S O F T W A R E   R E V I E W

Motion Simulation with Working Model 2D and MSC.visualNastran 4D

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1. Overview

MSC.Software Corporation (MSC), offers three motion simulation products [1]: Interactive Physics® (IP), Working Model® 2D (WM2D), and MSC.visualNastran 4D (vN4D). IP and WM2D simulate 2D motion on Mac and Windows® platforms. vN4D simulates 3D motion with dynamic finite element analysis (FEA) on Windows. IP is intended for physics and physical sciences in grades 7-12 and college. WM2D and vN4D are intended for higher education and engineering professionals.

IP and WM2D have the same user interface and simulation engine, but WM2D can import DXF files and has WMBasic, a scripting language for creating specialized macros. Since IP is a subset of WM2D, it is not discussed further.

2. Product Evolution

The evolution of these three simulation products is interesting, as their names have changed several times. Knowledge Revolution (acquired by MSC) first released Interactive Physics as Fun Physics in 1988. Renamed Interactive Physics in 1989, IP is distributed worldwide in seven different languages and is the standard in motion simulation for Newtonian physics. The latest version of IP was released in 2000.

Working Model was first released in 1993 for the engineering community. It was created by adding engineering functionality to IP and importing DXF drawings from CAD packages such as AutoCAD. Working Model was renamed Working Model 2D when R4 was released in 1996. The latest version of WM2D is R5, released in 1999.

Working Model 3D was first introduced in 1996. When MSC acquired Knowledge Revolution in 1999, dynamic FEA capability was added and Working Model 4D was born. The product was later renamed MSC.visualNastran 4D when R6 was released in 2000. The latest version of vN4D is R2001R2 released in June 2001.

3. Working Model 2D (WM2D)

WM2D employs Newton's law along with physical constraints, applied forces, and numerical integration to calculate constraint forces and motions of rigid bodies. Complex simulations can be controlled by Excel®, MATLAB®, or other programs that support Windows Dynamic Data Exchange (DDE) to carry out calculations.

Engineers can create rigid bodies by importing DXF objects or by using the WM2D sketching tools to draw a primitive or NURB (smooth) body. Using tools on the tool palette, engineers can quickly and easily connect the bodies with joints, gears, actuators, ropes, rods, separators, curved slots, and motors. Once connected, engineers can rotate and translate the bodies while maintaining connectivity with its "Smart Editor." The mechanical system is set in motion by clicking the Run button. WM2D has automatic collision detection and simulates contact, collision, and friction.

Geometric modeling in WM2D can incorporate data points calculated by other programs. A pair of meshed involute spur gears shown in Fig. 1 contains over 500 data points calculated from a MATLAB file[2]. The WM2D file shows that the contact point of the gears always lies on the pressure line. The Geneva mechanism in Figure 2 demonstrates the product's ability to import complex DXF parts.

WMBasic, a scripting language similar to Visual Basic, extends Working Model's functionality. For example, the snap joint (fastener) shown in Fig. 3 was modeled with the Flexbeam script, which simulates flexible beams using rigid bodies connected by spring-dampers. By matching the stiffness (EI) of a cantilever beam, a five-body discrete model simulated the flexible snap joint. As shown in Figures 3(a)-3(c), the mating part snaps to the left in a closed position.

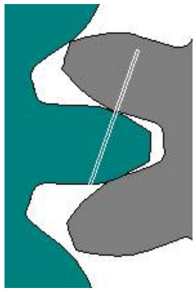


Fig. 1 Involute Spur Gears

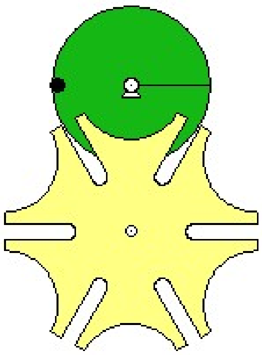
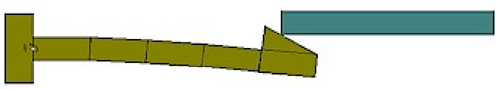
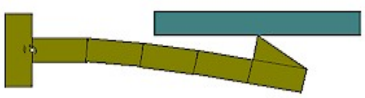


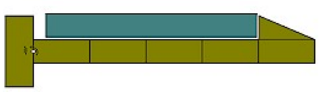
Fig. 2 Geneva Wheel



(a)



(b)



(c)

Fig. 3 Snap Joint

WM2D can analyze a mechanical system by measuring the forces and motions of any part in the system. The measured data can be shown in graphs, digital displays, and bar charts, and can be customized with the versatile WM2D formula language. For example, the mechanical advantage of a compound shear shown in Figure 4 is calculated from the ratio of output force vs. input force.

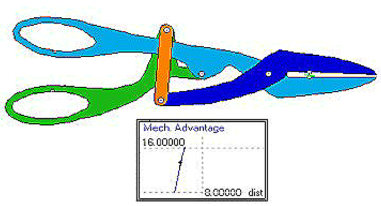


Fig. 4 Mechanical Advantage of a Compound Shear

With its user-friendly interface, WM2D is a conceptual design tool. A design can be optimized with the fast build-run-analyze-refine cycle before a physical prototype is built.

