# ACAML – a Markup Language for Ancient Chinese Architecture

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**Abstract:**
*Although computer technologies have been widely used in the architectural domain, there is a serious lack of standards and formalisms to support the semantic annotation of architectural resources on the Web. We propose ACAML, Ancient Chinese Architecture Markup Language, for representing, modelling and analysing different types of traditional Chinese buildings. For implementation of ACAML, we follow the paradigm of XSLT and extend XSLT to transform ACAML into animation. More precisely, for a given ACAML file describing a standard or real-world building, a 3D animation is generated demonstrating the construction process of this building. Semantic Web technologies are used to support the whole process of animation generation, including an OWL ontology and SWRL rules. The animation generated can be in VRML for real-time preview or in animation software file formats for rendering. ACAML and its animation implementation can support semantic queries, and our system currently covers more than 180 combinations of Chinese traditional architecture.*

**Key Words:** *Ancient Chinese Architecture, Markup Language, Animation, Semantic Web*

## Introduction

Ancient Chinese architecture has a history of more than five thousand years, and is one of the major parts of China's cultural heritage. Its first peak point appeared in the Qin Dynasty (221 BC – 207 BC). The emperor of Qin ordered to build a huge building block called the Epang Palace, which was reported by archaeologists to cover an area of 60 square kilometres. However, the Qin dynasty was short-lived and only existed for 14 years. The Epang Palace was also affected by the dynasty's collapse and it burnt down before it was finished (Fig. 1a). The second blooming period of Chinese architecture was in the Tang Dynasty (618 AD - 907 AD), when many large-scale timber structures were invented and constructed, mainly for palace and temple buildings. Timber structures were the unique contribution of the Chinese architects to the world. Unfortunately most of these buildings were destroyed and it is believed that for some time no timber buildings survived in China. In 1937 two young Chinese architects Sicheng Liang and Huiyin Lin discovered a fully timber building constructed in the Tang dynasty for the first time, called the Foguang Temple (Fig. 1b) (Foguang Temple 2010). The third peak of ancient Chinese architecture was in the Song dynasty (960 AD – 1279 AD), when the *Yin Zao Fa Shi* (meaning "law of construction", Guo 1998) or the first official Chinese standards of civil engineering was published (Fig. 1c), covering all aspects of architecture including

*a*

*b*

*c*

*Figure 1. Wonder of Ancient Chinese Architecture (All pictures from the Web): (a) Epang Place of Qin Dynasty burning down. (b) Foguang Temple originating from Tang Dynasty. (c) China's first Civil Engineering standards published in Song Dynasty.*

materials, design, structures, measurements, and construction.

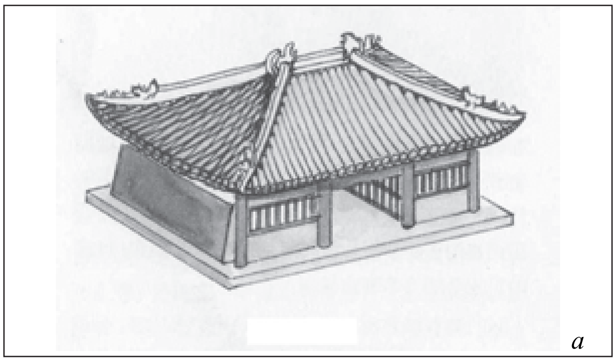
While ancient Chinese architecture represents a unique contribution to the world's architectural technologies, both with respect to its techniques and arts, there has been a serious lack of computer-supported tools for representing, modelling and analysing different types of traditional Chinese buildings. Moreover, despite the large amount of articles, pictures, videos, and documents on the Web about Chinese architecture, there are few standards or formalisms to support the semantic annotation of these resources. These issues motivated a collaborative research team of the Chinese Academy of Sciences and Beijing University of Technology in designing and implementing an architectural markup language. We propose ACAML - Ancient Chinese Architecture Markup Language. We started a project in 2006 aiming at demonstrating the ancient Chinese architectural technologies via computer animations (Zhang and Sun 2010). The result of this project forms a part of the implementation of ACAML.

## Markup Language ACAML

Similar to many other markup languages, ACAML is based on XML in syntax. The semantics of ACAML lie in its models being organized in a hierarchical structure. The lower level models inherit functions and properties from their ancestors and almost all models are composites of their sub-models. We differentiate between the following levels of models.

