Direct Manipulation Visualization of the Behavior of Framed Structures in the 'Dr. Frame' Environment

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Introduction

Dr. Frame, developed by Dr.Software, LLC, is a direct manipulation modeling environment for exploring the behavior of frame and truss membered structures. The Dr. Frame environment is presented in this paper in terms of its educational value to both instructors and students.

About Dr.Frame: Direct Manipulation Modeling of Frame Structures

The Dr. Frame modeling environment, available in Macintosh and Windows versions, simulates a two-dimensional structural testing laboratory in which users can interactively build and test model structures in quasi real-time. Dr. Frame provides immediate visual and numerical feedback of the primary quantities of engineering interest: displacement, internal forces, and reactions. Like its predecessor, Dr. Beam [Miller and Cooper, 1995, Cooper and Miller, 1996], the interface has been designed so that Dr. Frame's use is analogous to using a basic drawing program. Model generation and manipulation is accomplished visually, using readily available tools and mouse actions. Dr. Frame is capable of solving quasi-static, linear problems, with the notable feature that solution updating is handled automatically, and details of solution are completely transparent to the user.

This next-generation tool for engineering education provides several benefits. The Dr. Frame environment blurs the distinction between presentation or drafting software and numerical computational programs. By removing this traditional yet arbitrary segregation of exploration and design from analysis, Dr. Frame delivers to students a new level of understanding and affords them confidence to explore beyond the traditional scope of engineering education. To instructors, Dr. Frame offers a dynamic classroom laboratory where concepts can be introduced, problems can be posed, and solutions presented.

The Dr.Frame Modeling Environment

A screen shot of the Dr. Frame modeling environment is shown in Figure 1. A simple truss model is being analyzed with most display options turned off to avoid clutter. As shown, the Dr. Frame window consists of a main viewing pane, a toolbar, and a status/feedback pane at the bottom of the window. The main viewing pane itself can be subdivided. The primary view of the structure is on the left. This is the view which the user manipulates and modifies. For clarity this figure does not show the displaced state of the structure, but it possible – and frequently useful – to superimpose displacements on this main view of the structure. The

auxiliary view on the right is used to show internal quantities of interest – in this case a moment diagram. At the far left of the window, the toolbar provides a range of tools for building and manipulating structures. Various loads and supports, materials, frame members, springs, and hinges can be added, deleted or modified on structures in their original or deformed configurations. The status bar along the bottom of the window displays information important to a direct manipulation environment, including location information, numerical values of onscreen graphics, and quick help.

