Chapter

Compliance Analysis for Disabled Access

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Abstract: Accessibility regulations are federally enacted by the Americans with Disabilities Act (ADA). Design of buildings and facilities must comply with the guidelines developed by the authors of ADA. This paper discusses a hybrid approach using encoding prescriptive-based provisions and supplementing them with performance-based methods to support compliance and usability analysis for accessibility. The hybrid compliance analysis approach is applied to analyse a facility floor plan as a case example.

Key words: disabled access, compliance analysis, on-line code checking, performance-based code, motion planning, wheelchair simulation

1. INTRODUCTION

The handicapped accessibility regulations are federally enacted by the Americans with Disabilities Act (ADA). The intent of the handicapped accessibility regulations is to provide the same or equivalent access to a building and its facilities for disabled persons (for example, persons restricted to a wheelchair, persons with hearing and sight disabilities) and persons without qualifying disabilities. To fulfill this intent, the authors of the Americans with Disabilities Act (ADA) have developed prescriptive measures such as various clearances and reach thresholds for building components. For example, the ADA has developed guidelines for minimum clearances to allow transfer of a person from a wheelchair to a toilet and minimum lengths of grab bars associated with a toilet. Prescriptive statements are formulated to establish concrete tests for many of such measures. However, using prescriptive provisions often lead to problems such as conflicting and ambiguous statements, thus making the code difficult to parse not only by computers, but for humans as well. A design that fulfills the prescriptive code does not always imply usability. Conversely, a design that does not meet the prescriptive code could actually be accessible by a person in a wheelchair. This paper discusses code-related compliance analysis focusing on wheelchair access.

This research examines a hybrid approach combining prescriptive-based methods in which prescriptive statements are modeled as rules where there is no indeterminacy and conflict, whereas when such problems surface, a performance-based approach using simulation is adapted. There are several motivations for this approach. First, prescriptive-based provisions capture the design intent of the building code most of the time so encoding these provisions partially addresses the goal of automated building code checking. Second, encoding these provisions and analyzing the building model is computationally inexpensive compared to using performance-based simulations. Therefore, where the prescriptive-based provisions are adequate, they should be used. However, performance-based simulations could be deployed to resolve those issues where the prescriptive-based provisions are inadequate. In addition, certain prescriptive provisions are difficult to model using a prescriptive rule-liked system. In these cases, performance-based simulation could be an alternative that can be used to test these provisions. Finally, if a building design is found to be in violation of the building code based on the encoded prescriptive provisions, the design can be analyzed against available performance-based methods so that better insight can be gained about the design.

This paper is organized as follows: In the next section, a framework to support on-line code checking for building design is described. We then discuss the modelling of building facilities and regulations. A simulation approach for performance-based analysis of disabled accessibility is proposed. A case example is employed to illustrate the hybrid approach developed for compliance analysis for disabled access.

2. A FRAMEWORK FOR ON-LINE CODE CHECKING

Managing the code documents and allowing the documents to be accessible by users and applications are key issues to extend the usability of digital information such as regulations and codes. An important objective of this work is to provide the means to interface the regulations with usage such that the regulations are not passive but active documents that can be dynamically linked to application programs for users to search and access regulations, to perform compliance check and for supporting human functions such as design activities.

We have prototyped a proof-of-concept system that transforms the manual or on-line review process (Fig. 1(a)) and replaces it with a partially automated on-line compliance and permit approval process (Fig. 1(b)) using Internet and web-based technologies [Han97, Han98a, Han99]. The provisions in the Americans with Disabilities Act Accessibility Guide (ADAAG) [ADAAG97] are represented in HTML format with hyperlinks from the on-line code checking system. At any point in the design process, the client can send a design to the code-checking program that resides on a remote server. On the client side, the user develops a plan using a CAD package which produces design data in compliance with the Industry Foundation Classes (IFC) developed by the International Alliance of Interoperability (IAI) [IAI97]. The code-checking program examines the design data and summarizes the results in a generated web page. The web page contains a graphical representation of the building model along with "redline" information with hyperlinks to specific comments. As shown in Fig. 2, the analysis report has three frames. A VRML model of the submitted building design is displayed in the top left frame and is added with redline information if the design does not comply with the building code. These redlines have hyperlinks to associated comments. The user can click on the inaccessible building component, and the associated comment appears in the bottom frame. Finally, these comments, when applicable, have hyperlinks to the actual building code document provisions (in this case, the ADAAG [ADAAG97]) in the top right frame.