- *Level 1*: models for various types of Chinese buildings, including palaces, temples, pagodas, bridges, pavilions, etc.

- *Level 2*: the eight main works in construction, including the timber structure work, the stones work, the paints work, the tiles work, the decorative drawings work, and so on.




The timber structure of Chinese architecture is unique in the world with its remarkable design considerations for stability and quakeproof. The tiles work includes the ridges of the roof having decorations on them, mostly mythical small animal figures; and the drawings work includes the paintings on the wall.

- *Level 3*: the components of each main part of the construction. The components of timber structure include the roof, Dougong, network of columns, tenons-and-mortises, and so on. *Dougong* is a typical component of ancient Chinese architecture and used to support the eaves that are (sometimes widely) extended over the walls. The concept Dougong consists of two parts: the Dou which has the form of a wooden block, and the Gong which has the form of a bow-shaped arm. The interlocking set of Dou and Gong is inserted between the top of a column and a beam. They play not only a mechanical role of supporting the eaves, but also a role of decorating the building with their colourful and manifold structures. Tenons-and-mortises take the form of a rail and a hole, respectively, and are used to lock two wooden components together without using nail or glue.

- *Level 4*: various types of each component in the main parts of the building. Each component has attributes that determine its type. The roof mainly consists of Wudian, Xuanshan, Yingshan, and Xieshan types. Within each type of the roof there are also many detailed variations due to the material limitations and/ or architects' innovations.

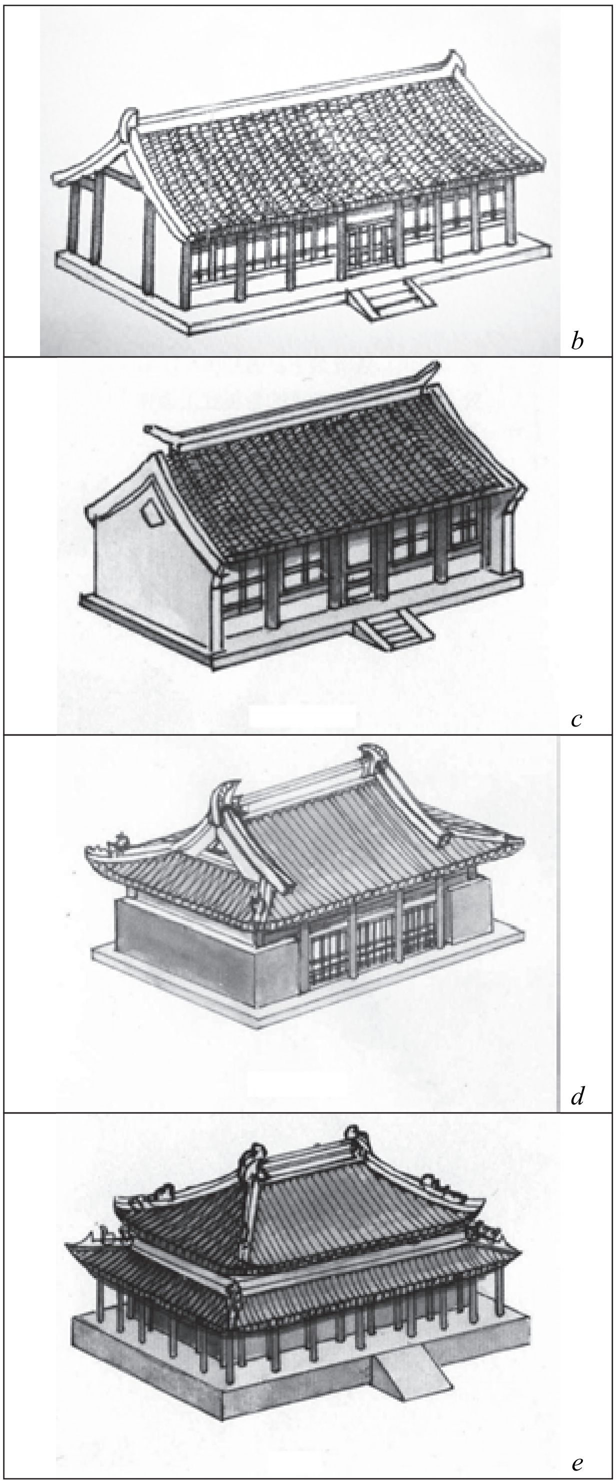



*Figure 2. Some of the Major Roof Types of the Chinese Ancient Architectures (All pictures from the Web): (a) Wudian. (b) Xuanshan. (c) Yingshan. (d) Xieshan. (e) Double-eave Wudian.*

- *Level 5*: various types of the pieces in each component in the above level. For a Wudian roof in the timber structure of a palace, there are many types of wooden pieces including purlins, beams, rafters, and so on, and each type has its own shape, size, location and function.

