

# TABLE OF CONTENTS

|   |          |
|---|----------|
| <b>CHAPTER 1 INTRODUCTION.....</b>                                  | <b>1</b> |
| 1.1 A BRIEF OVERVIEW OF COMPUTER ANIMATION .....                    | 1        |
| 1.2 MOTIVATION.....   | 3        |
| 1.3 OUTLINE OF THE THESIS.....                                      | 5        |
| <br>  |          |
| <b>CHAPTER 2 A REVIEW OF COMPUTER ANIMATION.....</b>                | <b>6</b> |
| 2.1 INTRODUCTION.....   | 6        |
| 2.2 THE TRADITIONAL ANIMATION .....                                 | 6        |
| 2.3 2-D COMPUTER ANIMATION .....                                    | 7        |
| 2.4 OVERVIEW OF 3-D COMPUTER ANIMATION.....                         | 7        |
| 2.4.1 <i>Animation Motion Control</i> .....                         | 8        |
| Key-frame Animation.....  | 8        |
| Algorithmic Animation .....   | 8        |
| 2.4.2 <i>Zeltzer's Control Levels</i> .....                         | 9        |
| 2.4.3 <i>Animation Methods</i> .....                                | 10       |
| The Dynamic Method.....   | 10       |
| The Kinematic Method .....  | 11       |
| 2.4.4 <i>World Modelling</i> .....                                  | 11       |
| Particle Systems.....   | 11       |
| Stick Models.....   | 12       |
| Wire Frames .....   | 12       |
| Polyellipsoids Display.....   | 12       |
| Constructive Solid Geometry (CSG).....                              | 12       |
| 2.5 PREVIOUS WORK ON AUTONOMOUS MOTION CONTROL .....                | 13       |
| 2.5.1 <i>Sensor-effector Approach</i> .....                         | 13       |
| The Artificial Fishes of Tu.....                                    | 13       |
| 2.5.2 <i>The Predefined Environment Approach</i> .....              | 14       |
| The Director's Apprentice System.....                               | 14       |
| 2.5.3 <i>The Behaviour Rule Approach</i> .....                      | 15       |
| The Paradise System.....  | 16       |
| The PetWorld System .....   | 16       |
| The Relation Approach .....   | 18       |
| NSAIL: Behavioural Animation using Constraint-Based Reasoning ..... | 19       |
| 2.5.4 <i>Other Related Work</i> .....                               | 20       |

|   |           |
|---|-----------|
| Actor Systems.....  | 20        |
| Animation of Multiple Actors.....                         | 21        |
| Knowledge-Based Systems.....                              | 22        |
| The Instruction Approach.....                             | 22        |
| A Blackboard Approach.....                                | 23        |
| 2.6 ESPLANADE.....  | 24        |
| 2.7 SUMMARY.....  | 25        |
| <br>  |           |
| <b>CHAPTER 3 CONCEPTS OF ARTIFICIAL INTELLIGENCE.....</b> | <b>26</b> |
| 3.1 INTRODUCTION.....                                     | 26        |
| 3.2 AI NOMENCLATURE.....                                  | 26        |
| 3.3 REASONING ABOUT ACTIONS.....                          | 27        |
| 3.4 PLAN SYNTHESIS.....                                   | 31        |
| 3.4.1 <i>Non-hierarchical Planning</i> .....              | 31        |
| 3.4.2 <i>Hierarchical Planning</i> .....                  | 32        |
| 3.4.3 <i>Script-based Planning</i> .....                  | 33        |