3. BUILDING PRODUCT MODEL AND PRESCRIPTIVE CODE REPRESENTATION

For a building design to be computer-interpretable, it must be adequately described by a symbolic building model. Further, the modeling and representation of regulations and codes need to be addressed from the perspectives of both the code as well as the users and the design application. Given a building model, analysis is performed to check the design against the building code. Clearly, for automated design analysis there is a need for a standard building model that provides more information than a collection of drawing primitives.

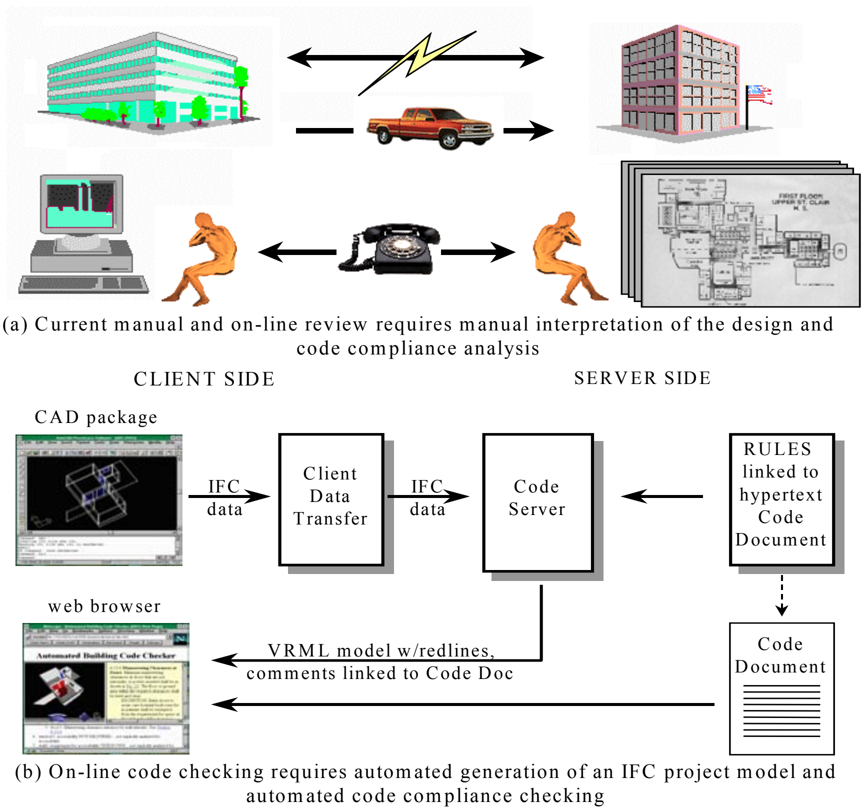


Figure 1. Manual versus On-Line Code Checking Process

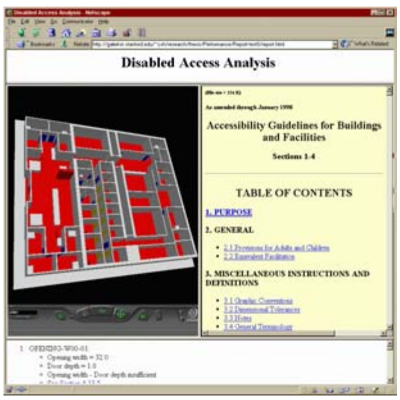


Figure 2. A Web Page Report for Disabled Access Analysis

There have been many research efforts to develop object-oriented CAD systems and object-oriented building models that contain the necessary geometric, functional, and behavioral relationships of building components. There is an on-going effort by the International Alliance of Interoperability (IAI), a consortium of CAD vendors and other AEC industry partners, to develop product model standards for facilities that enable interoperability between applications by different software vendors [IAI97]. The IAI's effort includes defining a set of objects called Industry Foundation Classes (IFC's) that adhere to the object-oriented paradigm. Fig. 3 illustrates a sample of the IFC hierarchy.

