An agent based architecture for constructing Interactive Simulation Systems

Zhao, Z.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
## Contents

1 Introduction .................................................. 1
   1.1 Territory .................................................... 1
   1.1.1 Computer simulation .................................... 1
   1.1.2 High performance computing ......................... 3
   1.1.3 Scientific visualisation ............................... 4
   1.1.4 Problem solving environments ....................... 5
   1.2 Towards an Interactive Simulation System .............. 6
   1.2.1 Requirements on the interconnection ............... 6
   1.2.2 Requirements on the code incorporation ............ 7
   1.2.3 Requirements on the Interaction module .......... 8
   1.3 Modularity and integration ............................. 8
   1.3.1 Middleware and interoperability ................... 8
   1.3.2 Activity orchestration ................................ 11
   1.4 Human-system interaction ............................... 12
   1.5 Real-time interaction .................................... 13
   1.5.1 Performance and service quality .................... 13
   1.5.2 Time management ....................................... 13
   1.6 Engineering methodologies ............................. 14
   1.6.1 Software Components and ISSs ....................... 15
   1.6.2 Agent technology and ISSs ........................... 16
   1.7 Summary ..................................................... 18
   1.8 Problem statement ........................................ 19
   1.9 Thesis organisation ..................................... 20

2 An agent based component architecture ................... 23
   2.1 Introduction ............................................... 23
   2.2 Interactive Simulation System Conductor ............. 24
   2.2.1 Modules as reusable components ..................... 24
   2.2.2 Basic architecture ..................................... 24
   2.3 Agent based design ....................................... 25
   2.3.1 Agent definition ....................................... 25
   2.3.2 Activity control ....................................... 27
   2.3.3 Performance considerations ......................... 27
   2.4 Constructing interactive simulation systems .......... 27
3 Agent based activity orchestration

3.1 An ISS as a multiple Module Agents system

3.2 Inherent functionality: component capability
   3.2.1 Basic model
   3.2.2 Capability modelling for the human interaction involved components

3.3 Interaction: story and scenarios
   3.3.1 Place transition net
   3.3.2 Scenario representation
   3.3.3 Transitions and actions
   3.3.4 Story: a scenario-net instance

3.4 World model
   3.4.1 Basic structure
   3.4.2 Perception and uncertain belief of the agent world

3.5 Controller
   3.5.1 Collecting observations
   3.5.2 Action execution control

3.6 Story execution
   3.6.1 Basic paradigm: distributed scenario execution
   3.6.2 Hierarchical execution paradigm
   3.6.3 Centralised coordinator paradigm
   3.6.4 Scenario switch and execution paradigm selection
   3.6.5 Handling run-time exceptions

3.7 Summary

4 Implementation and performance analysis

4.1 Communication agents
   4.1.1 Data object manager
   4.1.2 Distribution manager
   4.1.3 Events and action execution

4.2 Module Agents

4.3 Putting it all together
   4.3.1 Current implementation
   4.3.2 Actor and Conductor
   4.3.3 Capability and story descriptions
   4.3.4 Run-time configuration files