Figure 2 illustrates various types of roof. A Wudian roof has four slopes and five ridges (Fig. 2a). A Xuanshan roof includes two slopes and five ridges, where the slopes extend over the gables (Fig. 2b). In a Yingshan roof, which is similar to Xuanshan, both gables are either equal or higher than the roof (Fig. 2c). Lastly, a Xieshan roof is composed of a Yingshan sitting above a Wudian structure (Fig. 2d). Moreover, Wudian type roofs can further be of single- or double-eave Wudian style, the latter is presented in figure 2e. Among all the types, the double-eave Wudian was of the highest rank and solely used by emperors (like the Taihe Temple in the Forbidden City) and allowed for saints (like the Dacheng Hall in the Confucian Temple). The complex roof designs in Chinese ancient architecture required a large number of wooden pieces. For instance, for a single-eave Wudian building with five sections from left to right and nine purlins from front to rear, more than 6,200 wooden pieces were needed, including 16 inner columns, 24 outer columns, 30 various kinds of beams, and 1,480 rafters.

The markup language ACAML is designed according to these levels of models. Each ACAML model description consists of the following list of information. Some parts are optional depending on the differing granularity of the components.

**Identity part of the model:**

- Identification of the model to be illustrated.

**Architectural part of the model:**

- Type of the architectural building,
- Type of the structure of building,
- Type of the roof,
- Type of pillars,
- Type of beams,
- Type of eaves,
- Type of Dougong,
- Type of tenons and mortises,
- Type of decorations.

**Data part of the model:**

- Database of components,
- Database of established models.

**Functional part of the model:**

- Rule set for inference on the construction process,
- Library for demonstration.

**Cultural part of the model:**

- History of Ancient Chinese Architecture,
- History of the ancient buildings,
- Impacts of religion and monarchism on the architecture,
- Distribution of the ancient architecture types across the country.

**Technical part of the model:**

- Technical characteristics of the building structure,
- Technical characteristics of the components,
- Technical characteristics of the decorations.

Of note, the data part and functional part of the model are only for program control while the other parts are for direct displaying on the Web. ACAML does not only provide means for describing types of ancient Chinese architecture, but also concrete data for displaying the buildings. Furthermore, it does not only provide well-established models to be shown to the user, but also provides tools to help users construct models themselves. ACAML also includes background and historical knowledge of different types of ancient Chinese architecture and typical buildings. A piece of an ACAML program describing the architecture of the Foguang Temple from the Tang dynasty is given below.

```
<?xml  version = "1.0" ?>
<ACAML>
  <Identity name = "Foguang Temple" />
  <Architecture>
    <architecture type>  Temple  </architecture type>
    <structure type>
      <section number > 7 </section number >
      <row number > 4 </row number >
      <wide unit = "meter"  number = "34" />
      <depth unit = "meter"  number = "17.66" />
      <veranda exist = "yes" />
    </structure type>
    <component type>
      <roof type> Wudian </roof type>
      <beam type>
         <left beam  number = "4" />
         <right beam  number = "4" />
      </beam type>
      <eave type  unit = "meter"  number = "3.96" />
      <Dougong type  unit = "meter"  width = "210"  depth = "300" />
    </component type>
    <decoration type>
      <ridge decoration>
        <content> glaze animal </content>
        <color> {blue, green} </color>
      </ridge decoration>
      <wall decoration>
        <wall painting>
            <content>  Buddhist story  </content>
<size  unit = "square meter"  number = "30" />
       </wall painting>
       </wall decoration>
       <room decoration>
          <Buddha decoration>
             <content> Buddha Statue </content>
             <number> 33 </number>
          </Buddha decoration>
          <Arhat decoration>
```

Some remarks are given on how this ACAML program fragment should be understood:

