MICROCOMPUTER BASED SOFTWARE FOR BIODYNAMIC SIMULATION

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ABSTRACT

This paper presents a description of a microcomputer based software package, called DYNAMAN, which has been developed to allow an analyst to simulate the dynamics of a system consisting of a number of mass segments linked by joints. One primary application is in predicting the motion of a human occupant in a vehicle under the influence of a variety of external forces, specially those generated during a crash event. Extensive use of a graphical user interface has been made to aid the user in setting up the input data for the simulation and in viewing the results from the simulation. Among its many applications, it has been successfully used in the prototype design of a moving seat that aids in occupant protection during a crash, by aircraft designers in evaluating occupant injury in airplane crashes, and by users in accident reconstruction for reconstructing the motion of the occupant and correlating the impacts with observed injuries.

DESCRIPTION OF SIMULATION SOFTWARE

The software developed and used by us in occupant simulation is called DYNAMAN. This package consists of the following modules:

1. A preprocessor that enables the analyst to interactively set up an input data file or to modify an existing data file that is needed to carry out the simulation.

2. A simulation module which accepts the input file that was created using the preprocessor, and produces output files that contain various dynamic variables that describe the three-dimensional motion of the occupant, e.g. accelerations, displacements, contact forces, etc. (The simulation module is essentially the ATB Version 4.2)

3. A postprocessor that can be used to view the output of the simulation module in pictorial, graphical, and tabular forms.

4. A program to estimate dimensions of a human occupant based on sex, weight and height.

The software package will run on 80386- and 80486-based personal computers under DOS 3.xx and above. Both 16-bit and 32-bit versions are available. In addition, a workstation version has been developed, which will work on a Silicon Graphics Iris workstation.

Elements of Simulation Input

In order to simulate the motion of a vehicle occupant or pedestrian, the following broad categories of information are required:

1. Geometric and inertial properties of the occupant;
2. Motion of the vehicle;
3. Environment around the occupant;
4. Definition of functions for the interactions;
5. Definition of contacts between occupant and environment;
6. Initial position of the occupant;
7. Integration and output parameters to run the simulation module.

The DYNAMAN preprocessor is used to set up the various input data required to run a simulation. Typically these input data are read in from previously created files, and the input parameters are changed to produce a new input file. The preprocessor use a variety of menus, tables, dialog boxes, and graphics for both displaying the data and for accepting the user input. Figure 1. shows the menu from the primary screen of the DYNAMAN package which provides access to the different DYNAMAN programs.
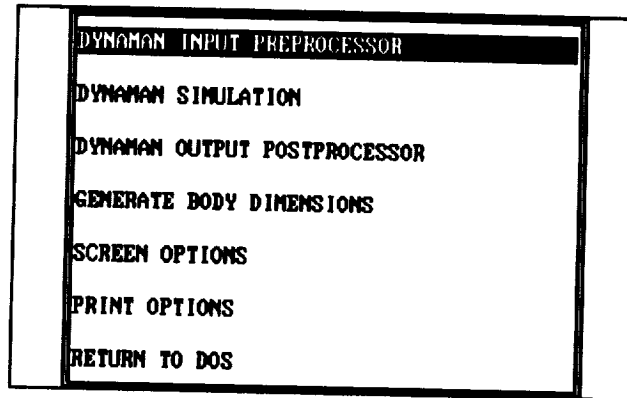

Figure 1: Primary Menu of DYNAMAN

Figure 2. shows a screen displaying a data table of information describing the various segments defined in a particular simulation. It shows the values of such things as segment masses and moments of inertia. The user can move to any field (like in a spreadsheet) and change the value by entering a new number.

Seg. Name	Prev. Seg.	Flxbl	Seg Wt	Ixx	Iyy	Izz
LT		YES	29.84	1.986	1.385	1.488
CT	LT	NO	3.888	.82126	.82126	.88869
UT	CT	NO	37.87	2.888	1.592	1.336
NECK	UT	NO	1.828	.81179	.81179	.88588
HEAD	NECK	NO	9.678	.2197	.2562	.1638
LUL	LT	NO	28.99	.7723	.7721	.1164
LLL	LUL	NO	7.888	.5949	.5987	.83216
LF	LLL	NO	2.768	.83838	.84348	.81328
RUL	LT	NO	28.99	.7723	.7721	.1164
RLL	RUL	NO	7.888	.5949	.5987	.83216
RF	RLL	NO	2.768	.83838	.84348	.81328

Figure 2: Screen for Defining Segment Data

In the next sections, we will discuss each of the broad categories of data listed above.

