CHAPTER 3

PERFORMANCE REQUIRENTS IDENTIFICATION

This chapter explains about the identification of performance requirements. It includes sub sections like importance of performance requirements identification, proposed model for identification and case studies. Requirements identification is an important activity in requirements engineering [112]. In requirements identification, both functional and nonfunctional requirements can be gathered. Performance is an important property for a software system which falls under the category of nonfunctional requirements. It is important and necessary to identify the performance requirements in the initial stages of the development of any software system. If performance requirements are not identified properly, then the product developed with improper performance requirements specification may not be accepted by the customers [113].

3.1 Importance of Performance Requirements Identification

The main reason for failure of the software projects in most of the cases is poor system performance [114]. The causes of poor performance are improper specification performance requirements at requirements analysis. Since performance problems often have their roots in poor performance requirements specification, the early establishment of performance requirements for a new system is crucial to the project’s success [115, 116]. As the importance of performance requirements increasing in recent times, researchers are showing a lot of interest in this area. Most of the times, non-compliance of performance requirements of the software occurs is due to improper identification models. There are some models available for performance prediction, such as queuing
network models, which are widely used for performance prediction and the feasibility of the performance requirements can be validated by the output of these models. The earliest decisions which can be made during the requirements analysis can affect the performance of a software system. There are some approaches proposed in the literature for performance requirements identification. These approaches were discussed in the literature survey in chapter 2.

The proposed approaches are not that much effective and complete in identification of performance requirements. Each approach has its own advantages and disadvantages. One of the disadvantages is, they depend on design information. They cannot identify the performance requirements in the initial stages of the project. If these approaches are used, probably it is difficult to identify the performance requirements of the software system correctly and completely. Since the existing approaches do not identify the performance requirements properly and completely, in this thesis a five layered model is proposed to identify performance requirements properly and completely, in the initial stages of the project.

3.2 Performance Requirements Identification Approach

As the identification of performance requirements is an important activity in software development, a layered model is proposed for identification of performance requirements. This model includes five layers. These are stakeholder, goals, sub goals, performance parameters, and performance requirements. The first layer is about stakeholders. Single view does not provide information about all the requirements; it considers only one particular perspective. Multiple views must be considered in order to identify the
performance requirements completely to meet all stakeholder expectations [117]. The second layer is goals. In this layer all the goals of stakeholders will be identified. The third layer is sub goals. In this layer, goals identified in the second layer can be decomposed into sub goals. The fourth layer is performance requirements. In this layer, all the performance requirements for corresponding sub goals will be identified. Fifth layer is performance parameters. After identifying the performance requirements, the respective performance parameters for performance requirements will be identified. The five layered model is shown in figure 3.1.

Figure 3.1: General architecture of the five layered model for performance requirements identification
This approach contains set of rules and layered model for identification of performance requirements. This approach is used to identify the goals of all stakeholders, sub goals of all goals, performance requirements and finally performance parameters (Response time, Throughput, Resource utilization, and Execution demand) from different views of various stakeholders. The aim of the proposed approach is to identify all performance requirements of the system.

There are many advantages of proposed layered model, they are:

- **Scalability:** Layered approach is better in scaling than horizontal approaches.

- **Flexibility:** Flexibility can be improved in terms of choices and options by using layered approach.

- **Cost Effective:** Any software system can be developed economically by using the layered approach.

- **Task segmentation:** Dividing the complex and large systems into sub-components that are manageable by which any system development become easy.

- **Enhanced Understanding:** Understanding and examining each Layer in the layered model is very easy like what processes and procedures can be used in each layer.

- **Rapid Application Development:** Identification of performance requirements can be done in short time span by using layered approach, which leads fast application development.
The following three statements are used to describe requirements of any software system [118].

*Each user* wants the *system* to do *something* for *him*.

*Each system* provides *services* to *user*.

*Each service* must satisfy some *constraints* in order to meet customer needs.

Functional requirements state *what* the system supposed to do, and nonfunctional requirements state *how* the system supposed to be.

The above process uses the following rules. These are:

*Who* are stakeholders?

*What* are services (goals)?

*What* are sub goals of each service?

*How* these sub goals are achieved under performance constraints?