*Remark 1*: we introduce a set of domain specific tags in ACAML. This set of tags is divided in two levels: the basic level and the derived level. For example, ‘reconstruction’ belongs to the basic level but ‘first-reconstruction’ belongs to

```
          <content> Arhat Statue </content>
          <number> 296 </number>
     </Arhat decoration>
     <Mortal decoration>
          <content> Mortal Statue </content>
          <number> 2 </number>
          <name> Gongyu Ning, Yuan-Cheng Monk </name>
       </Mortal decoration>
     < /room decoration >
   </ decoration type >
 </Architecture>
 <Culture>
     <construction history>
       <construction  after = “BC 471”  before = “BC 499”
             dynasty = “Northern Wei” />
     <first-destruction  year = “BC 577”  dynasty = “BeiZhou” / >
     <first-reconstruction  year = “BC 633”  dynasty = “Tang” />
       <second-destruction  year = “BC 845”  dynasty = “Tang” />
       <second-reconstruction  year = “BC 857”  dynasty = “Tang” />
     </construction history>
     <construction background>
       <constructor  name = “Tobahong”  title = “Xiaowen Emperor”
             dynasty = “Northern Wei” />
     <construction motivation>
         <superficial motivation> promote Buddhism </superficial motivation>
         <deep motivation> promote nationality fusion </deep motivation>
     </construction motivation>
       <first-destructor name = “Yu Wenyong”
             title = “Wu Emperor” dynasty = “Northern Wei” />
     <first-destruction motivation> promote national economy
     </first-destruction motivation>
       <first-reconstructor name = “Jietuo Monk”  title = “Chanshi”
             dynasty = “Tang” />
     <first-reconstruction motivation> promote Buddhism
     </first-reconstruction motivation>
       <second-destructor name = “Li Yan”  title = “Wu Emperor”  dynasty
            = “Tang” />
     <second-destruction motivation> {promote Daoism, promote national
             economy}
           </second-destruction motivation>
     <second-reconstructor name = “Gongyu Ning, Yuan-Cheng Monk”
             dynasty = “Tang” />
           <second-reconstruction motivation> promote Buddhism
     </second-reconstruction motivation>
    </construction background>
   </Culture>
  </ACAML>
```

the derived level, where ‘first’ is the modifier of ‘reconstruction’. Since there may be an infinite number of such modifier prefixes the derived tag set is open while the basic tag set is always finite.

*Remark 2*: in ACAML the tags are context sensitive. Each tag-pair defines a scope. A tag is context sensitive to the scope it belongs to. There may be more than one occurrence of the same tag in different contexts. In the above example the tag ‘content’ occurs in the scope of many different ‘decorations’ without forming a conflict. For the same reasons the values of the same attribute may be different in different scopes. For example, the value of ‘dynasty’ is different in various scopes. Furthermore, the values of attributes can be dependent on each other. For example, the value of ‘year’ in the scope ‘construction’ must be earlier than that in the scope ‘first-destruction’, which must in turn be earlier than that in ‘first-reconstruction’, and so on.

Remark 3: this program fragment only includes the identity, architectural and culture parts of the Foguang Temple model. We will introduce the functional and data parts in the implementation section. The technical part belonging to the general information about ancient Chinese architecture, which is not specific to the Foguang Temple, will be introduced in the infrastructure of ACAML implementation.

## Implementation and Infrastructure

One of the major applications of an XML document is to specify how the content of this document should be displayed on the Web. To this end, CSS (Cascading Style Sheets, CSS 2011 http://www.w3.org/Style/CSS/) or XSL (Extensible Style Language, XSL 2006 http://www.w3.org/TR/xsl/) files are used to specify the format of demonstration, and both CSS and XSL are mainly for displaying texts. However, for ACAML we propose to display models of ancient Chinese architecture not only in textual format, but also in three-dimensional animations. For this purpose, we have extended the XSL language. The extension is not as straightforward as one might think. The role of XSL, in particular that of XSLT (Extensible Style Language Transformations, XSLT 1998 http://www.w3.org/TR/xslt), is to specify how to transform an XML program with an XSL specified format into HTML. However, HTML does not directly possess tags for running an animation. Animations can be shown on the Web because we can get access to the animation running procedures on the server. These procedures are designed and programmed independently of the XML style sheets. This solution has the following disadvantage. The style programming of Web pages is split into two parts: that specified with the CSS or XSL language, and that programmed and implemented on the server with conventional programming facilities. The former is used to specify format of literal texts, while the latter for specifying the format of multimedia presentations, particularly formats of animations and videos. We intend to go a step further to developing a unified style description by introducing tags for animation running requirements to XSL. The XSL extended in this way is called DXSL (Dynamic Extensible Style Language). Below we use the ACAML program given previously as an example to show how the XSL language is extended and how the DXSL tags work.