Geometric and Inertial Properties of the Occupant

The vehicle occupant in DYNAMAN is modeled as a number of segments that are connected by joints. Each body segment and joint is identified by a number and a mnemonic assigned to it. The maximum number of segments you can use currently to model the crash victim is 60.

The principal source of validated data for occupants come from testing done on anthropometric test devices (ATD) or crash test dummies. Occupant input data may also be obtained from the BODGEN program which accesses a database of occupant size data. This database was created from a study of several thousand male and

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female volunteers of different age groups and from a large sample of children. The software estimates the dimensions of an occupant of specified sex, weight and height from regression equations set up for each of the body segments that are used in the simulation software. The BODGEN program is derived from the GEBOD program.

Each body segment can be described fully by defining its weight, moments of inertia, and the orientation of its principal axes. In addition each body segment also has one or more contact ellipsoids attached to it. These ellipsoids are described by their semiaxes and location of their centers. The ellipsoids are used in determining the contact forces generated when contacts between body segments and vehicle interior planes exist.

Joints are used to connect body segments to each other. There may a number of different linked systems, each system consisting of a set of segments connected together, but the systems themselves being distinct from each other. Different kinds of joints can be defined to constrain the relative motion between the connected segments. The joints can model a hinge, a ball and socket or a more complicated type of motion. The torques required to rotate the adjacent segments at a joint in various directions are input into the model.

Vehicle Motion

The motions of upto six different segments can be specified in DYNAMAN. These motions determine the crash event in which the occupant is placed. The motion can be specified as unidirectional or with full 6 degrees of freedom. The initial location and orientation of the segments undergoing the prescribed motion can also be specified.

Environment Around the Occupant

The environment to which the occupant is exposed may consist of one or many of the following:

1.   Vehicle contact planes: Each contact plane that is defined can be allowed to contact any defined segment during the course of the simulation.

2.   Belt restraint systems: A belt restraint system can be made up of several harnesses each consisting of a number of belts. Several belts may be joined together at tie-points. Each belt can be in contact with a number of segments at several points.

4.   Airbag restraint systems: The airbag is modeled as a stretchless ellipsoidal bag and it interacts with contact ellipsoids attached to selected occupant segments and reaction panels on the vehicle.

5.   Constraints: These are distance constraints imposed on the relative motion between a pair of segments. You can constrain a specified point (a) on a segment to move, in such a way that there is a constant distance (this distance can be zero) between it and a point (b) on another segment.

6.   Spring-dampers: You can use a spring-damper combination to connect two segments. One situation where you might like to use a spring-damper combination is when you want to model the thorax as two segments (spine and sternum) connected by a spring-damper combination. You can then evaluate chest deflection.

7.   External forces and torques: You can apply specified forces and torques on prescribed points of a segment.

8.   Additional contact ellipsoids: These may used to model the contact between certain segments with greater fidelity.

9.   Joint restoring forces: Joint restoring torques are defined as functions of the joint flexure angle for specified joint azimuth angles and are used to model the joint torques with greater detail than given by a simple joint torque coefficient.

Definition of Functions

A number of functions are required which define the interaction between various body segments and the environment, and possibly between two different body segments.

The contact between a plane and a segment (or between two segments) is governed by the force-deflection, inertial spike, energy absorption, permanent deflection, and friction coefficient functions that must be defined by the user. Functions which describe the stretch characteristics of the belts can also be defined, as well as, the deflection characteristic of a segment with a belt. The screen setup for entering function data is shown in Figure 3.
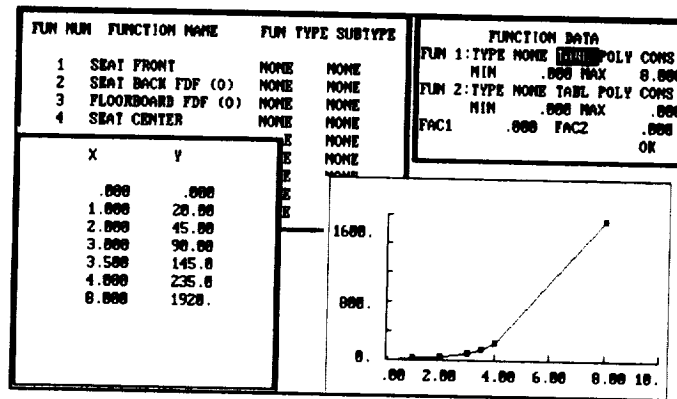