4. MSC.visualNastran 4D (vN4D)

vN4D is named for four parts of the design cycle, namely Draw It, Move It, Break It, Control It.

The **Draw It** tools consist of CAD integration with Autodesk® Inventor, SolidWorks®, Solid Edge®, and Pro/ENGINEER®, as well as native 3D solid modeling tools. vN4D imports complex geometries in a variety of formats, e.g., ACIS (*sat*), Parasolid (*x_t*), and STEP (AP203)., IGES, and STL. Additionally, vN4D has photo-realistic rendering, shadowing, and .avi movie creation.

The **Move It** tools consist of sophisticated motion analysis combined with key-framed animation. As in WM2D, vN4D measures forces, torques, positions, velocities, acceleration, kinetic energy, etc. Bodies are joined with constraints in vN4D through coordinate frames (Coords), much like in WM2D. vN4D is more difficult to use than WM2D because vN4D requires Coords to be attached to bodies before constraints can be defined. Unlike the snapping feature in many CAD software packages and in WM2D, snapping is restricted to cylindrical shapes, and is difficult when multiple objects overlap. vN4D has a smart editor that allows rotation and translation of joined parts. Occasionally, there are difficulties joining or moving bodies in a multi-closed-loop mechanism such as the Stewart platform shown in Fig. 5.

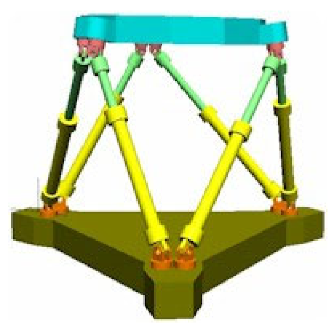


Fig. 5 Stewart Platform

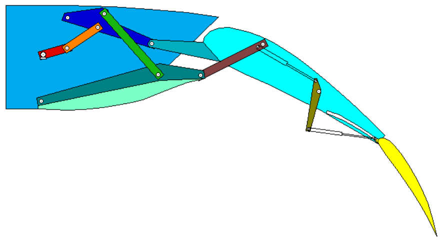


Fig. 7 Flap Actuator

Break It tackles the challenging task of combining motion simulation with FEA. vN4D has H-adaptivity that automatically clusters mesh elements around areas of greatest stress -- providing a more accurate answer in less time and with a smaller mesh. A pair of gear segments was modeled in Figure 6 to assess stress distribution. As expected high stresses are shown in the engaged tooth. However, the disengaged tooth still shows relatively high stresses. This could mean that the link between motion simulation and FEA is not without errors.

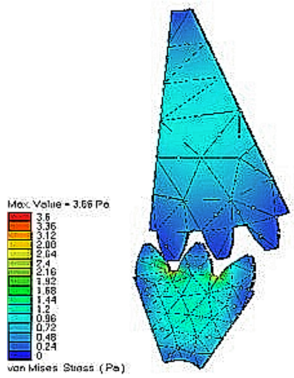


Fig. 6 Gear Stresses

Control It consists of integration with MATLAB/Simulink® and links through Visual Basic to Excel and Excel macros. Visualizing a MATLAB/Simulink® control system with real CAD geometry is an important part of vN4D.

vN4D is the only Windows native 3D motion simulation software. While other UNIX based motion simulation programs can run on Windows, a native Windows program provides an engineer with a familiar, consistent user interface, and provides integration and association with other Windows-based CAD packages.

Although 3D motion simulation is more appropriate for engineering professionals because most mechanical assemblies can be modeled in 3D CAD programs, 2D motion simulation is much faster and less confusing. For example, modeling the fourteen-bar flap actuator shown in Fig. 7 with vN4D is a daunting task, but is easy with WM2D. Figure 8 shows the 3D motion simulation of the Mars Rover with its rocker-bogie suspension. The front and middle wheels of the rover are connected with links to form a bogie that pivots (rocks), for climbing an obstacle. An individual motor drives each wheel. The simulation effectively demonstrate the unique suspension and its excellent maneuverability in rough terrain, as in the sequence from Figure 8(a) to 8(d). As shown in Figure 9, the reviewer attempted to use the same geometry, constraints, and actuators in vN4D as were used in WM2D to demonstrate the rover's step climbing capability. The task proved to be very challenging. A much more complex vehicle, the South-Pointing Chariot, shown in Fig. 10, was successful. The chariot is a two-wheel, 12-gear mechanism vehicular navigation system containing a bevel-gear differential. The simulation file demonstrates that the man's extended arm would continue to point in its initial direction regardless of the chariot's motion.

In some cases, 3D simulation is much clearer than its 2D counterpart. In Figure 11(b), a 2D (top view) simulation of a door closer is not an effective presentation as compared to that in Figure 11(a).

