



World Heritage / Patrimoine Mondial

Name: Elham

Surname: Andaroodil

Nationality of author: Iranian

Language of thesis: English

Title of thesis: Architectural Spatial Ontology Model, On a Silk Road's Caravanserais for Advanced Classification

Type of thesis: Ph. D

Supervisor of thesis:

Associate Prof. Dr. Frederic Andres

Prof. Pierre Lebigre

Prof. Kinji Ono

Institution of Supervisor: National Institute of Informatics

Research Organization of Information and Systems

Tokio, Japan

■ Please provide a 500 words abstract outlining your thesis; you may wish to attach a table of contents or any other relevant material:

In this Ph.D. research the design and implementation of ontology knowledge model for management of architectural heritage information is done as part of Silk Roads study and Digital Silk Roads research (Digital Silk Road's Initiative Framework Between NII and UNESCO). It is focused on a special corpus of an important subset of cultural heritage of Silk Roads, caravanserais.

The research processes are as follows:

1- Study of background knowledge on the corpus of caravanserais of the Silk Roads, state of arts of ontology definition, techniques and application; Then, spatial studies and systematic analysis of space in shape grammar in architecture, taxonomic numerical descriptive rules, systems of qualitative representation of space, etc.

2- Design of architectural spatial ontology schema through:

2-1-Design of a lexical model through data acquisition, component-recognition and a multilingual technical term-set for components of caravanserais;

The terminology is completed basically in Persian language as the country of origin of caravanse-rais. Later it is extended to English language and in a collaborative study (by UNESCO experts) to other important languages of the Silk Roads.

2-2- Design of a thesaurus-based model of lexical data by manual mapping from available ontologies.

This ontology knowledge model covers the lexical attributes of a term such as definition, etymology, quotation, pronunciation and synonym.

2-3- Design of a spatial knowledge model by development of two complementary schemas: archi-tectural schema with support of spatial relations and shape rule schema with support of shape grammar knowledge for the specific corpus and formalization of both schema inside the Protégé tool.

The architectural schema is consisting of taxonomy of relationships such as spatial relationships, building construction, environmental and upper level relationships. These relationships specify the spatial attributes of entities or components and the way they are interconnected to each other in space in caravanserais.

Due to the ambiguity of architectural schema considering shape, topology and dimensions, the ontology is supported by define of shape grammar for a specific corpus of caravanserais. Shape grammar defines a set of shape rules in order to verify the concept of 2D plan of a caravanse-rai. Accordingly the shape grammar rules are represented either by drawing or by natural language equivalents and the ontology schema for shape grammar is developed.

3- Evaluation and application of the ontology system through tool based exploitation of the ontolo-gy, technical consistency checking, and advanced systematic classification of 137 cases of a specific corpus of caravanserais.

The domain application of ontology is advanced classification of the selected corpus. The target of classification is for verification of the conceptual design of caravanserais buildings and accordin-gly the development of an historical hypothesis of their creation. In this process the complete enti-ty verification schema of ontology is exploited in two levels of precision: general classification of six categories of caravanserais and precise classification of subcategories for each class. The classification is done by the help of knowledge extraction tools and the classification features and schema is represented in the ontology.

The ontology has a tool-based application called Image Learning Ontology (under development by engineering team) for advanced semantic annotation and retrieval to image data of caravanse-rais.

Table of Contents

Preface	iii
Acknowledgement	iv
Contents	vi
List of Tables	xii
List of Figures	xiii
Part I: An Architectural, Spatial and Multilingual Ontology for Caravanserais of Silk Roads	1
1. Introduction	2
1.1 Motivation: Knowledge Management and Systematic Recognition of Cultural Heritage	2
1.2 Statement of Problem: Ontology Knowledge Model for Architectural Heritage	3
2. Target Corpus: Historical Buildings of Silk Roads	5
2.1 The Silk Roads Study	5
2.2 General Category: Caravanserais of Silk Roads	6
2.2.1 Definition and Short Introduction	6
2.2.2 Background Study	10
2.3 Particular Type: Iranian Safavid and Qajar Open, On-route Samples	12
2.3.1 Introduction to the Historical Background	12
2.3.2 Typology Features	12
3. Thesis Question and Outline	15
3.1 Question of the Thesis: An Architectural Spatial Ontology Model for Caravanserais of the Silk	