Figure 3: Windows Defining Function Values

Contact Definitions

The actual contacts that will be allowed between different planes and contact ellipsoids have to be defined by the user. Similarly the characteristics of each contact point of a belt have also to be defined. Contacts between segments and the airbag are also defined.

Initial Position and Belt Position

The preprocessor allows the user to interactively set up an initial configuration where the reaction forces from the initial contacts with vehicle planes are reduced to a minimum. The appearance of the screen for this procedure is shown in Figure 4.
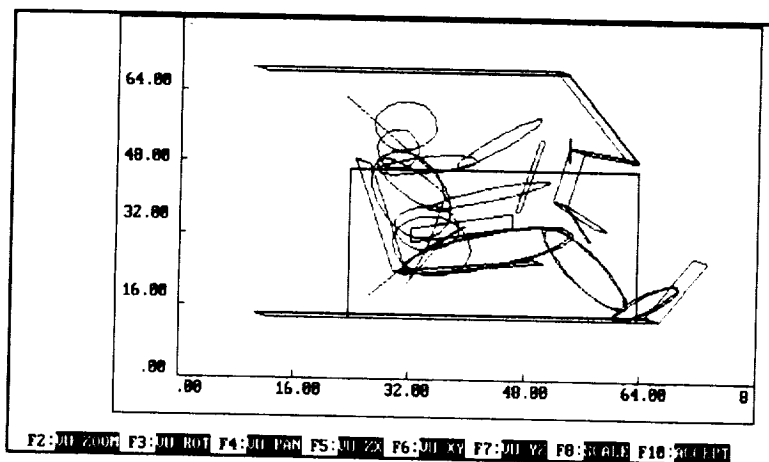

Figure 4: Initial Position Screen

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A similar graphical procedure is used to create and position harness belts about occupant segments. The user can insert, delete and move points defining a belt using a fully graphical interface.

Integration and Output Parameters

In order to properly control the numerical features of the simulation model, the program requires the user to define several parameters. These are the initial integration step size, and the maximum and minimum integration step size and the length of the simulation.

Postprocessing

The DYNAMAN postprocessor allows the user to view the output in a variety of ways. One can get pictorial, graphical and tabular output information from the simulation module. The output can be tailored to one's requirements by defining the type of information needed, and the interval between two successive points when output is produced. Pictures from two simulations can be compared, e.g. to see the effect of varying a parameter. Plots from one or more simulations can be compared with experimental data directly through the postprocessor. Options are available to produce pictures and plots according a number of user defined formats. Hard copies of the pictures and plots can be made on laser printers and plotters.

APPLICATIONS

DYNAMAN has been used in a number of different areas by both government researchers and commercial clients. Some of the major areas of application are in accident reconstruction, as a tool for measuring injury potential during a crash event, and in the design of vehicle components such as seats and airbags, and