| 3.4.4 <i>Opportunistic Planning</i> .....                 | 34        |
| 3.5 KNOWLEDGE-BASED SYSTEMS.....                          | 35        |
| 3.6 KNOWLEDGE REPRESENTATION.....                         | 36        |
| 3.6.1 <i>Literals</i> .....                               | 36        |
| 3.6.2 <i>Variables</i> .....                              | 37        |
| 3.6.3 <i>Predicates</i> .....                             | 37        |
| 3.6.4 <i>Semantic Networks</i> .....                      | 37        |
| 3.6.5 <i>Frames</i> .....                                 | 38        |
| Inheritance.....  | 39        |
| Instances.....  | 40        |
| 3.6.6 <i>Production Rules</i> .....                       | 40        |
| 3.6.7 <i>Procedures</i> .....                             | 41        |
| 3.7 THE REASONING PROCESS.....                            | 42        |
| 3.7.1 <i>Rule Chaining</i> .....                          | 42        |
| 3.7.2 <i>Conflict Resolution</i> .....                    | 44        |
| 3.8 FRAMEWORKS IN KBS.....                                | 45        |
| 3.8.1 <i>Expert Systems</i> .....                         | 45        |
| 3.8.2 <i>Blackboard Systems</i> .....                     | 46        |
| 3.9 SUMMARY.....  | 49        |

|   |           |
|---|-----------|
| <b>CHAPTER 4 THE BASIC ANIMATION SYSTEM.....</b>                                | <b>50</b> |
| 4.1 INTRODUCTION.....   | 50        |
| 4.2 THE HUMAN FIGURE.....   | 51        |
| 4.2.1 <i>The Representation of Articulated Bodies as a Chain of Links</i> ..... | 51        |
| 4.2.2 <i>Representation of the Human Figure</i> .....                           | 53        |
| 4.2.3 <i>Motion in Articulated Bodies</i> .....                                 | 53        |
| 4.2.4 <i>The Skeleton as Data Type Structure</i> .....                          | 54        |
| 4.2.5 <i>The Representation of a Limb Data Type</i> .....                       | 55        |
| 4.2.6 <i>Motion Representation</i> .....  | 56        |
| 4.2.6.1 <i>The Interpreted Mode</i> .....                                       | 57        |
| 4.2.6.2 <i>The Procedural Mode</i> .....  | 57        |
| 4.3 COMPONENTS OF THE ANIMATION SYSTEM.....                                     | 58        |
| 4.3.1 <i>The Decor Controller</i> .....   | 59        |
| 4.3.2 <i>The Cast Controller</i> .....  | 60        |
| 4.3.2.1 <i>The Active Objects</i> .....   | 60        |
| 4.3.2.2 <i>The Static Objects</i> .....   | 61        |
| 4.3.3 <i>The Visualisation Component</i> .....                                  | 61        |
| 4.3.4 <i>The Structure of Executing Motion</i> .....                            | 62        |
| 4.3.5 <i>Goal-directed Motion</i> .....   | 63        |
| 4.3.6 <i>Goal-directed Arm Reach</i> .....                                      | 65        |
| 4.3.7 <i>Holding and Releasing an Object</i> .....                              | 67        |
| 4.3.8 <i>The Locomotion of the Human Figure</i> .....                           | 68        |
| 4.3.8.1 <i>The Walking Motion</i> .....   | 69        |
| First Stage: <i>Leg Lifting and Change of Direction</i> .....                   | 70        |
| Second Stage: <i>Step Forward</i> .....   | 71        |
