^2}$$

$$x = \sqrt{(PB)^2 - z^2}$$

Fig 2. Calculation of X, Y, Z Coordinates.

RESULTS:

This method suggests a new approach to the 3-D Kinematic data collection. in sports of high precision as well as in the study of very fine movements. The information which can be obtained is respect to:

* Shooter's Posture. That is, Joint Angles, 3-D coordinates of the Joints and BCGs of the body segments. (Fig. 4).

* Shooter's Posture **Stability**, the variation of 3-D coordinates in the Time and Frequency Domain. (Fig. 3). At first sight the sampling rate of the Sonic Digitizer seems limited but previous tests, in our Lab, using one emitter at a time (33 Hz) for every joint and for the weapon of the gun, demonstrated that frequency spectra were upto 2 Hz, so we can use at least 8 emitters at the same time without the danger of "aliasing".

* Shooting Simulation, for dry training, calculating the intersection of the aiming line, which is defined by the 2 emitters climbed on the rifle, with the previously calibrated plane of the target.

* It is possible to combine the results of the Kinematic Analysis with these from Stabilography, considering the relation between the rotations of the body segments and the displacement of the Center of Pressure. For this reason we have synchronized the Sonic Digitizer with a strain-gauge Force Platform. According to Koles, Z.J. and Castelein, R.D. (1980) "it is fair to say that Stabilography as it stands today has provided little real knowledge about the mechanisms controlling human posture".

* Possibility to establish in Real-Time a Feedback loop providing the shooter with a continuous acoustical signal of variable frequency as a function of the deviation of the supposed hit point from the center of target . (Gianikellis, K. et al. 1991).

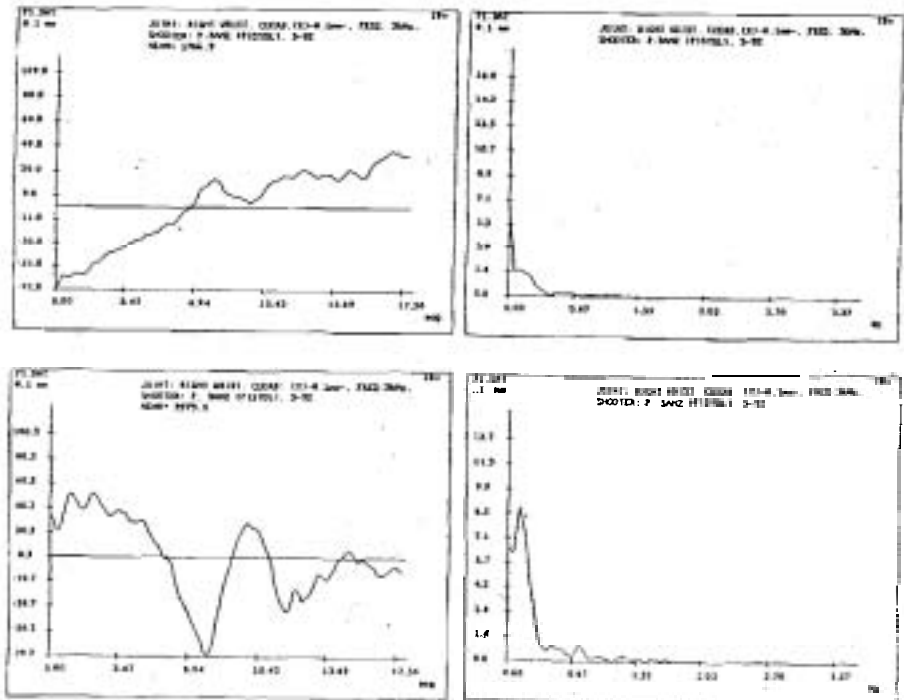


Fig. 3. X,Y coordinates of Ore wrist in the time and frequency domain.

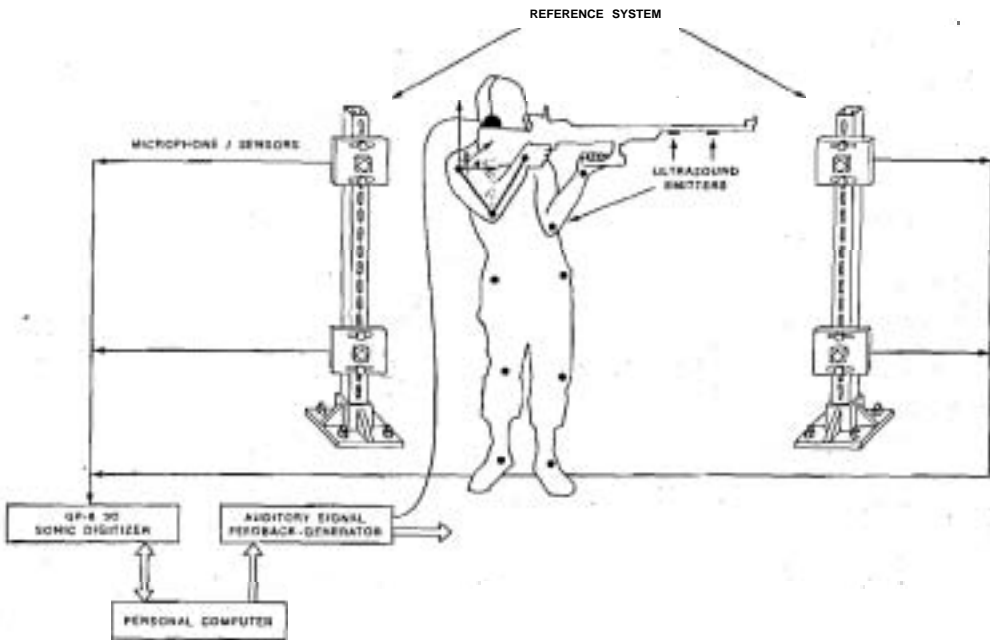


Fig. 4. Sonic Digitizing set up.

CONCLUSIONS:

On the basis of *Precision, Resolution, Device Attachment Convenience, On-Line Computer Analysis Capability and Cost*, the SONIC DIGITIZING METHOD would be useful for Biomechanical Analysis in movements and Sports of high precision.

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