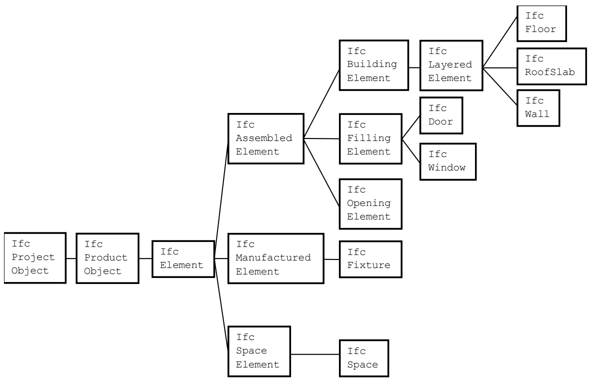


Figure 3. An Example of IFC Class Hierarchy

In our current prototype (see Fig. 1), the IFC (Release 1.5) project model is used and extended as the common product model, represented in the EXPRESS file format (in the form of a data stream as opposed to a static file). The IFC-compliant design data stream transfers from one application via the communication protocol interface to the product model interface of another service. The communication protocol interface and the common product model interface do not specify how the design data is stored. The product model interface constructs an IFC-compliant internal representation of the design data from the data stream. A Java class structure that mirrors the IFC EXPRESS schema's class hierarchy, attributes, and relationships has been constructed for the internal representation. In the prototype, the code-checking program takes an IFC project model in EXPRESS file format and sends it to the code-checking program.

The representational model implemented for the prescriptive-based encoded provisions uses the same structure as the IFC project model hierarchy. For example, all encoded provisions concerning door accessibility would be instances of a door accessibility class. Therefore, an individual component can be checked against all the applicable instances of provisions for that class of building component. By structuring the encoded provisions in this manner, we loosely categorize building component provisions by design intent since similar building components have similar behavior. One building code class can have several instances that correspond to related provisions in the building code—for example, there may be a class in the building code representation corresponding to the issue of door clearance of which there are several variations or instances. This relationship is analogous to a particular building design having several instances of a door class. The prototype code-checking program currently implements the encodable provisions that can be classified as prescriptive checks. Each building component is analyzed against a set of rules that capture the intent of the building code provisions (in many cases, a rule is some form of geometrical interference tests.) Provisions that address issues such as door width and door clearances are provided as heuristics that test for disabled access. If a door complies with these provisions, then it fulfills the design intent for accessibility.

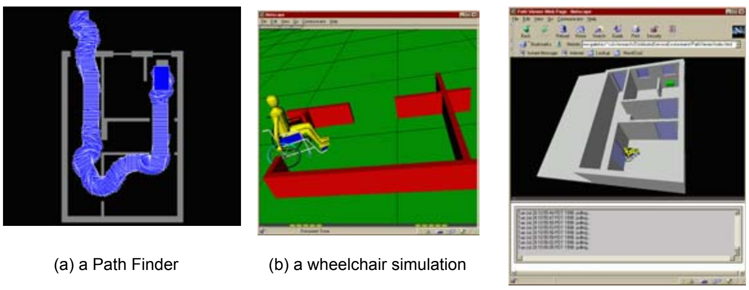
4. PERFORMANCE-BASED ANALYSIS USING SIMULATION

While prescriptive code checking is possible for individual building components, global issues of accessibility would require directly capturing the design intent of a set of provisions. Performance-based methods directly test the design intent for usability of a facility as opposed to relying on the prescriptive-based provisions to check for compliance. In the case of disabled access, the design intent is clear: provide the same or equivalent access for disabled persons and non-disabled persons. Focusing on wheelchair access, persons in wheelchairs must be provided the same or equivalent access to a building and its facilities as persons who do not use wheelchairs. "Equivalent" access is somewhat ambiguous, but the intent is that a person in a wheelchair need not go through extreme methods to be able to have access to a building's facilities. For example, if a person not using a wheelchair needs to travel a certain distance to get to a bathroom facility, then a person using a wheelchair should have to travel approximately the same distance to use either the same or a different bathroom facility. The concept of access is a system-wide issue related to the entire floor or building as well as a local issue confined within a defined space. The encoded provisions can be used to analyze local prescriptive issues such as clearances around building components. However, testing for compliance of global issues such as the existence of an accessible path can be more easily done using simulation techniques.

Simulation can be employed to address provisions that are difficult to analyze statically such as the existence of an accessible path in a building design. These provisions examine global issues of a project as opposed to looking at localized phenomena. In examining the issues of disabled access, the design analysis program must consider accessible path. For example, if a door is on an accessible path, the program can check its necessary clearances. However, since these are local and static checks, the program cannot guarantee that in getting from one room to another, even if individual doors meet the code, a disabled person can actually get to these doors.