| Second Stage: <i>Step Sideways</i> .....  | 71        |
| Third Stage: <i>Straightening Up</i> .....                                      | 72        |
| 4.3.9 <i>Gestures</i> .....   | 72        |
| 4.4 PATH PLANNING.....  | 72        |
| 4.4.1 <i>The Segment Sub-division Approach</i> .....                            | 73        |
| 4.5 CONCLUSIONS .....   | 76        |
| <br>  |           |
| <b>CHAPTER 5 THE ANIMATION FRAMEWORK .....</b>                                  | <b>77</b> |
| 5.1 INTRODUCTION.....   | 77        |
| 5.2 THE ANIMATION SYSTEM.....   | 78        |
| 5.3 THE ANIMATION CONTROLLER .....  | 79        |
| 5.3.1 <i>The Blackboard Data Structure</i> .....                                | 81        |

|   |            |
|---|------------|
| 5.3.2 <i>The Knowledge Sources</i> .....                    | 81         |
| 5.3.3 <i>Control</i> .....                                  | 82         |
| 5.4 THE EXAMPLE OF ANIMATION SCENARIO: BAR .....            | 83         |
| 5.5 THE ANIMATION ENTITIES .....                            | 85         |
| 5.6 THE AGENT ENTITY .....                                  | 87         |
| 5.7 CONCLUSIONS .....                                       | 88         |
| <br>  |            |
| <b>CHAPTER 6 THE INSTRUCTION</b> .....                      | <b>89</b>  |
| 6.1 INTRODUCTION .....                                      | 89         |
| 6.2 THE INSTRUCTION CONCEPT .....                           | 90         |
| 6.3 PLANNING IN THE INSTRUCTION .....                       | 91         |
| 6.4 INSTRUCTION OPERATION .....                             | 93         |
| 6.5 THE INSTRUCTION FRAME .....                             | 93         |
| 6.6 THE ROOT FRAME REPRESENTING PROCESS .....               | 94         |
| 6.7 THE INSTRUCTION PARAMETER TEMPLATE .....                | 95         |
| 6.8 THE PLAN REPRESENTATION .....                           | 96         |
| 6.9 PLAN SELECTION .....                                    | 97         |
| 6.10 CONTEXT IDENTIFICATION .....                           | 99         |
| 6.11 PLAN INSTANTIATION .....                               | 101        |
| 6.11.1 <i>Forward binding</i> .....                         | 102        |
| 6.11.2 <i>Backwards binding</i> .....                       | 104        |
| 6.12 GROUPING INSTRUCTIONS .....                            | 104        |
| 6.13 RECURSION IN INSTRUCTION PLANNING .....                | 105        |
| 6.14 PLAN EXECUTION .....                                   | 106        |
| 6.14.1 <i>The Instruction Knowledge Source</i> .....        | 107        |
| 6.14.2 <i>Failure Control State</i> .....                   | 109        |
| 6.15 EXAMPLES OF INSTRUCTION PARAMETERS .....               | 112        |
| 6.16 EXAMPLE OF AN INSTRUCTION - <i>CLEAR_COUNTER</i> ..... | 112        |
| 6.17 SUMMARY .....  | 115        |
| <br>  |            |
| <b>CHAPTER 7 THE MESSAGE CONCEPT</b> .....                  | <b>116</b> |
| 7.1 INTRODUCTION .....                                      | 116        |
| 7.2 A BRIEF BACKGROUND .....                                | 117        |
| 7.2.1 <i>Applications in Computer Animation</i> .....       | 117        |
| 7.2.2 <i>Robotics</i> .....                                 | 118        |