4.4 Performance analysis
   4.4.1 Example components and the test bed
   4.4.2 Delay for remote updating shared objects
   4.4.3 Location of the RTI execution
### Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4.4 Remotely updating objects to multiple Consumers</td>
<td>60</td>
</tr>
<tr>
<td>4.4.5 Message passing</td>
<td>60</td>
</tr>
<tr>
<td>4.4.6 Object model and update delay</td>
<td>62</td>
</tr>
<tr>
<td>4.4.7 Summary</td>
<td>63</td>
</tr>
<tr>
<td>4.5 Performance for action reasoning and story execution</td>
<td>63</td>
</tr>
<tr>
<td>4.5.1 Overall observations on the action reasoning</td>
<td>64</td>
</tr>
<tr>
<td>4.5.2 Overhead of the reasoning kernel</td>
<td>66</td>
</tr>
<tr>
<td>4.5.3 Reasoning complexity and delay</td>
<td>67</td>
</tr>
<tr>
<td>4.5.4 Brief comparison between execution paradigms</td>
<td>69</td>
</tr>
<tr>
<td>4.5.5 Summary</td>
<td>69</td>
</tr>
<tr>
<td>4.6 Discussion and conclusions</td>
<td>70</td>
</tr>
<tr>
<td>4.6.1 Evaluation</td>
<td>70</td>
</tr>
<tr>
<td>4.6.2 Conclusions</td>
<td>71</td>
</tr>
<tr>
<td>5 Rapid Prototyping of a surgical pre-operative planning environment</td>
<td>73</td>
</tr>
<tr>
<td>5.1 Introduction</td>
<td>73</td>
</tr>
<tr>
<td>5.1.1 Background</td>
<td>73</td>
</tr>
<tr>
<td>5.1.2 Goal of the chapter</td>
<td>75</td>
</tr>
<tr>
<td>5.2 From Legacy systems to reusable components</td>
<td>76</td>
</tr>
<tr>
<td>5.2.1 Basic steps</td>
<td>76</td>
</tr>
<tr>
<td>5.2.2 Legacy flow simulation and visualisation systems</td>
<td>77</td>
</tr>
<tr>
<td>5.2.3 Component 1: C.\textit{Flow Simulator}</td>
<td>78</td>
</tr>
<tr>
<td>5.2.4 Component 2: C.\textit{Desktop VRE}</td>
<td>80</td>
</tr>
<tr>
<td>5.2.5 Discussion</td>
<td>81</td>
</tr>
<tr>
<td>5.3 Coupling component instances</td>
<td>82</td>
</tr>
<tr>
<td>5.3.1 Basic analysis: roles and interactions</td>
<td>82</td>
</tr>
<tr>
<td>5.3.2 Making an interaction story</td>
<td>83</td>
</tr>
<tr>
<td>5.3.3 Executing an ISS</td>
<td>84</td>
</tr>
<tr>
<td>5.3.4 Asynchronous data update</td>
<td>85</td>
</tr>
<tr>
<td>5.4 Automatic tuning of service quality</td>
<td>87</td>
</tr>
<tr>
<td>5.4.1 Adaptable state update</td>
<td>87</td>
</tr>
<tr>
<td>5.4.2 Solutions in ISS-Conductor</td>
<td>88</td>
</tr>
<tr>
<td>5.4.3 An example: adaptable rate for exporting \textit{Flow Data}</td>
<td>88</td>
</tr>
<tr>
<td>5.5 Collaborative interaction in an ISS</td>
<td>89</td>
</tr>
<tr>
<td>5.5.1 Requirements</td>
<td>90</td>
</tr>
<tr>
<td>5.5.2 Basic support</td>
<td>91</td>
</tr>
<tr>
<td>5.6 Collaborative data analysis and decision making</td>
<td>92</td>
</tr>
<tr>
<td>5.6.1 User opinions and decision points</td>
<td>92</td>
</tr>
<tr>
<td>5.6.2 Collaboratively exploring data</td>
<td>93</td>
</tr>
<tr>
<td>5.6.3 Experimental results</td>
<td>94</td>
</tr>
<tr>
<td>5.7 Multiple instances of a scenario net</td>
<td>95</td>
</tr>
<tr>
<td>5.7.1 Scenario template and data class mapping</td>
<td>96</td>
</tr>
<tr>
<td>5.8 Summarising discussion</td>
<td>97</td>
</tr>
<tr>
<td>5.9 Conclusions</td>
<td>98</td>
</tr>
</tbody>
</table>
6 Towards an intelligent planning environment for interactive simulations

6.1 Introduction ................................................. 101
6.2 A global picture ........................................... 103
   6.2.1 Proposed functional subsystems ......................... 103
   6.2.2 Design requirements .................................. 105
   6.2.3 ISS-Studio and Grid environments ...................... 105
   6.2.4 In the context of a PSE framework....................... 106
6.3 Intelligent planning of ISS-Conductor based interactive simulations . 106
   6.3.1 Describing experiment requirements .................... 107
   6.3.2 Component searching .................................. 108
   6.3.3 Story generation .................................... 110
   6.3.4 Generating execution scripts .......................... 110
6.4 Prototype and preliminary results ................................ 110
   6.4.1 A multi-agent based experiment planning environment ... 110
   6.4.2 Experimental results ................................ 111
6.5 Discussion and conclusions ................................ 113

7 Summary and discussion ...................................... 115
   7.1 Summary ................................................. 115
   7.2 Conclusions and discussion ............................... 116
   7.3 Future work ............................................ 118

References ......................................................... 123

Nederlandse Samenvatting ....................................... 143

Publications ...................................................... 145

Index .............................................................. 147

Acknowledgments ................................................ 149