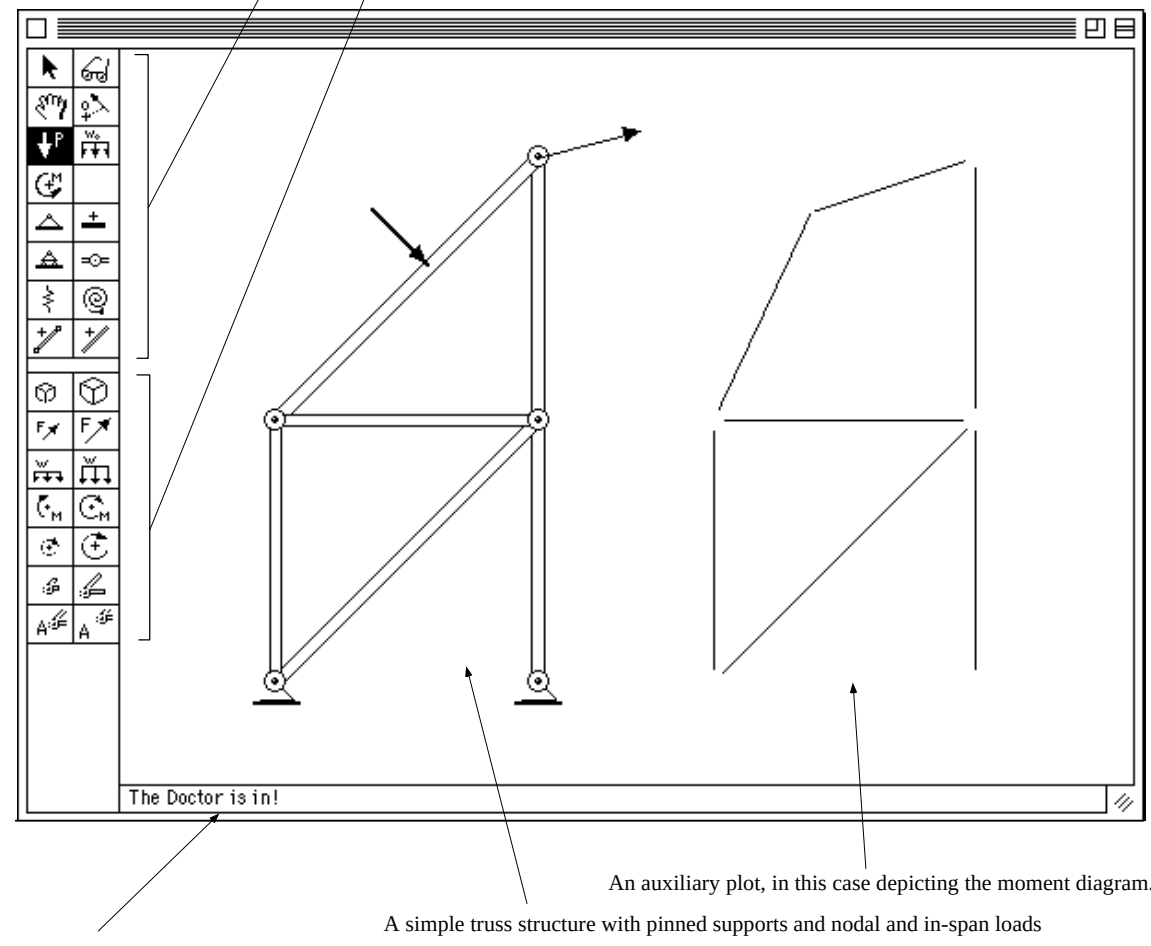

Figure 1: The Dr. Frame Modeling Environment

In addition to the basic display options shown in Figure 1, other options include joint and member isolation, direct numerical feedback via labels, color coding of member forces, vector decomposition and reaction force display among others. Figure 2 demonstrates a sampling of these display options: specifically joint isolation, value labeling, display of reaction forces and vector decomposition.

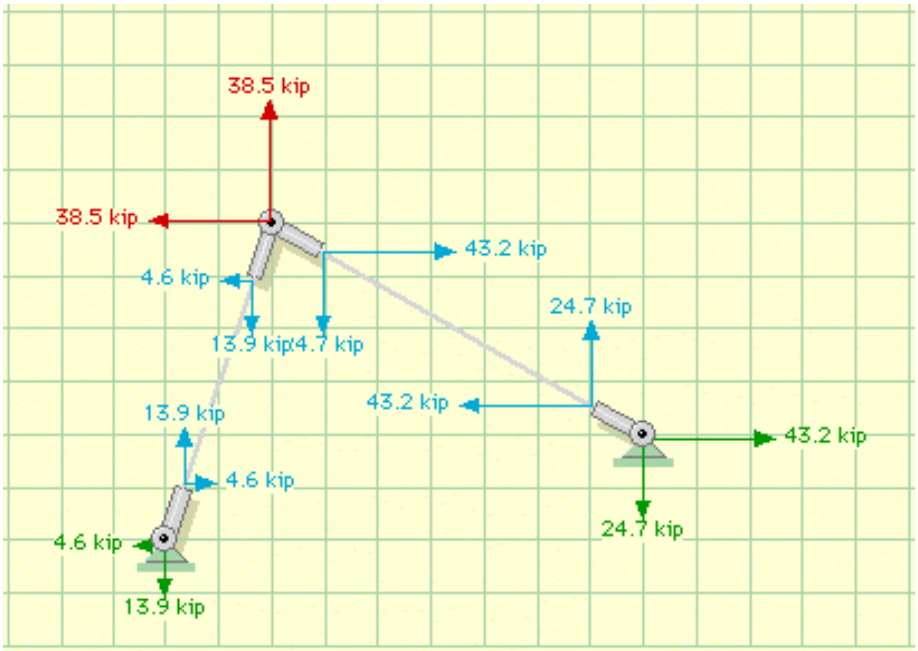

Figure 2: Sampling of Dr. Frame Display Options

Other important modeling capabilities include the capability to simultaneously model multiple structures, as shown in Figure 3, and the automatic formation of plastic hinges.

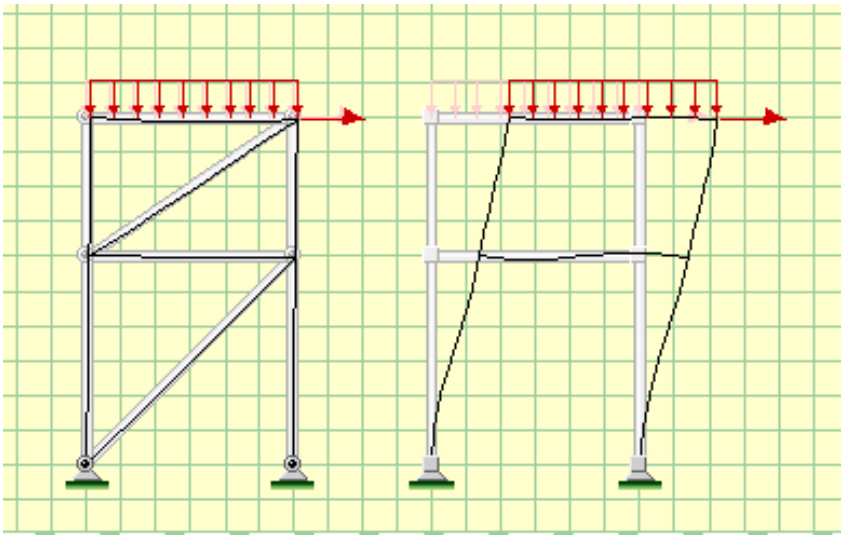

Figure 3: Direct Comparison of Modeling Assumptions via Simultaneous Structures

It is worth reiterating that the views shown in the previous figures are merely snapshots – when using Dr. Frame the structures are updated as quickly as 15 times per second during user manipulation.