*What* is the performance parameter of each performance requirement?

The rules proposed are visualized in the following rule.

*Who* is stakeholder *What* are the services (goals) that system should provide to the stakeholder, *What* are the sub goals for the goals, *How* the system will perform sub goals under constraints, *What* is the performance parameter related to performance requirement.
Key words like `<who>`, `<what>`, `<how>` are variables which can be assigned for specific words in the given context.

Key words used in the rules are:

Who: Stakeholders.

What: Functional requirements/services/parameters.

How: Performance requirements/constraints.

Figure. 3.2. Performance requirements identification process

The main objective of this approach is the identification of performance requirements (constraints). The identification process is divided into four steps, which is shown in the
activity diagram in figure 3.2. The fourth activity in the figure 3.2 “Identify constraints over sub goals” refers to “identify performance constraints over sub goals”.

Step 1: Identify key stakeholders of system.

Step 2: Identify goals of all stakeholders.

Step 3: Decompose goals into sub goals.

Step 4: Identify performance constraints for each sub goal.

All the performance requirements are identified by using the procedure stated in figure 2.

3.3 Metrics for Performance Requirements Specification

Davis has proposed a metric for identifying and measuring the quality of software requirements specifications [119]. This metric is used for determining the completeness of performance requirements in this thesis.

The metric used to determine completeness of requirements is:

\[
MCR = \frac{n_c}{n_c + n_{nv}}
\]  
(3.1)

Where \(n_c\) represents the number of requirements that are validated as correct and \(n_{nv}\) is number of requirements that are not yet validated. In this chapter, the equation (3.1) is used for finding the completeness of performance requirements.

3.4 Performance Requirements Validation

For validating software performance requirements, the following checklist is used [120].

- Is each requirement unambiguous and bounded?
- Is the requirement is quantitatively bounded?
- Does any requirement conflict with other requirements?
- Is each requirement testable if it gets implemented?
- Are requirements clearly stated? Can they be misinterpreted?
- Is each requirement technically achievable?
- Does each requirement have the source?
- Is the requirement traceable to goals of the system?

The above mentioned checklist has been used to validate the proposed approach. The information used in the validation was collected in the form of answers for the questions from different people for the library management system, online shopping system and Automatic Teller Machine (ATM) system with respect to performance requirements.

3.5 Case Studies

The proposed model was applied on three case studies. First one is library management system, second one is online shopping system and third one is ATM system. It helps to identify all performance requirements. Along with performance requirements, performance parameters are also identified by using the proposed model. Different stakeholders may use these systems where each stakeholder will have various goals from various perspectives. In this approach the proposed rules are used in identifying the performance requirements and parameters in three case studies.
3.5.1 Library Management System

For this library management system different stakeholders are there like member, librarian etc. Each stakeholder is defined with their own goals and performance requirements. The performance requirements are identified using the rules.

Rule 1: \textit{who} are stakeholders?

The identified stakeholders’ information is given in the table 3.1.

Rule 2: \textit{What} are the services (goals)?

The identified services (goals) for all the stakeholders are given in the table 3.1.

Rule 3: \textit{What} are the sub goals of each service?

Sub-goals for stakeholders Member and Librarian are presented in figure 3.3. The other sub-goals are identified for all the stakeholders and given in table 3.1.

Rule 4: \textit{How} the sub goals are achieved under performance constraints?

Rule 5: \textit{What} is the performance parameter of each performance requirement?

Table 3.1 gives the information about the identified performance requirements of all the stakeholders, and figure 3.3 shows the performance requirements for stakeholders “Librarian” and “Member”.
Figure 3.3 Five layered performance requirements identification sample for Library Management System
The computed value of MCR for the library management system as per equation 3.1 is:

\[ MCR = \frac{21}{21+0} = 1. \]

The completeness of the requirements is the maximum if the value of MCR is closer to 1. In this chapter, the equation 3.1 is used for performance requirements. The validation of the requirements is done based on the check list which is given in section 3.4. It is found that for all 8 questions the answer is yes. The validation metric value is 8/8 = 1 Hence, the completeness of the requirements is validated.

