

## TABLE OF CONTENTS

| CHAPTER NO. | TITLE   | PAGE NO. |
|-------------|---|----------|
|             | <b>ABSTRACT</b>   | iii      |
|             | <b>LIST OF TABLES</b>                                   | xii      |
|             | <b>LIST OF FIGURES</b>                                  | xiii     |
|             | <b>LIST OF SYMBOLS AND ABBREVIATIONS</b>                | xv       |
| <b>1</b>    | <b>INTRODUCTION</b>                                     | 1        |
|             | 1.1 CONCEPTION AND EVALUATION OF IDEAS                  | 2        |
|             | 1.2 SCOPE OF THE PRESENT INVESTIGATION                  | 3        |
|             | 1.3 ORGANIZATION OF THE THESIS                          | 4        |
| <b>2</b>    | <b>REQUIREMENTS ENGINEERING</b>                         | 5        |
|             | 2.1 INTRODUCTION  | 5        |
|             | 2.2 IMPORTANCE OF REQUIREMENTS<br>ENGINEERING           | 8        |
|             | 2.3 CURRENT DEVELOPMENTS IN<br>REQUIREMENTS ENGINEERING | 11       |
|             | 2.4 REQUIREMENTS DEFINITION AND<br>CLASSIFICATION       | 16       |
|             | 2.4.1 Definitions                                       | 16       |
|             | 2.4.2 Classifications of Requirements                   | 18       |
|             | 2.5 THE SDLC MODELS                                     | 20       |
|             | 2.5.1 Waterfall Model                                   | 20       |

| <b>CHAPTER NO.</b> | <b>TITLE</b>   | <b>PAGE NO.</b> |
|--------------------|--|-----------------|
|                    | 2.5.2 Prototyping Model                                | 22              |
|                    | 2.5.3 Incremental Model                                | 24              |
|                    | 2.5.4 Spiral Model                                     | 26              |
|                    | 2.5.5 RUP Process                                      | 28              |
|                    | 2.5.6 XP Model   | 32              |
| 2.6                | OTHER TECHNIQUES                                       | 34              |
|                    | 2.6.1 Modeling Requirements                            | 34              |
|                    | 2.6.2 Types of Modeling                                | 35              |
|                    | 2.6.3 Formal Methods                                   | 36              |
| 2.7                | SUMMARY  | 37              |
| <br>               |  |                 |
| <b>3</b>           | <b>FUZZY LOGIC</b>                                     | <b>40</b>       |
|                    | 3.1 INTRODUCTION                                       | 40              |
|                    | 3.2 EVOLUTION  | 41              |
|                    | 3.3 THE BASE ON WHICH FUZZY LOGIC<br>IS BUILT          | 43              |
|                    | 3.4 FUZZY LOGIC ANALYSIS AND CONTROL                   | 44              |
|                    | 3.5 THE FUZZY LOGIC METHOD                             | 45              |
|                    | 3.6 FUZZY PERCEPTION                                   | 46              |
|                    | 3.7 MISCONCEPTIONS AND CONTROVERSIES                   | 47              |
|                    | 3.8 FUZZY LOGIC REPRESENTATION                         | 49              |
|                    | 3.9 FUZZY LOGIC IS SIMPLE                              | 50              |
|                    | 3.10 FUZZY LOGIC TERMS                                 | 52              |
|                    | 3.11 PROGRESS IN FUZZY LOGIC                           | 55              |
|                    | 3.12 FUZZY LOGIC CONTROL INPUT - HUMAN<br>AND COMPUTER | 56              |
|                    | 3.13 BUILDING A FUZZY SYSTEM                           | 60              |

| <b>CHAPTER NO.</b> | <b>TITLE</b>  | <b>PAGE NO.</b> |
|--------------------|---|-----------------|
| 3.14               | THE STEPS IN BUILDING A FUZZY<br>SYSTEM                                       | 61              |
| 3.15               | SUMMARY   | 68              |
| <b>4</b>           | <b>REQUIREMENTS ENGINEERING APPLYING<br/>FUZZY LOGIC</b>                      | <b>71</b>       |
| 4.1                | AIR QUALITY - SURFACE OZONE   | 71              |
| 4.2                | FAT THEOREM - FUZZY APPROXIMATION<br>THEOREM WITH FUZZY ASSOCIATIVE<br>MEMORY | 72              |
| 4.3                | POLLUTION MAPPING AND FORECASTING<br>MODEL                                    | 80              |
| 4.4                | ADAPTIVE SYSTEMS  | 87              |
| 4.5                | AIR QUALITY - SURFACE OZONE<br>(ADAPTIVE SYSTEM)                              | 92              |
| 4.6                | ADAPTIVE FUZZY SYSTEM FOR<br>PREDICTING ENVIRONMENTAL<br>CHARACTERISTICS      | 92              |
| <b>5</b>           | <b>SUMMARY AND CONCLUSION</b>   | <b>99</b>       |
| 5.1                | SUMMARY   | 99              |
| 5.2                | CONCLUSION  | 99              |
| 5.3                | THE ROAD AHEAD  | 101             |
| 5.3.1              | Problem Frames  | 101             |
| 5.3.2              | Goal-Oriented Requirements Analysis   | 103             |
| 5.3.3              | Safety-critical Requirements  | 104             |
| 5.3.4              | Inquiry-Based Requirements Analysis   | 104             |
| 5.4                | CONTINUATION OF THIS WORK   | 105             |

| <b>CHAPTER NO.</b> | <b>TITLE</b>                | <b>PAGE NO.</b> |
|--------------------|-----------------------------|-----------------|
|                    | <b>REFERENCES</b>           | 107             |
|                    | <b>LIST OF PUBLICATIONS</b> | 115             |
|                    | <b>VITAE</b>                | 116             |