Educational Value of Dr. Frame

The modeling capabilities available in Dr.Frame make it appropriate for a wide range of engineering courses, such as engineering statics, mechanics of materials, and structural analysis. Regardless of the context, the combination of an easy to learn interface with immediate visual feedback allows students to concentrate on exploring structural concepts and behavior rather than the details of program operation and layout. In an engineering statics course, Dr. Frame can model trusses and simple frames while providing feedback on reactions and internal forces. It's ability to provide detailed analysis of beams, including feedback on deflections and rotations, make it useful in an engineering mechanics course. Finally, Dr. Frame is a natural match for courses in structural analysis as well as for courses in steel, concrete and timber design.

In the classroom, Dr. Frame can be used for visualizing structural behavior in real-time, and for illustrating and reinforcing concepts as they are introduced to students. Dr. Frame affords the instructor the ability to present and quiz students about a variety of structures in rapid succession, yet requires little or no preparation time for such presentations. "What if...?" questions are easily posed and answered. Key response quantities can be dynamically cued by the instructor, encouraging students to develop their own intuitive sense of structural response.

As an individual learning tool, the facility of model manipulation and the immediacy of the feedback provided by Dr. Frame are valuable in developing structural intuition, which is an essential component of the foundation upon which students can build further theoretical and analytical knowledge. The ability to transparently apply, observe, and monitor loads and displacements is also very useful in exploring the various principles underlying structural analysis itself.

Of Particular Interest: Dr. Frame in Design

Faster and smaller computers are making computer-based analysis increasingly common for structural engineers. As a result, future generations of engineers will find that simply knowing how to perform analyses merely qualifies them as technicians. In recognizing this fact, engineering schools are shifting emphasis in education from analysis to design and behavioral understanding. In structures, this means students don't spend weeks learning to use conjugate beam, moment-area and virtual work methods. Instead, existing design classes are being broadened, more design classes are being introduced, and design and behavior are being integrated into engineering science classes.

An effective simulated design experience has many components including multiple optimization parameters, group interaction, and open endedness. A tool designed to facilitate the group design experiences must allow the students to iterate through many proposed solutions, observe directly how variations of design parameters affect the total solution, and present ideas to co-workers in a clear fashion. Dr. Frame's graphical nature combined with it's ability to simulate structural response dynamically makes it ideally suited for students of structural design.

Not only can Dr. Frame be incorporated into existing design classes, it also opens the door on a wealth of new problems for the introductory design classes being instituted at many engineering schools. Traditionally, design projects have been pushed to the senior year because "the students don't yet have all the tools to do proper design." Yet the design experience is often the great motivator. Many people choose engineering over the pure sciences because they enjoy tinkering more than analysis. Dr. Frame opens the world of true design problems to any level of student. Not only does the student get a glimpse of what makes engineering exciting, but at the same time they learn that engineering analysis is not an end in itself, but an essential tool in the engineering process.

Concluding Remarks

This paper presents an overview of the Dr.Frame environment and describes how it can be useful in an educational setting. It must be emphasized, however, that a series of static screen shots cannot convey the dynamic nature of the environment. It is, in fact, the instantaneous feedback provided by Dr.Frame that separates it from other tools. This crucial linking of action to reaction, design to analysis, allows users to develop an intuition of structural behavior, one of the most valuable assets of a practicing engineer.

References

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Biographical Information

Michael D. Rucki, a former Ph.D. student of Greg Miller at the UW, has researched a range of finite element-based computational and user-interface issues and is presently a structural nonlinear finite element modeling specialist at the Boeing Company.

Gregory R. Miller, a faculty member of the Department of Civil Engineering at the University of Washington since 1984, is currently a visiting scholar at the University of New South Wales, Australia. His research interests include solid mechanics, computational methods, and engineering education.

Stephen C. Cooper is a Ph.D. candidate at the UW under the direction of Greg Miller. His primary research interests relate to the implementation and use of multimedia tools in engineering education and has participated in the ECSEL project at the UW.

Dr. Software, LLC is a software company specializing in educational and professional products for the mechanical, structural, and civil engineering fields. All products feature unique direct manipulation, real-time feedback interfaces that focus attention on modeling and understanding.