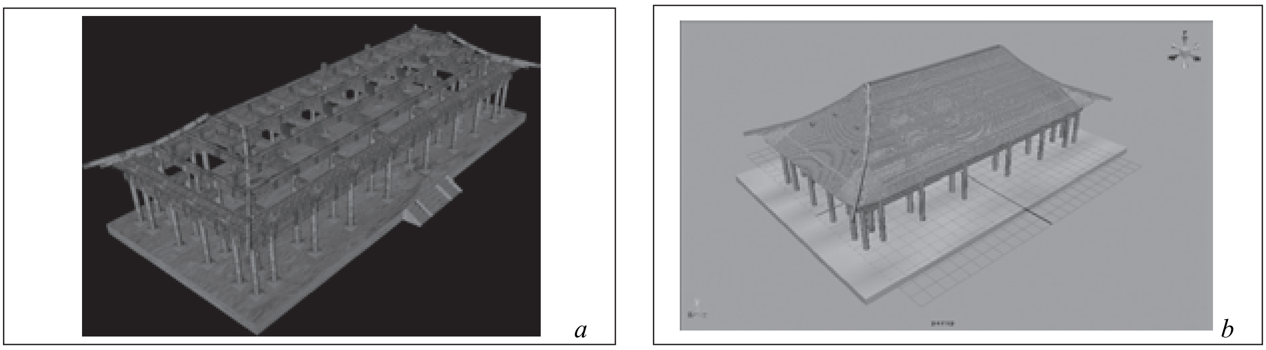
This piece of ACAML program (in HTML) illustrates how the Foguang Temple animation would be displayed when the user opens the web page. The animation starts automatically in a 300 by 200 screen, showing the whole construction process of the Foguang Temple, including how each column or beam is installed step by step. The animation will be displayed only once, but can also be repeated upon request.

Obviously DXSL requires the extension of HTML with dynamic demonstration facilities.

```
<?xml  version = “1.0” ?>
   <xsl: stylesheet  xmlns : xsl = “http://www.w3.org/TR/WD-xsl”>
     <xsl:template match = “/”>
       <HTML  xmlns:xsl = “http://www.w3.org/TR/WD-xsl”>
         <HEAD>
           <TITLE>
              Foguang Temple Originating from Tang Dynasty
           </TITLE>
         </HEAD>
         <BODY>
           <H1>
              Foguang Temple Originating from Tang Dynasty
           </H1>
           <ANIM>
             <anim name> Foguang Temple </anim name>
             <anim width pixels = “point”  size = “300” />
             <anim height pixels = “point”  size = “200” />
             <anim demo>
                 <anim show = “yes” />
                 <anim show-req = “full construction process”>
                 <anim show-music = “jasmine.mp3” />
                 <anim show-times = “1” />
                 <anim show-repeatable = “yes” />
             </anim demo>
          </ANIM>
         </BODY>
     </xsl:template>
</xsl: stylesheet>
```

For the moment, this extension of HTML is still under design. We have used other technical means to implement the dynamic format setting. Our implementation has focused on two architecture types, the palace/temple and the pagoda. Currently the ACAML system collects more than 180 combinations of ancient Chinese architecture, covering three main roof types, Wudian, Yingshan and Xieshan, which are the most common structures used in ancient as well as in modern Chinese buildings. For components with jointing functions we have implemented 13 types of Dougong brackets and 10 types of tenons-and-mortises. In addition to timber structures, we have constructed six types of pagoda - a paradigm of architecture introduced from India and Nepal that has been very popular in China for thousands of years. Figure 3 shows some images extracted from the architecture animations generated by our system, while Figure 4 presents a Xieshan building in construction as well as some types of wooden pieces involved.