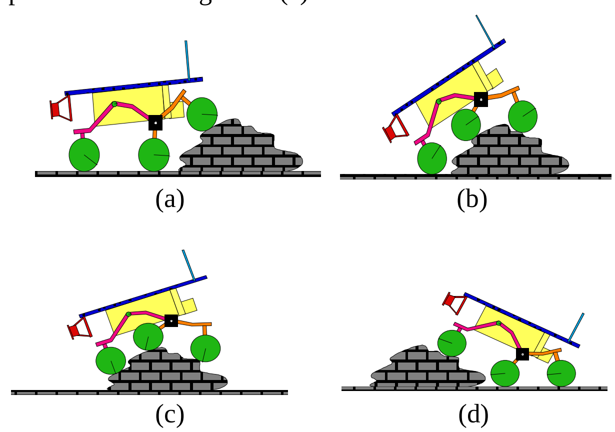


Fig. 8 Mars Rover's Rock Climbing

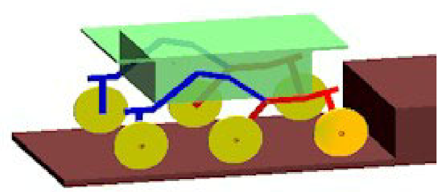


Fig. 9 Mars Rover's Step Climbing

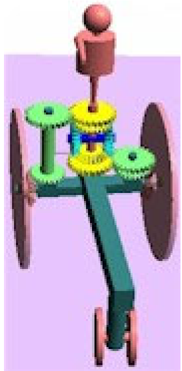
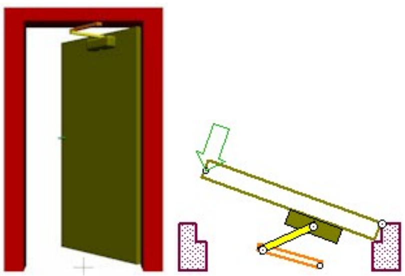


Fig. 10 South-Pointing Chariot



(a) (b)

Fig. 11 Door Closer

5. Discussion

If WM2D and vN4D are integrated into a single product it may encourage more adoptions in the engineering curriculum. Many best-selling engineering textbooks are now packaged with WM2D [3,4,5] or vN4D [6,7].

WM2D R5 (released in 1999) is almost identical to R4 (released in 1996), as R5 files may be run in R4. Five years without a major update leaves users wondering if MSC is overly focused on a new Japanese translation, online delivery, web seminars, training, and new documentation. For example, the WM2D file extension (.wm) is now in conflict with Microsoft Media Video/Audio files, and there is no easy fix. The new file extension .wm2 is scheduled for the next release in early 2002. Many features available in the more frequently updated vN4D should trickle down to WM2D. For example, vN4D has vastly superior zoom and pan features. Additionally, vN4D has a Parts Window, Connections Window, and a Property Window, as shown in Figure 12. The Connections Window displays related joints and bodies, and is extremely useful for debugging. Lastly, the vN4D Formula Window shown in Figure 13 has built-in functions and pull-down menus, and its ease-of-use would help simplify formula creation in WM2D.

~~Many error and warning messages in running WM2D and vN4D, especially when simulating a closed-loop mechanism like a non-Grashof linkage, are confusing to users who lack the understanding of its simulation engine, which is not adequately explained in the user's manual or addressed in undergraduate-level textbooks.~~

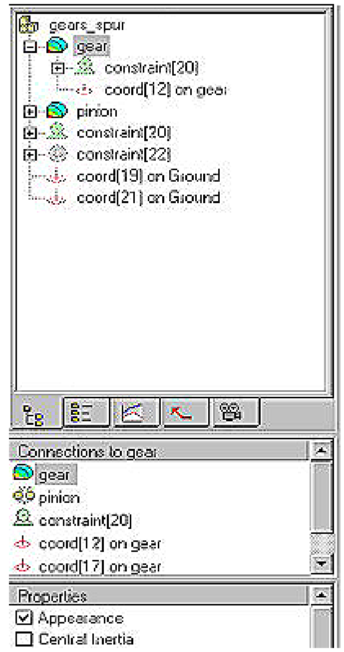


Fig. 12 Parts and Connection Windows

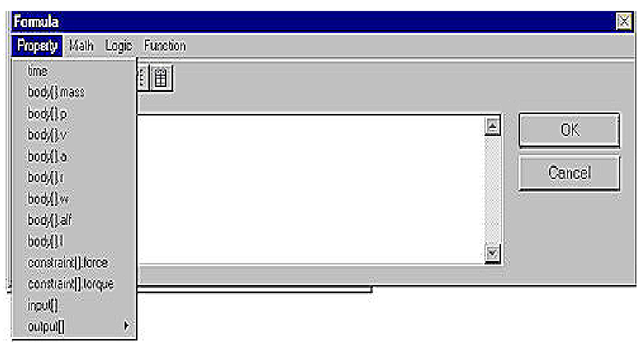


Fig. 13 Formula Window

There is room for improvement in vN4D too. The avi video files generated by vN4D are large and are not smooth. The reviewer generated video files exceeding 50 Meg in size (which are 100 times larger than their parent vN4D files) for about 100 frames with a jagged motion. Video format in MPEG or Flash should be considered for the next release.

Last, vN4D's graphics rendering manipulation (rotation, translation and zooming) is good with an OpenGL graphics card. Since most laptops do not have OpenGL cards, you may experience difficulty.

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Company Profile
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