| 7.2.3 <i>AI</i> .....                                       | 118        |
| 7.3 THE MESSAGE EXCHANGE SCHEME .....                       | 118        |

|   |            |
|---|------------|
| 7.4 OPERATION OF THE MESSAGE MECHANISM.....         | 120        |
| 7.5 CHAINING TWO MESSAGES .....                     | 123        |
| 7.6 SUMMARY .....                                   | 124        |
| <br>  |            |
| <b>CHAPTER 8 THE TASK CONCEPT .....</b>             | <b>125</b> |
| 8.1 INTRODUCTION.....                               | 125        |
| 8.2 THE OPERATION OF TASK CONTROL ENTITY.....       | 126        |
| 8.3 THE TASK FRAME.....                             | 127        |
| 8.4 ALLOCATION OF RESOURCES.....                    | 127        |
| 8.5 PRIORITY TO ACCESS RESOURCES.....               | 129        |
| 8.6 CALLING PROCESSES BACK TO ACTIVITY.....         | 130        |
| 8.7 THE TASK SPECIFIC PROCESS .....                 | 131        |
| 8.7.1 Data Retrieval and Checking Constraints ..... | 133        |
| 8.7.2 Associated Actions.....                       | 133        |
| 8.7.3 Database Update .....                         | 133        |
| 8.8 TASK CONTROL STATES.....                        | 135        |
| 8.9 EXAMPLE .....                                   | 136        |
| 8.10 SUMMARY .....                                  | 138        |
| <br>  |            |
| <b>CHAPTER 9 SCHEDULING INSTRUCTIONS.....</b>       | <b>139</b> |
| 9.1 INTRODUCTION.....                               | 139        |
| 9.2 OVERVIEW OF THE SCHEDULING STAGE.....           | 140        |
| 9.3 CATEGORIES OF MOVEMENTS.....                    | 141        |
| 9.3.1 Primary Instructions .....                    | 142        |
| 9.3.2 Secondary Movements.....                      | 142        |
| 9.3.3 Signalling Movements.....                     | 143        |
| 9.4 SOURCES OF INSTRUCTIONS.....                    | 143        |
| 9.4.1 The Animation Script .....                    | 144        |
| 9.4.2 Actions Triggered by the System .....         | 145        |
| 9.4.2.1 Actions requested through Messages .....    | 145        |
| 9.4.2.2 Task Generated Actions.....                 | 146        |
| 9.4.2.3 Default Motion.....                         | 148        |
| 9.5 SCHEDULING OF PRIORITIES .....                  | 148        |
| 9.6 TIMING-OUT PROCESSES.....                       | 150        |
| 9.7 EXAMPLE OF “FORKING” PARALLEL ACTIONS.....      | 150        |
| 9.7.1 Motion Continuation.....                      | 152        |
| 9.7.2 Intermediate Motions.....                     | 153        |

|  |            |
|--|------------|
| 9.7.3 <i>Coordinating Multiple Interleaved Actions</i> ..... | 153        |
| 9.7.4 <i>Conclusions</i> .....                               | 155        |
| 9.8 SUMMARY .....  | 156        |
| <br>   |            |
| <b>CHAPTER 10 CONCLUSIONS AND FUTURE WORK</b> .....          | <b>157</b> |
| 10.1 CONCLUSIONS .....                                       | 157        |
| 10.2 FUTURE WORK: THE ANIMATOR'S INTERFACE .....             | 160        |
| 10.3 FUTURE WORK: COORDINATION OF ACTIONS .....              | 162        |
| <br>   |            |