Roads	15
3.1.1 Caravanserais study: Question and Target	15
3.1.2 Ontology Study: Question and Target	15
3.1.3 Target Applications	16
3.2 Outline and Contributions of the Dissertation	16
Part II: Review of Background Knowledge	19
4. Discussion on Ontology Definition and Design	20
4.1 Discussion on Definition	20
4.2 Literature Review of Ontology	22
4.2.1 Examples of Large Ontologies	23
4.2.2 Examples of Specific Ontologies	25
4.2.3 Examples of Knowledge Representation Tools	28
4.2.4 Discussion on the Ontology Examples and Tools	33
5. Discussion on Spatial Studies	35
5.1 Systems of Qualitative Representation of Space	35
5.2 Descriptive Taxonomic Numerical Rules	36
5.3 Shape Grammar for Architecture	38
5.4 Discussion on Contribution of Spatial Studies and Shortcomings	40
Part III: Design Study and Methodology of Ontology Development for Selected Corpus	41
6. Methodology	42
6.1 The methodology of the Ontology Development	42
6.1.1 The Process of Designing Lexical Knowledge Model	42
6.1.2 The Process of Designing Spatial Knowledge Model	42
6.1.3 Evaluation and Application of the Ontology	43
6.2 The Architecture of Architectural Spatial Ontology for Caravanserais (ASOC)	43
7. Lexical Knowledge Model	45
7.1 Terminology	45
7.2 Multilingual Equivalents	46
7.2.1 Challenges of Multilingual Equivalences	47
7.3 Taxonomy of Thesauruses	47
7.4 Formalization of Lexical Ontology	49
7.4.1 Lexical Ontology Schema, Attributes Language-Dependant	49
7.4.2 Lexical Ontology Schema, Attributes Language-Independent	50
7.4.3 Multilingual Equivalents	53
7.4.4 Exploitation of Lexical Ontology for Knowledge Input	54
8. Spatial Knowledge Model	58
8.1 Architectural Ontology Model	58
8.1.1 Architectural Taxonomy Entity Set	58
8.2 Architectural Relationships	60
8.2.1 Architectural Relationships Background Study	61
8.2.2 Define of Architectural Relationship Schema	64
8.3 Methodology of Define and Formalization of Architectural Relationships	72
8.3.1 entity relationship starts Property:	72
8.3.2 entity relationship Property	73
8.4 Taxonomic Numerical Descriptive Rules for Specific Corpus	75
8.4.1 Taxonomy of Main Rules	75
8.4.2 Taxonomy of Sub Rules	76
8.4.3 Implementation and Formalization	80
8.5 Knowledge Input for Architectural Ontology Using the Protégé Tool	81
8.6 Comparison of Architectural Ontology with Other Ontologies (FMA)	82
Part IV: Design Study of Shape Knowledge Model	85
9. Shape Grammar Concept for Specific Final Corpus of Caravanserais	86
9.1 Capturing Background Knowledge for Development of Shape Grammar	86
9.1.1 Employing a Middle-Up Approach	86
9.1.2 Final Corpus , A Systematic Inventory	88
9.1.3 Definition of Shape Spatial Features	89
9.2 General Concept of Shape Grammar	92
9.2.1 Formations of Major Features	92
9.2.2 Specific Formations	92
10. Shape Grammar Rules for Specific Corpus	94
10.1 Shape Grammar Process	94
10.2 Shape Grammar Output Entity Represented by Drawing	95
10.3 Conceptual Generation for Cases within Selected Corpus	98
10.4 Shape Grammar Input Entity	98
10.4.1 Verification of Spatial Element as "Entity"	98
10.4.2 Verification of Shape Elements of "Entity"	99
10.4.3 Verification of Dimension Parameter of "Entity"	99
10.4.4 Verification of Direction of "Entity"	100
10.4.5 Verification of a Point Location on Entity	100
10.5 Shape Grammar Function	101