Reconstruction of Accidents

One major application of DYNAMAN is in the reconstruction of accidents. The flowchart given in Figure 5. describes the steps usually involved in setting up a simulation with the DYNAMAN occupant simulation program in order to model a real life accident.
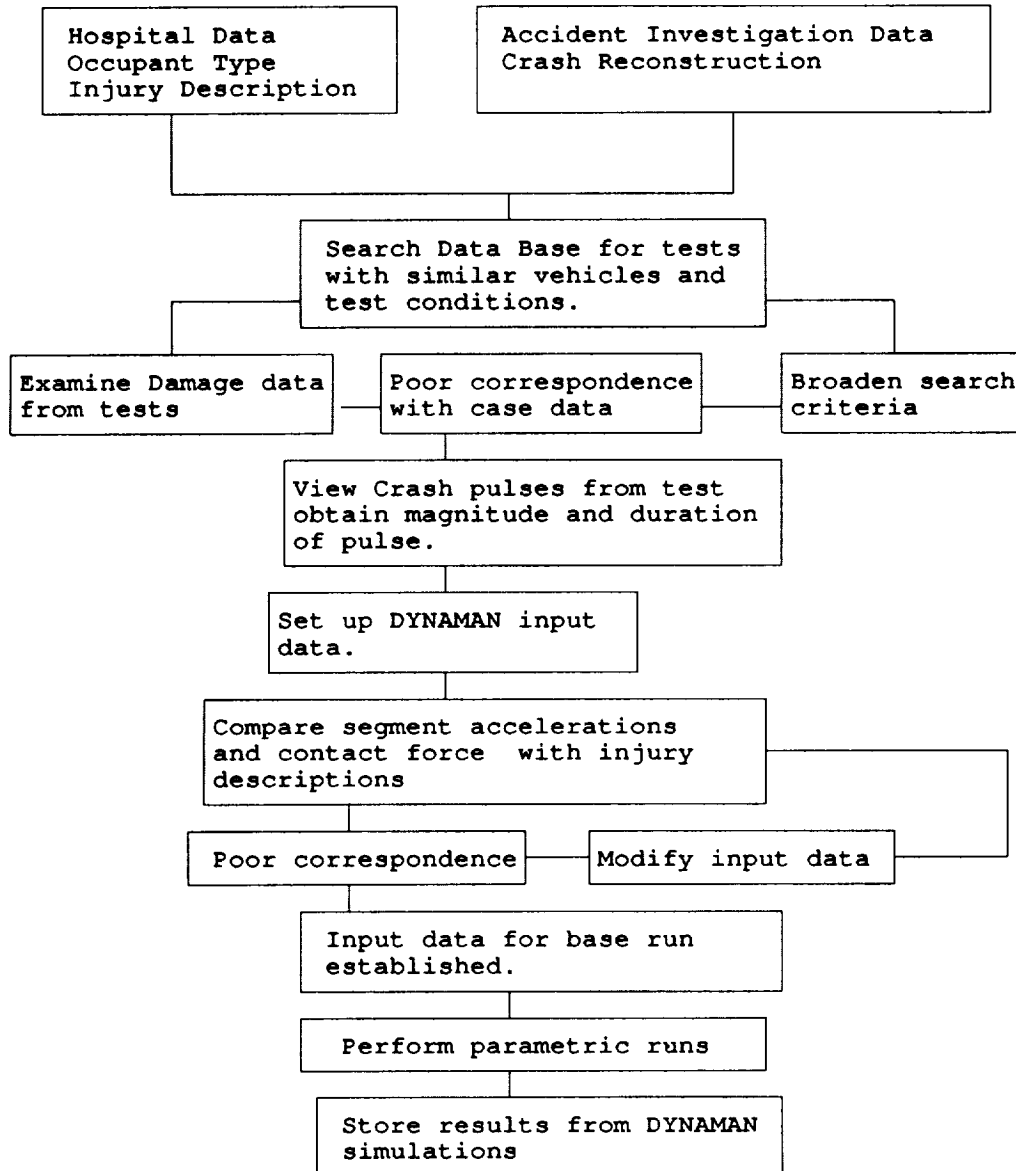
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┌─────────────────────┐      ┌────────────────────────────┐
│ Hospital Data       │      │ Accident Investigation Data│
│ Occupant Type       │      │ Crash Reconstruction       │
│ Injury Description  │      │                            │
└─────────────────────┘      └────────────────────────────┘
                │                          │
                │                          │
                └──────────┬───────────────┘
                ┌─────────────────────────┐
                │ Search Data Base for     │
                │ tests with similar       │
                │ vehicles and test        │
                │ conditions.              │
                └─────────────────────────┘
   ┌──────────────────┐  ┌──────────────────┐  ┌──────────────────┐
   │ Examine Damage   │  │ Poor             │  │ Broaden search   │
   │ data from tests  │  │ correspondence   │  │ criteria         │
   │                  │  │ with case data   │  │                  │
   └──────────────────┘  └──────────────────┘  └──────────────────┘
            ┌─────────────────────────────┐
            │ View Crash pulses from test  │
            │ obtain magnitude and duration│
            │ of pulse.                    │
            └─────────────────────────────┘
            ┌─────────────────────────────┐
            │ Set up DYNAMAN input         │
            │ data.                        │
            └─────────────────────────────┘
            ┌─────────────────────────────┐
            │ Compare segment accelerations│
            │ and contact force  with injury│
            │ descriptions                 │
            └─────────────────────────────┘
        ┌──────────────────┐    ┌──────────────────┐
        │ Poor             │────│ Modify input data│
        │ correspondence   │    │                  │
        └──────────────────┘    └──────────────────┘
            ┌─────────────────────────────┐
            │ Input data for base run      │
            │ established.                 │
            └─────────────────────────────┘
            ┌─────────────────────────────┐
            │ Perform parametric runs      │
            └─────────────────────────────┘
            ┌─────────────────────────────┐
            │ Store results from DYNAMAN   │
            │ simulations                  │
            └─────────────────────────────┘
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Figure 5: Methodology for Accident Reconstruction