| <b>BIBLIOGRAPHY</b> .....                                    | <b>164</b> |
| <br>   |            |
| <b>APPENDIX A</b> .....                                      | <b>176</b> |
| A.1 ANIMATION SCENARIO: BAR .....                            | 176        |
| A.2 AN EXAMPLE OF A SCRIPT .....                             | 177        |
| A.3 GOAL-DIRECTED ACTIONS DERIVED FROM THE SCRIPT .....      | 180        |
| A.4 EXAMINING INSTANCES DURING RUNTIME .....                 | 181        |
| A.5 THE DETAILED SCRIPT .....                                | 184        |
| A.6 THE ANIMATED SCENE.....                                  | 190        |

# TABLE OF FIGURES

|   |    |
|---|----|
| FIGURE 2-1: INTERACTION AND ABSTRACTION. ....   | 9  |
| FIGURE 2-2: PLANNING THE MOTION OF ACTORS ON A STAGE. ....  | 15 |
| FIGURE 2-3: PET'S BEHAVIOUR PATTERNS DEFINED BY RULES. ....   | 17 |
| FIGURE 2-4: HIERARCHY OF A DECISION TREE. BOLDER LINES INDICATE TRAVERSAL OF THE HIERARCHY<br>THROUGH SELECTED BRANCHES OF THE TREE UNTIL THE LIFT ACTION IS SELECTED. .... | 17 |
| FIGURE 2-5: EXAMPLE OF RELATIONS. ....  | 19 |
| FIGURE 2-6: ACTOR MESSAGE OPERATORS ....  | 21 |
| FIGURE 2-7: SCHEMATIC PRESENTATION OF ACTORS'S PERFORMANCE AND EVENTS. ....   | 21 |
| FIGURE 2-8: ZELTZER'S FRAME EXAMPLE. ....   | 22 |
| FIGURE 2-9: KARP AND FEINER'S FILM STRUCTURE. ....  | 25 |
| FIGURE 3-1: A TYPICAL STRIPS OPERATOR. ....   | 29 |
| FIGURE 3-2: CHANGES IN JOHN'S WORLD STATE AS HE ACCOMPLISHES AN ACTION. ....  | 30 |
| FIGURE 3-3: APPLICABILITY OF SINGLE AND MULTIPLE OPERATORS CASES. ....  | 31 |
| FIGURE 3-4: EXAMPLE OF THE NON-HIERARCHICAL PLANNING APPROACH. ....   | 32 |
| FIGURE 3-5: EVOLUTION OF A PLAN IN AN HIERARCHICAL MODEL. ....  | 33 |
| FIGURE 3-6: EXAMPLE OF SCRIPT-BASED PLANNING. ....  | 34 |
| FIGURE 3-7: EXAMPLE OF OPPORTUNISTIC PLANNING. ....   | 35 |
| FIGURE 3-8: TYPICAL COMPONENTS OF A KNOWLEDGE-BASED SYSTEM. ....  | 36 |
| FIGURE 3-9: FRAGMENT OF A SEMANTIC NETWORK. ....  | 38 |
| FIGURE 3-10: FRAME. ....  | 39 |
| FIGURE 3-11: FRAME INHERITANCE: ARROWS POINT TO NEW INHERITED CLASSES. ....   | 40 |
| FIGURE 3-12: PROLOG CLAUSE AS RULE. ....  | 42 |
| FIGURE 3-13: EXAMPLE OF FORWARD CHAINING PROCESS. ....  | 43 |
| FIGURE 3-14: EXAMPLE OF BACKWARD CHAINING FROM A GOAL. ....   | 44 |
| FIGURE 3-15: BACKWARD-CHAINING: (A) DEPTH FIRST ORDER; (B) BREADTH FIRST ORDER. ....  | 44 |
| FIGURE 3-16: EXPERT SYSTEM EXECUTION CYCLE. ....  | 46 |
| FIGURE 3-17: NII'S GENERIC BLACKBOARD FRAMEWORK. ....   | 48 |
| FIGURE 3-18: THE GENERAL FORMAT OF A KNOWLEDGE SOURCE. ....   | 48 |
| FIGURE 4-1: CHAIN OF LINKS. ....  | 51 |
| FIGURE 4-2: THE HUMAN BODY AS AN HIERARCHICAL CHAIN. ....   | 53 |
| FIGURE 4-3: THE FIX OPERATOR AVOIDS THE "SLIPPING" EFFECT. ....   | 54 |
| FIGURE 4-4: CASES OF BEND AND PIVOT OPERATORS APPLIED TO THE KNEE. ....   | 54 |
| FIGURE 4-5: THE HUMAN OBJECT TYPE. ....   | 55 |
| FIGURE 4-6: A LIMB DATA STRUCTURE. ....   | 56 |

|   |     |
|---|-----|
| FIGURE 4-7: REPRESENTATION OF SKILLS IN THE INTERPRETED MODE. ....                      | 57  |
| FIGURE 4-8: REPRESENTATION OF SKILLS IN THE PROCEDURAL MODE. ....                       | 58  |
| FIGURE 4-9: ORGANISATION OF THE ANIMATION SYSTEM. ....                                  | 59  |