While implementing ACAML, we have developed a technology of full life-cycle automatic animation generation of ancient Chinese architecture (Lu and Zhang 2002) and implemented a software system that encodes this technology. Starting from a (limited) natural language description of the building that the user wants up to the generation of a 3D animation demonstrating the construction process of this building, the whole process is performed automatically by the system, including the reasoning of the construction



process, computation of the 3D size and position of each piece of wood, generation of a qualitative description for the animation, and transforming the latter into a corresponding quantitative animation specification. For a Wudian building with five sections, nine purlins and a veranda, 26 types of wooden components are needed and a total of 6,235 pieces of wood are generated. The animation shows how these pieces are installed one-by-one to form the correct joinery. The animation generated can be either in VRML format for real-time preview or animation software files ready for rendering. ACAML and its animation implementation can support such semantic queries as "what does a Chinese traditional building look like with five sections from left to right and nine purlins from front to rear?". The answer returned can contain all the Web pages describing those buildings fully or partially satisfying the requirements. Moreover, the user can get an additional animation on-the-fly illustrating the details of the construction of such a building.

Our system consists of an ontology, rule bases, a database, a natural language module for understanding limited and architectural domain specific Chinese language, and uses Semantic Web tools including inference engines (Wei et al. 2010). We use ontology (OWL 2009, http://www.w3.org/TR/owl2-overview/) as the basic form of knowledge representation for architectural data: for example, *Wudian ô TimberStructure*. Pellet is used to ensure the logical consistency of the ontology. We built SWRL rules (Horrocks et al. 2004) for inferring

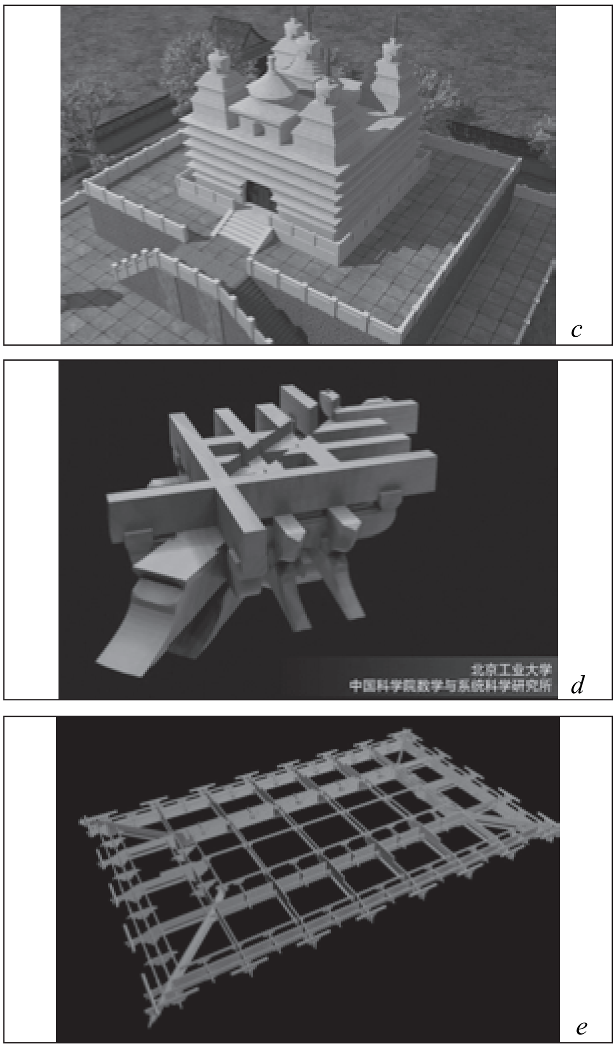



*Figure 3. Some Segments Cut from the Animations Generated by our System: (a) Wudian in construction. (b) Wudian completed. (c) Diamond Thronen Pagoda. (d) Interconnecting Dou and Gong. (e) The complete Dougong layer of the Foguang Temple.*