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An example of an accident reconstruction simulation of a belted driver of a pickup truck which hit the side of another vehicle at about 40 mph. Figures 6 and 7 show the state of the occupant at a time just prior to the crash and 150 msec after the crash.
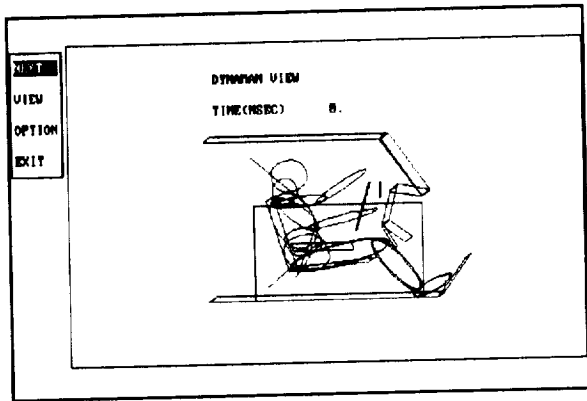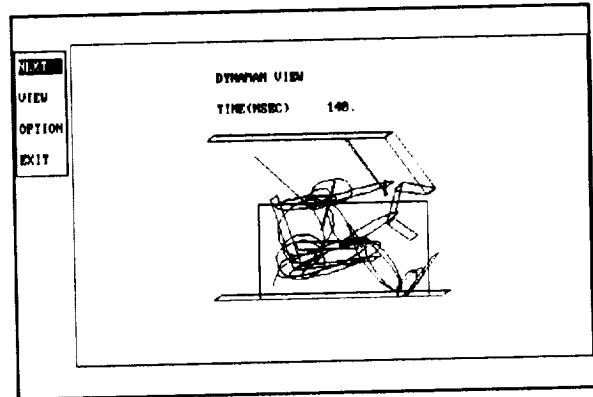

Figure 6: Side View at 0 msec

Figure 7: Side View at 150 msec

Injury Evaluation

DYNAMAN has been employed in evaluating the injury potential during a variety of crash events. Apart from vehicle crashes, it has been used in aircraft and helicopter crashes, as well as, pilot ejection. Figure 8 shows an example of the motion of helicopter pilot sitting in an energy absorbing seat during vertical crash. The position of the pilot and seat at two points in time are shown.
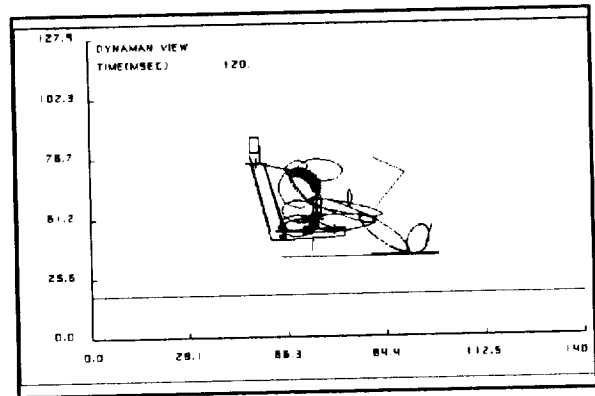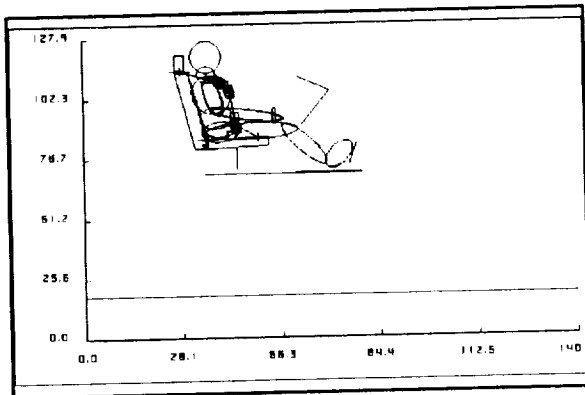
Figure 8: Simulation of Pilot during a Helicopter Crash