Table 3.1: Performance requirements identification for library management system

<table>
<thead>
<tr>
<th>System</th>
<th>Library management system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholders</td>
<td>Member, Librarian, System administrator</td>
</tr>
<tr>
<td>All Performance requirements</td>
<td>Login response time must be &lt; 2 sec, Search book within 5 sec, Response time for select book is 6 sec, Get book within 10 sec, Provide details within 5 sec, Response time for return book &lt; 10 sec, Add 10 students per 2 min, Add 10 employees per 2 min, Add 10 publishers per 3 min, Add 10 books per 2 min, Add 10 journals per 2 min, Add 20 CD’s per 2 min, Verification must be fast, Issue book must be &lt; 1 min, Update account for every transaction, Details should verified within 2 sec, Update account for every 10 min.</td>
</tr>
<tr>
<td>Performance parameters</td>
<td>Response time, Throughput, Resource utilization, Execution demand</td>
</tr>
</tbody>
</table>

Performance requirements and parameters identification for library management system is shown in the figure 3.3, is only for two stakeholders. The information about all stakeholders is given in table 3.1.
3.5.2 Online shopping System

Online shopping is an application which provides various services to customers to purchase goods through internet directly from sellers. The main stakeholders in online shopping system are system and customer. Each stakeholder is defined with their own goals and performance requirements. The performance requirements are identified by using the rules.

Rule 1: *who* are stakeholders?

The identified stakeholders are given in table 3.2.

Rule 2: *what* are the services (goals)?

The identified services (goals) for all the stakeholders are given in table 3.2.

Rule 3: *what* are the sub goals of each service?

Sub-goals for stakeholders Customer and System are presented in figure 3.4. The other sub-goals are identified for all the stakeholders and given in table 3.2.

Rule 4: *how* the sub goals are achieved under performance constraints?

Rule 5: *what* is the performance parameter of each performance requirement.

The identified performance requirements for all the stakeholders are given in table 3.2, and performance requirements for system and customer are shown in figure 3.4.
Figure 3.4: Five layered performance requirements identification sample for online shopping system
The metrics MCR is computed for the online shopping system based on equation (3.1).

The computed value of MCR for the online shopping system is:

\[ \text{MCR} = \frac{16}{16+0} = 1 \]

The completeness of the requirements is the maximum if the value of MCR is closer to 1. The validation of the requirements is done based on the check list which is given in section 3.4. It is found that for all 8 questions the answer is yes. The validation metric value is \( \frac{8}{8} = 1 \). Hence, the identified PRs are validated.

Table 3.2. Performance requirements identification for online shopping system.

<table>
<thead>
<tr>
<th>System</th>
<th>Online shopping system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholders</td>
<td>Customer, System</td>
</tr>
<tr>
<td>All Goals for all stakeholders</td>
<td>Login, Select product category, Select product, Add to cart, Check the shopping cart, Checkout, Confirm the order</td>
</tr>
<tr>
<td>Sub goals for all goals</td>
<td>User login, New user registration, Search product by name, Search product by type, Search product by category, View details, Select the item, Provide bill details, Provide delivery details, Provide payment details, Confirm the order, Receive input, Display product, Display product details, Receive details, Process the order.</td>
</tr>
<tr>
<td>All performance requirements</td>
<td>Login response time must be &lt; 2 sec, Search product should be completed within 5 sec, Time for add item is 6 sec, Checkout should process large amount data, Process order within 7 sec, Payment must be completed within 30 sec, Checkout within 5 sec.</td>
</tr>
<tr>
<td>All Performance parameters</td>
<td>Response time, Throughput, Resource utilization, Execution demand</td>
</tr>
</tbody>
</table>

Performance requirements and parameters identification for online shopping system is shown in the figure 3.4, is for only two stakeholders. The information about all stakeholders is given in table 3.2.
3.5.3 ATM System

ATM system is a device which provides various financial services to users, such as withdrawing, transferring, depositing the money and other payments of different banks and institutions. Customer and system administrator are main stakeholders in ATM system. Each stakeholder will have their own goals and performance requirements. The performance requirements are identified by using the rules.

Rule 1: <who> *are the stakeholders*?

The identified stakeholders are given in table 3.3.