Simulation of a wheelchair moving through the space is a logical approach. Using motion planning, a research area in robotics, such a simulation is possible [Latombe91]. Here, a wheelchair agent is the robot that searches for a possible path. The robot is constrained to move only forward and with prescribed turning radius. The former constraint is consistent with satisfying a design intent concerning reasonable motion and the latter physical constraint is determined by examining closely the provisions as given in ADAAG. Detailed development of the wheelchair robot is described in [Han00, Han01].

The robot's path is calculated as per [Latombe91] with some modifications. Before the path planner generates a path, we must specify the initial position and the goal position of the wheelchair robot. Based on these two positions, the planner will generate a potential field in the configuration space (the space defined by the open areas, obstacles, and the wheelchair robot) that has a high point at the initial position and a low point at the goal position. The robot starts at the high point and essentially travels downhill to reach the goal position. Fig. 4 shows the tools developed for the simulation of accessible route and wheelchair motion.



(a) a Path Finder (b) a wheelchair simulation (c) Animated Route

Figure 4. Simulation of Accessible Route and Wheelchair Simulation

5. CASE EXAMPLE

This section presents a case example of disabled access analysis for a floor plan as shown in Fig. 5. Recall that the performance-based approach is able to determine the usability of a facility, and usability does not necessarily equate to code-compliance. Fig. 2 shows the generated analysis report with a view of the modeled floor plan. Specifically, the floor of the entire facility has been set to darker color (red in the generated VRML frame), indicating that there are critical components of the facility that are inaccessible. The comments associated with inaccessible building components have links to the prescriptive provisions of the ADAAG document as an informative guide. The following discuss the results of two facilities, namely the Men's Bathroom and the Women's Bathroom.

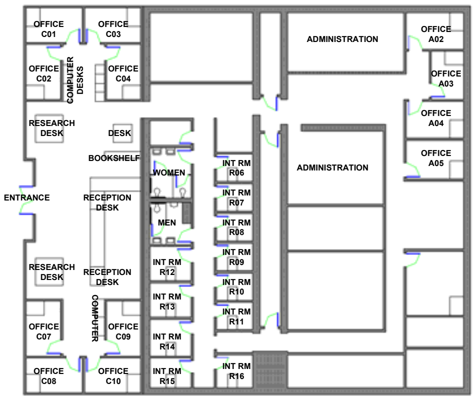


Figure 5. Floor Plan of a Facility

<u>Men's Bathroom</u>

The analysis reports that there is no accessible route to the accessible toilet in the Men's Bathroom as illustrated in Fig. 6. Since there are no other accessible toilets, the bathroom is not considered to be accessible, and in turn, the whole facility is deemed inaccessible.

Fig. 7 confirms the inaccessibility of the toilet. Here, the wheelchair user is not able to pass through the stall's doorway. It is interesting to note that the partition walls were added to the original plan to ensure privacy for the toilet user. Ironically, the addition of these walls has made the toilet inaccessible. With the removal of the partitions, the Men's bathroom would revert back to a single-occupancy from a multiple-occupancy toilet. As shown in Fig. 8, without the partition walls, the motion planner can generate an accessible route to the stall.