| FIGURE 4-10: COORDINATE OF THE SKELETON IN RESTING POSITION. ....                       | 60  |
| FIGURE 4-11: GRAPHICAL REPRESENTATION OF THE STRUCTURE OF MOTION DURING EXECUTION. .... | 63  |
| FIGURE 4-12: KOREIN'S APPROACH TO REACHING A POINT GOAL. ....                           | 64  |
| FIGURE 4-13: KOREIN'S ALGORITHM FOR THE REACH APPROACH. ....                            | 64  |
| FIGURE 4-14: CONFIGURATIONS OF AN ARM. ....   | 66  |
| FIGURE 4-15: PHASES OF THE WALKING IN TIME AND DISTANCE. ....                           | 68  |
| FIGURE 4-16: PROCEDURE IMPLEMENTING RIGHT LEG SWING OF THE WALKING MOTION. ....         | 69  |
| FIGURE 4-17: TURN 50 DEGREES TO THE LEFT, SWINGING RIGHT LEG. ....                      | 70  |
| FIGURE 4-18: TURN 50 DEGREES TO THE RIGHT, SWINGING RIGHT LEG. ....                     | 70  |
| FIGURE 4-19: TURNING THE DIRECTION OF WALK. ....  | 71  |
| FIGURE 4-20: WALKING STRIDE AS A COMPASS GAIT. ....                                     | 71  |
| FIGURE 4-21: POTENTIAL FIELD USED TO GUIDE A ROBOT. ....                                | 73  |
| FIGURE 4-22: MARKING THE VISIBLE CELLS WITH DISTANCE TO THE TARGET. ....                | 73  |
| FIGURE 4-23: PATH DETERMINATION WITH OBSTACLES. ....                                    | 74  |
| FIGURE 4-24: DETERMINATION OF ALTERNATIVE POINT. ....                                   | 75  |
| FIGURE 4-25: DETERMINATION OF ALTERNATIVE POINT FOR A RECTANGLE. ....                   | 75  |
|   |     |
| FIGURE 5-1: ANIMATION FRAMEWORK COMPOSED BY TWO INTERACTING BLOCKS. ....                | 78  |
| FIGURE 5-2: ORGANISATION OF THE ANIMATION CONTROLLER. ....                              | 80  |
| FIGURE 5-3: THE THREE CONTROL STAGES OF PROCESS. ....                                   | 81  |
| FIGURE 5-4: A VIEW OF THE BAR SCENARIO FROM THE TOP. ....                               | 85  |
| FIGURE 5-5: EXAMPLE OF HIERARCHY OF AN ANIMATION CAST. ....                             | 86  |
| FIGURE 5-6: THE PERSON FRAME. ....  | 87  |
| FIGURE 5-7: EXAMPLE OF STATE MACHINE FOR THE WALK MOTION. ....                          | 88  |
|   |     |
| FIGURE 6-1: CONTRAST OF GOALS: STATE ORIENTED AND ACTION ORIENTED. ....                 | 90  |
| FIGURE 6-2: TWO ABSTRACTIONS FOR THE SAME PLAN. ....                                    | 92  |
| FIGURE 6-3: PLANNING WITH EXISTING ACTIONS. ....  | 92  |
| FIGURE 6-4: ACTIVITY OF AN INSTRUCTION INSTANCE. ....                                   | 93  |
| FIGURE 6-5: DERIVATION OF AN INSTRUCTION FRAME FROM THE GENERIC FORM. ....              | 94  |
| FIGURE 6-6: ROOT FRAME. ....  | 95  |
| FIGURE 6-7: LINKING AGENT, ROOT, AND PLAN TREE. ....                                    | 95  |
| FIGURE 6-8: INSTRUCTION AS A "BLACK BOX". ....  | 96  |
| FIGURE 6-9: RULESET FOR PLAN SELECTION ASSOCIATED TO AN INSTRUCTION. ....               | 98  |
| FIGURE 6-10: USE OF RELATIONS IN A CONTEXT IDENTIFICATION. ....                         | 100 |
| FIGURE 6-11: AN EXAMPLE OF A PLAN SELECTOR, FOR THE <i>PICK_UP</i> INSTRUCTION. ....    | 101 |



|   |     |
|---|-----|
| FIGURE 6-12: PLAN INSTANTIATION AND PARAMETERISATION. ....  | 102 |
| FIGURE 6-13: EXAMPLE OF PARAMETER BINDING. ....   | 103 |
| FIGURE 6-14: INSTRUCTION AS A COLLECTION OF ACTIVITIES. ....  | 105 |