**LIST OF TABLES**

| <b>TABLE NO.</b> | <b>TITLE</b>   | <b>PAGE NO.</b> |
|------------------|--|-----------------|
| 4.1              | Details of Air quality monitoring stations in<br>Chennai, India  | 72              |
| 4.2              | National Ambient Air Quality Standards (NAAQS)<br>Air pollutants | 73              |
| 4.3              | Pollutant readings in different areas                            | 74              |

## LIST OF FIGURES

| FIGURE NO. | TITLE   | PAGE NO. |
|------------|---|----------|
| 2.1        | Main phases in the SDLC   | 7        |
| 2.2        | Relative cost to repair a defect at different software<br>life cycle phases   | 10       |
| 2.3        | Major problems in software development  | 11       |
| 2.4        | Distribution of errors in the SRS   | 13       |
| 2.5        | Relationships of requirements, specifications,<br>and domains   | 17       |
| 2.6        | Categories of non-functional requirements   | 19       |
| 2.7        | Waterfall model   | 21       |
| 2.8        | Rapid prototyping models  | 23       |
| 2.9        | Incremental model   | 25       |
| 2.10       | Spiral model  | 27       |
| 2.11       | Extreme programming model   | 33       |
| 3.1        | The fuzzy logic control-analysis method   | 46       |
| 3.2        | Motor speed control system  | 61       |
| 3.3        | Cause-effect  | 64       |
| 3.4        | Speed above target value  | 65       |
| 3.5        | Determination of control voltage to motor   | 66       |
| 4.1        | Hourly variations of ozone and meteorological<br>parameters obtained from 25 to 26 May 2005<br>at Koyambedu Ozone and wind speed, (b) ozone<br>and wind direction and (c) ozone and relative humidity | 76       |

| <b>FIGURE NO.</b> | <b>TITLE</b>  | <b>PAGE NO.</b> |
|-------------------|---|-----------------|
| 4.2               | Hourly variations of ozone and meteorological parameters obtained from 31 to 1 May June 2005 at Mandaveli. Ozone and wind speed, (b) ozone and wind direction and (c) ozone and relative humidity   | 77              |
| 4.3               | Hourly variations of ozone and meteorological parameters obtained from 03 to 04 June 2005 at Taramani. Ozone and wind speed, (b) ozone and wind direction and (c) ozone and relative humidity       | 78              |
| 4.4               | Hourly variations of ozone and meteorological parameters obtained from 04 to 05 July 2005 at Vallalar Nagar. Ozone and wind speed, (b) ozone and wind direction and (c) ozone and relative humidity | 79              |
| 4.5               | Ozone distribution  | 81              |
| 4.6               | Relative humidity distribution  | 82              |
| 4.7               | Ozone to relative humidity  | 83              |
| 4.8               | RH 30% comfortable - 50% low  | 85              |
| 4.9               | “x” geometric centroid  | 85              |
| 4.10              | Fuzzy associative memories  | 87              |
| 4.11              | DIRO black box  | 88              |
| 4.12              | Ozone readings on many different days at a particular place on hourly basis – Dot clusters  | 94              |
| 4.13              | Quantized Dot clusters from Figure 4.12 and graph showing trend   | 95              |
| 4.14              | Ozone readings against relative humidity on different days at same place – Dot clusters   | 97              |
| 4.15              | Quantized Dot clusters from Figure 4.14 and graph showing trend   | 98              |

## LIST OF SYMBOLS AND ABBREVIATIONS

### Symbols

|                 |   |                    |
|-----------------|---|--------------------|
| CO <sub>2</sub> | - | Carbon dioxide     |
| NO <sub>x</sub> | - | Oxides of Nitrogen |
| O <sub>3</sub>  | - | Ozone              |
| ppb             | - | Parts per billion  |

### Abbreviations

|        |   |   |
|--------|---|---|
| AOP    | - | Aspect-Oriented Programming                               |
| AOSD   | - | Aspect-Oriented Software Development                      |
| DOD    | - | Department of Defense                                     |
| ESPITI | - | European Software Process Improvement Training Initiative |
| FAM    | - | Fuzzy Associative Memory                                  |
| FAT    | - | Fuzzy Approximation Theorem                               |
| FCM    | - | Fuzzy Cognitive Mapping                                   |
| IDE    | - | Integrated Development Environment                        |
| IE     | - | Integrated Environment                                    |
| JAD    | - | Joint Application Design                                  |
| NAAQS  | - | National Ambient Air Quality standards                    |
| NASA   | - | National Aeronautic and Space Agency                      |
| NFR    | - | Non-Functional Requirements                               |
| NPP    | - | Nuclear Power Plant                                       |
| NRC    | - | National Research Council                                 |
| PC     | - | Personal Computer   |
| PD     | - | Participatory Design                                      |



|      |   |   |
|------|---|---|
| PLC  | - | Programmable Logic Controllers          |
| PSI  | - | Pounds per square inch                  |
| RH   | - | Relative Humidity                       |
| RSPM | - | Respirable Suspended Particulate Matter |
| RUP  | - | Rational Unified Process                |
| SRS  | - | Software Requirements Specification     |
| TSPM | - | Total Suspended Particulate Matter      |
| WD   | - | Wind Direction                          |
| WHO  | - | World Health Organization               |
| WS   | - | Wind Speed                              |