10.5.1	Verification of Functions for The Organization of Spatial Elements	101
10.5.2	Verification of Supporting Functions	102
10.6	Formalization of Shape Grammar Ontology	102
10.6.1	Shape Grammar Representation in Natural Language Description	103
10.6.2	Shape Grammar Ontology Schema inside the Protégé tool	105
10.6.3	Exploitation of Shape grammar Ontology for Knowledge Input	110
10.7	Discussion on the Application, Comparison and Shortcomings of Shape Grammar	112
11.	Architectural Spatial Ontology	114
11.1	Methodology to Define Factual and Conditional Relationships	114
11.2	Complementary Shape Grammar and Lexical Schemas	115
Part V:	Assessment and Evaluation of Ontology for Caravanserais of Silk Roads	117
12.	Evaluation of the Spatial-Lexical Ontology	118
12.1	Technical Ontology Evaluation	118
12.2	Tool-based Application and Evaluation	119
12.3	Content Evaluation	120
12.3.1	The Process of Content Evaluation	121
12.3.2	Suggested Modifications	122
13.	Assessment of Spatial Lexical Ontology for Classification of Specific Corpus	124
13.1	Evaluation of Ontology Features	124
13.2	Implementation of Features for Classification	125
13.3	Conceptual Design Classification	128
13.3.1	Classification by Bayesian Network	128
13.3.2	Caravanserais Clustering	129
13.3.3	Target Classification: Conceptual Design	134
13.3.4	Verification of Subclasses	139
13.3.5	Ontology-Based Evaluation of the Target Classification	140
13.4	Assessment and Extraction of Historical Hypothesis	142
14.	Formalization of Classification by Employing Protégé Tool	144
14.1	Caravanserais Features	144
14.2	Caravanserais Classification	144
14.3	Discussion and Conclusion	145
14.3.1	Domain Based Results	145
14.3.2	Knowledge Representation Results	147
Part VI:	Conclusion and Future Trend	149
15.	Summary of Ph.D. Contribution	150
15.1	Main Achievements	150
15.2	Contribution of the Dissertation	150
15.2.1	A Clear Formulation of the Research Question.	150
15.2.2	An Identification of the Significant Problems	150
15.2.3	A Description of the Ph.D. Project's Contribution to the Problem Solution	151
15.2.4	A Discussion of the Ph.D. Project's Originality	154
15.3	Contribution for Domain Experts of Architecture	154
16.	Concluding Discussion	156
16.1	Remaining Challenge	157
16.2	Future Trend of the Research	157
	Bibliography:	159
	Appendix I	2
	Appendix II	39
	Appendix III	133
	Appendix IV	152

■ Thematic Structure (max. 5)

<input type="checkbox"/>	Heritage and sustainable development	<input type="checkbox"/>	Cultural Landscapes
<input type="checkbox"/>	Heritage and tourism	<input type="checkbox"/>	Historic Urban Landscapes (HUL)
<input checked="" type="checkbox"/>	Heritage and ICTs (Information and Communication Technologies)	<input type="checkbox"/>	Intangible heritage and methodology for its protection and promotion
<input checked="" type="checkbox"/>	Promotion, awareness-raising and communication on heritage	<input type="checkbox"/>	Sacred, military, maritime, colonial, industrial, modern, contemporary, vernacular and rock-painting heritage
<input type="checkbox"/>	Heritage and the media	<input type="checkbox"/>	Trans-boundary heritage (Barocco /Art Nouveau /Pilgrimage Routes, etc.) and itineraries or roads
<input type="checkbox"/>	Cities and historic centres: urban management and planning, habitats	<input type="checkbox"/>	Heritage and indicators (Measuring tourism and/or World Heritage inscription's impact(s))

<input checked="" type="checkbox"/>	Archaeological sites	<input checked="" type="checkbox"/>	Integrated management of heritage
<input type="checkbox"/>	Museums and site interpretation centres	<input type="checkbox"/>	The legal framework of heritage protection
<input type="checkbox"/>	Inter-disciplinary research investigations on materials (stone, earth, brick, wood, ceramics, bamboo, zellidj, etc.)	<input type="checkbox"/>	Youth and heritage, heritage education (Educational sciences, educational policies, youth summer camps and summer universities, heritage volunteers, school manuals, etc.)
<input type="checkbox"/>	Natural heritage/Environmental sciences	<input type="checkbox"/>	Heritage for dialogue, reconciliation and peace, heritage and social and human sciences
<input checked="" type="checkbox"/>	Other: Documentation of Architectural Heritage		