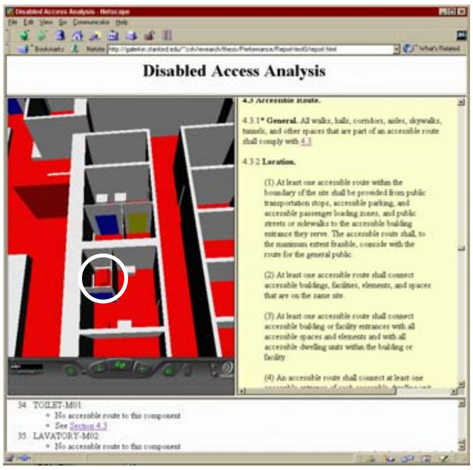


Figure 6. Disabled Access Analysis Report for Men's Toilet

Figure 7. Wheelchair User Unable to Access Men's Toilet

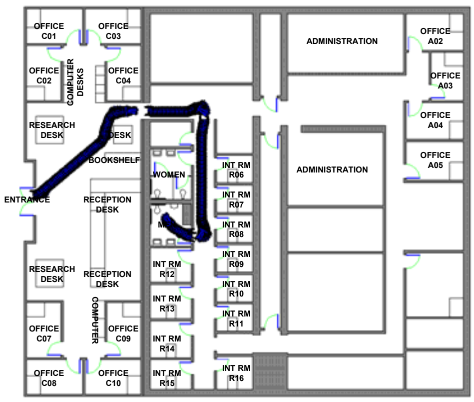


Figure 8. Wheechair Route to Men's Toilet with Stall Partitions Removed

Women's Bathroom

The analysis also reports that there is no accessible route to the accessible toilet in the Women's Bathroom as illustrated in Fig. 9. The performance-based parameters are developed using the ADAAG toilet stall clearance areas as a guideline for the evaluation of the toilets, and the accessible stall violates these guidelines. Since there are no other accessible toilets, the bathroom is not considered to be accessible, and in turn, the whole facility is deemed inaccessible.

As shown in Figure 10, however, the wheelchair user actually has a comfortable access to this toilet. The user in fact can easily position for side transfer, a position that is more difficult to achieve than a diagonal transfer for this given stall. By slightly adjusting the toilet parameters as prescribed by ADAAG, the analysis shows that the toilet is actually accessible as illustrated in the generated path shown in Fig. 11. This example illustrates that, in this case, the parameter (as given in ADAAG) that was used for evaluating accessibility may be too restrictive, and that the performance-based method is more flexible by describing a range of possible goal areas and orientations.

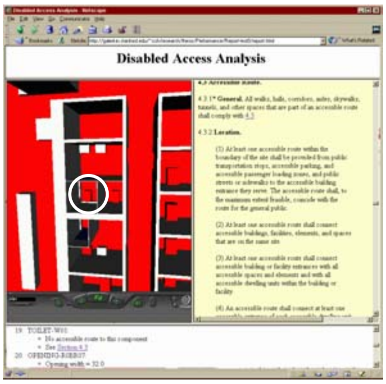


Figure 9. Disabled Access Analysis Report for Women's Toilet

Figure 10. Wheelchair User Access to Women's Toilet

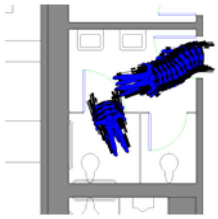


Figure 11. Wheelchair Route to Women's Toilet

6. SUMMARY AND DISCUSSION

This paper examines using encoding prescriptive-based provisions and supplementing them with performance-based methods to support compliance and usability analysis for disabled access. Currently, the prototype code-checking program is able to check individual building components as well as a system of building components for compliance and the simulation techniques implemented can analyze access path existence and facility access. The compliance analysis program has been implemented as part of an on-line service framework to take advantage of Internet and web-based technologies.

The automated approach has been applied to analyze a facility for disabled access. As illustrated in the case example, for the Men's bathroom, the analysis can be employed to check for compliance as well as usability of critical building components. For the Women's bathroom, the results and a comparison with an actual wheelchair user's interaction with the facility also reveal some of the shortcomings of using the prescriptive-based parameters to develop the performance-based methods.

In this work, we have compared the analysis results with an individual wheelchair user's ability. It should be noted that the ability to use the facility represents strictly a qualitative test as there are many different levels of disability, but such a comparison still provides important insight into the analysis. The discrepancy between one's mobility and the usage parameters set forth by the ADAAG illustrates the difficulty in providing a performance-based access code that encompasses all wheelchair users and provides guidelines for usage and comfort. However, adjustments to the performance-based analysis tailored to a group of similar users might provide insight to the actual accessibility of a facility.

Ensuring usability of the facility for wheelchair users should be the main priority. All spaces and critical building components should at least be made usable. The performance-based motion-planning accessible route methods developed in this work could be a viable tool to determine the usability of new critical spaces. As the intent of the ADAAG is to give equivalent access to facilities, whether or not these facilities actually meet some set of prescribed measurements should be secondary to providing actual usability. Note that not all possible configurations can be covered by the prescriptive-based code. It is important to make sure that all accessible spaces were at least made usable as measured by some alternative metrics. This work provides a hybrid approach combining prescriptive-based and performance-based methods which may be able to test for usability and compliance of a facility for disabled access.

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