Rule 2: <What> *are the services (goals)?*

The identified services (goals) for all the stakeholders are given in table 3.3.

Rule 3: <What> *are the sub goals of each service?*

Sub-goals for stakeholders Customer and System administrator are presented in figure 3.5. The other sub-goals are identified for all the stakeholders and given in table 3.3.

Rule 4: <How> *the sub goals are achieved under constraints?*

Rule 5: <What> *is the performance parameter of each performance requirement?*

Performance requirements identified for stakeholders Customer and system administrator are shown in figure 3.5.
<table>
<thead>
<tr>
<th>Layer1: Stakeholder</th>
<th>Layer 2: Goals</th>
<th>Layer 3: Sub Goals</th>
<th>Layer 4: Performance requirements</th>
<th>Layer5: Performance Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Customer</td>
<td>Withdraw Money</td>
<td>Select account</td>
<td>Select account within 15 sec</td>
<td>Response time</td>
</tr>
<tr>
<td></td>
<td>Check Balance</td>
<td>Enter amount</td>
<td>Enter amount within 10 sec</td>
<td>Response time</td>
</tr>
<tr>
<td></td>
<td>Transfer Money</td>
<td>Process transaction</td>
<td>Process transaction in 30 sec</td>
<td>Response time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Receive cash</td>
<td>Receive cash within 30 sec</td>
<td>Response time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Select account</td>
<td>Select account within 15 sec</td>
<td>Response time</td>
</tr>
<tr>
<td>2. System Administrator</td>
<td>Manage cash</td>
<td>Check availability</td>
<td>Check details in 2 min</td>
<td>Response time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Update Account</td>
<td>Update account for every</td>
<td>Resource utilization</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>transaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Update system</td>
<td>Update system every week</td>
<td>Resource utilization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resolve issues</td>
<td>Solve issues within 24 hours</td>
<td>Response time</td>
</tr>
</tbody>
</table>

Figure 3.5: Five layered performance requirements identification sample for ATM system
The metrics MCR is computed for ATM System based on equation (3.1). The computed value of MCR for ATM system is:

\[ MCR = \frac{16}{16+0} = 1 \]

The completeness of the requirements is the maximum if the value of MCR is closer to 1. The validation of the requirements is done based on the check list which is given in section 3.4. It is found that for all 8 questions the answer is yes. The validation metric value is \( \frac{8}{8} = 1 \). Hence, the identified PRs are validated.

The performance requirements identified for all the stakeholders are given in the table 3.3.

<table>
<thead>
<tr>
<th>System</th>
<th>ATM System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholders</td>
<td>Customer, System administrator</td>
</tr>
</tbody>
</table>

All Goals
- Withdraw money, Check balance, Deposit money, Transfer money, Get mini statement, Display Information, Verify card, Process transaction, Update account, Update database, Print receipt, Change password.

All Sub goals
- Enter pin number, Send result, Receive pin number, Verify pin number, Select account type, Enter amount, Check account type, Process transaction, Dispatch cash, Receive cash, Select option, Takes envelope, Put cash, Place the envelope, Select account, Enter amount, Send money, Display account information, Receive details, Update details.

All performance requirements
- Select account in 15 sec, Enter amount within 10 sec, Display information in 5sec, Customer should take money within 30 sec, Transfer money should be done within 6sec, Transaction process must be completed within 5 sec, Update data base for every 2 min, Print receipt within two 5sec, Update the system for every week, Check details in 10 sec, Send money in 10 sec, Enter pin in 10 sec, Confirm pin in 5 sec.

All performance parameters
- Response time, Throughput, Resource utilization, Execution demand
3.6 Summary

Customers always prefer the system with good performance. To produce the product with acceptable performance, all the performance requirements must be identified and incorporated in the software. In this chapter a five layered model is proposed for identifying performance requirements. Set of generic conceptual rules are proposed in this approach, which are used in the performance requirements identification process. One of the metrics proposed by David is used for completeness of performance requirements and check list for requirements validation. By this model and rules, it is possible to identify all the performance requirements required by all stakeholders. The proposed model is applied on three case studies successfully and found that the proposed approach is better in finding the performance requirements completely.