Figure 9 shows the motion of a pilot being ejected from an aircraft. Again, it shows the pilot and ejection seat at two time positions, but this time the two positions are superimposed on the same frame.
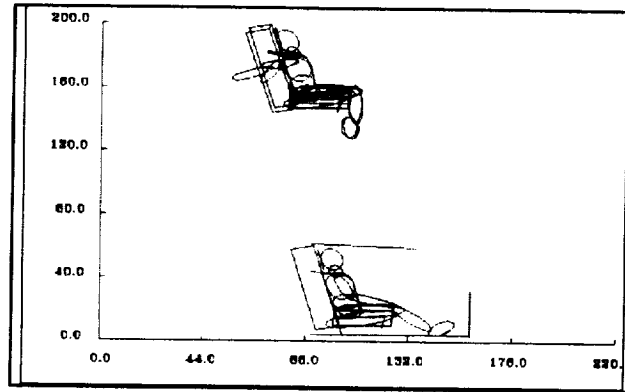
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Figure 9: Simulation of Pilot Ejecting from Aircraft

DYNAMAN as Design Tool

DYNAMAN can be used as a tool for formulating the basic design of such devices as airbags, child seats, and belts. For such a purpose, the basic simulation is conducted with input based on known parameters for the system under consideration. A number of design parameters are then identified, and a series of simulations are done by varying the values of the specific design parameters. From the matrix of simulations, the set of design parameters that provide the best degree of safety with an optimum level of comfort are then selected for producing a prototype of the device.

As an example, in the design of a child seat, DYNAMAN can be used to determine appropriate ranges for child seat weight and geometry, its seat cushion characteristics and its restraint system. Figure 10 shows output from a simulation with the child seat at the point of maximum excursion.
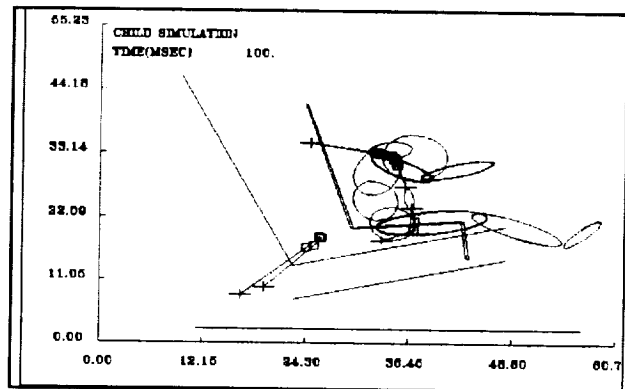

Figure 10: Simulation of Child in Child Seat

DYNAMAN has been successfully used in the design of a car seat which will undergo a motion during a crash event. The seat motion was designed to produce a lowering of the injury potential of the occupant, as compared to a non-moving seat. The seat motion can be optimized to work with other restraint systems such as two-point belts and airbags. Figure 11 shows a setup of an unbelted driver with a driver side airbag.
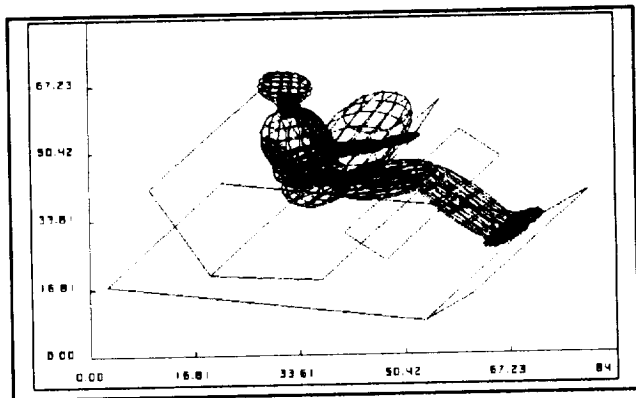
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Figure 11: Simulation of Driver with Airbag