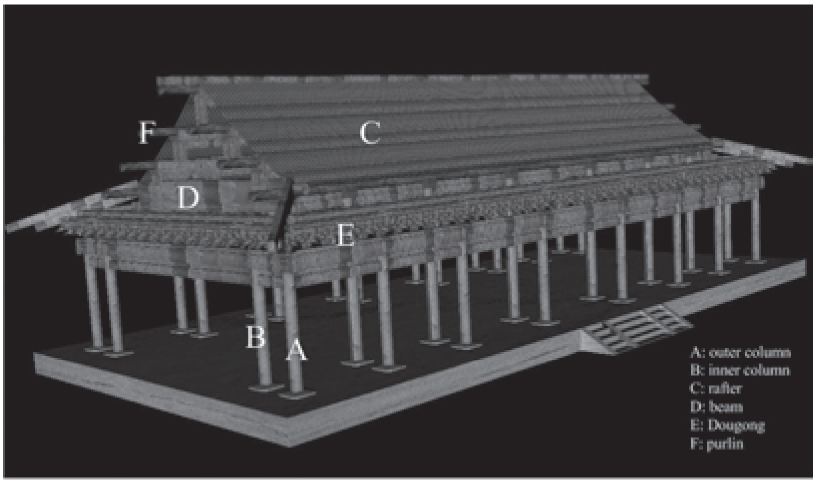



*Figure 4. A Xieshan Building in Construction from the Animation Generated by our System, where A-F means outer column, inner column, rafter, beam, Dougong and purlin, respectively.*

the construction sequence and computing size and position, and Jess (Friedman-Hill 2008) is used as the rule engine. Ontology and rules represent knowledge about the standard buildings as regulated by *Yin Zao Fa Shi*, and the database in our system collects detailed measurement data of real world buildings that are often not in full compliance with the standards.

## Conclusions and Future Work

Since the birth of XML many XML-based markup languages have been developed. But to the best of our knowledge there has not been any markup language specifically designed for ancient architecture, and this is even less likely to exist for ancient Chinese buildings. We should note, however, that although Architecture Description markup Language ADML (http://www.opengroup.org/architecture/ad) looks like it could be used for the architectural domain, it is actually designed for describing software architecture. SBML (http://sbml.org/Main_Page) is a system biology markup language which contains spatial concepts like 'apartment'. We consider it as an architecture-oriented markup language, more precisely a biological architecture markup language. The architecture described by SBML is simple and merely topological. It cannot be used to markup the delicate structures in building architecture. Due to similar reasons the Chemical Markup Language (http://www.xml-cml.org/) is again not suitable for use in the domain of building architecture.

Moreover, multimedia techniques oriented markup languages have been a hot research topic since the last decade. In this direction we have seen audio-based markup languages such as VoiceXML (http://www.w3.org/TR/voicexml20/) for recognizing, processing and generating audio signals; the Speech Synthesis Markup Language SSML (http://www.w3.org/TR/speech-synthesis11/) for speech analysis and synthesis; the Music Markup Language MML (http://www.musicmarkup.info/) for describing and sequencing various musical objects and events; Scalable Vector Graphics SVG (http://www.w3.org/TR/SVG/) for describing two-dimensional graphics including vector graphic shapes, images and text; the Pervasive Multimedia Markup Language PMML (http://www.dmg.org/pmml-v3-0.html) for specifying rich media content without making any assumptions about the capability of viewing devices; the Multimedia Retrieval Markup Language MRML (http://www.mrml.net/) for standardizing access to multimedia retrieval software components; and the Synchronized Multimedia Integration Language SMIL (http://www.w3.org/TR/REC-smil/), which can synthesize nearly all kinds of multimedia sources, including animation. Compared with these languages, ACAML features the automatic production of 3D animation from natural language text. On the other hand, ACAML and these multimedia markup languages could be complementary to each other, and linking among them would empower ACAML with more multimedia facilities in animations.

The work reported in this paper is the result of the first phase of development of ACAML and its implementation. In our future work the ontology we developed for specifying the timber structures shall be incorporated in ACAML so that the tags can have semantic definitions. Moreover, we plan to extend ACAML to cover more types of ancient Chinese architecture such as pavilions, bridges, doors and gardens. Also the architecture types that are already covered by the current ACAML should be improved and further detailed. In addition to ancient Chinese architecture, our methods can be applied to produce XML programs and corresponding animations for demonstrating other types of architecture in the world. One direction would be extending ACAML to AAML (Ancient Architecture Markup Language) for representing, modelling, analysing, and more importantly comparing and integrating ancient architectures in different schools.

## Acknowledgements

This research was supported by the MOST project ACA in China, NSFC 61073012, NSFC key project 60736011 and China 973 Project 2009CB320701, Tsinghua - Tencent Joint Laboratory for Internet Innovation Technology.

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