| FIGURE 6-15: TWO TYPICAL TYPES OF INSTRUCTION PLANS. ....   | 106 |
| FIGURE 6-16: INSTRUCTION PLAN AS PRODUCTION RULES. ....   | 106 |
| FIGURE 6-17: CONTRASTING KNOWLEDGE WITH GOAL. ....  | 107 |
| FIGURE 6-18: INSTRUCTION CONTROL SCHEME. ....   | 109 |
| FIGURE 6-19: STRUCTURE OF THE FAILURE CONTROL. ....   | 110 |
| FIGURE 6-20: PARTIAL CODING FOR FAILURE HANDLING. ....  | 111 |
| FIGURE 6-21: PARTIAL DESCRIPTION OF THE <i>BARMAN</i> AND <i>GLASS</i> FRAMES. (SLOTS WITHOUT “DEFAULT” ARE<br>EXAMPLES OF INSTANTIATED VALUES.) .... | 113 |
| FIGURE 6-22: DEVELOPING AN INSTANCE OF <i>CLEAR_COUNTER</i> INSTRUCTION. ....   | 115 |
|   |     |
| FIGURE 7-1: EQUIVALENCE OF PLAN TO TWO PARTIAL PLANS WITH MESSAGE. ....   | 119 |
| FIGURE 7-2: GENERAL MESSAGE EXCHANGE SCHEME. ....   | 120 |
| FIGURE 7-3: MESSAGE FRAME. ....   | 121 |
| FIGURE 7-4: MESSAGE CONTROL. ....   | 122 |
| FIGURE 7-5: MESSAGE COMMUNICATION PROCESS. ....   | 123 |
| FIGURE 7-6: MULTIPLE MESSAGE EXCHANGE. ....   | 124 |
|   |     |
| FIGURE 8-1: TASK CONTROLLER SCHEME. ....  | 126 |
| FIGURE 8-2: THE GENERAL TASK FRAME. ....  | 127 |
| FIGURE 8-3: PROCESS CALLBACK SCHEME. ....   | 131 |
| FIGURE 8-4: MESSAGE CALL TO <i>BAS</i> . ....   | 132 |
| FIGURE 8-5: SCHEME. ....  | 132 |
| FIGURE 8-6: THE TASK <i>KS</i> . ....   | 135 |
| FIGURE 8-7: THE DRINK TASK PROCEDURE. ....  | 136 |
| FIGURE 8-8: BLENDING STATES FOR TASK CONTROL. ....  | 137 |
| FIGURE 8-9: SCHEDULING MOTION COMMANDS TO THE ANIMATION SYSTEM. ....  | 137 |
|   |     |
| FIGURE 9-1: OVERVIEW OF THE SCHEDULER CONTROL. ....   | 141 |
| FIGURE 9-2: SOURCE OF ACTIVITIES. ....  | 144 |
| FIGURE 9-3: THE EVENT "JOHN ENTERING A NEW AREA" CAUSES REACTIONS FROM OTHERS. ....   | 148 |
| FIGURE 9-4: PRIORITY ACCORDING TO SOURCE OF ACTION. ....  | 149 |
| FIGURE 9-5: TWO VERSIONS OF PLANS FOR THE “COLLECT GLASS” ACTION. ....  | 151 |
| FIGURE 9-6: <i>PARALLEL TASK</i> HOLD GLASS IS INITIATED AND TERMINATED WITHIN THE SAME PLAN. ....  | 152 |
| FIGURE 9-7: THE ACTION OF CHEERING OCCURS OPPORTUNISTIC WHILE THE AGENT IS HOLDING A GLASS. ....  | 152 |
| FIGURE 9-8: CONTINUOUS AND INTERRUPTED SEQUENCES OF MOTIONS. ....   | 153 |
| FIGURE 9-9: EXAMPLE OF PARALLEL TASKS DEVELOPED BY THE DRINK INSTRUCTION. ....  | 154 |
| FIGURE 9-10: SET OF RULES IMPLEMENTING THE DRINK INSTRUCTION. ....  | 155 |

|   |     |
|---|-----|
| FIGURE A.1: LAYOUT OF THE ANIMATION SCENARIO WITH 9 CAMERA VIEWING POSITIONS. ....                                | 176 |
| FIGURE A.2: THE ANIMATOR’S SCRIPT. ....   | 180 |
| FIGURE A.3: GOAL-DIRECTED ACTIONS GENERATED BY THE ANIMATION SYSTEM IN RESPONSE TO THE<br>ANIMATOR’S SCRIPT. .... | 181 |
| FIGURE A.4: INSTANCES OF THE ACTIVE AGENTS FRAMES. ....   | 182 |
| FIGURE A.5: THE ACTIONS HIERARCHIES. ....   | 183 |
| FIGURE A.6: TWO SUB-ACTIONS INTERNAL TO THE CORRESPONDENT GOAL-DIRECTED ACTIONS. ....                             | 183 |
| FIGURE A.7: TWO PROCESSES CORRESPONDENT TO THE GOAL-DIRECTED ACTIONS.....   | 183 |
| FIGURE A.8: PRINTOUT OF INSTANCES OF SOME OF THE ANIMATED OBJECTS. ....   | 184 |
| FIGURE A.9: DETAILED SCRIPT GENERATED BY THE CONTROLLER AND SET TO THE BAS. ....                                  | 189 |
| FIGURE A.10: SELECTED FRAMES OF THE ANIMATED SCENE. (CONT.).....  | 191 |