

# Quantify Autonomy for Agent Based Systems

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**Abstract :** Technology is accumulative intricacy of software hence Agents are acquainting with as a paradigm in software engineering. Agents are centred on societal opinion of computations and assistance by the sensors that are the reason after their continuous environment sensing. Autonomous feature of software agent differentiates it from objects in object oriented paradigm. Agent is capable to take decision without the human intervention. Agent autonomy also reflects the social aspects as in human society. Autonomy behavior of an agent must be designed by designer in a way so that requirements can be minimized for behavior and internal structure to support heterogeneity. In this paper, autonomy is evaluated with the help of framework. Autonomy is considered one of the important feature compare to others which align towards pro-activity and autonomy in the organization. Autonomy is calculated with the help of Analytical Hierarchy Process (AHP) lined on psychology and mathematics. The weight values are evaluated using for characteristics. These weight values are used with the actual value of characteristic for measurement of autonomy.

**Keywords :** Agent Based System, AHP, Autonomy, Measurement, Metrics.

## 1. INTRODUCTION

Various software design paradigms *i.e.* procedural, object, component and agent oriented paradigms etc. have been introduced in software engineering. One of emerging paradigm is agent orient paradigm where object is in active form unlike in object and component oriented paradigm.

Agents are centred on societal opinion of computations and assistance by the sensors those are the reason after their continuous environment sensing. Franklin and Grasser [1] discussed that Agent being intelligent organism placed in environment is capable to take autonomous actions to fulfil their design objectives for a system. An agent stays within an environment, sense and acts on it, next time, in pursuit of its own agenda it affects sensed in the future [2]. Dynamic environment is the best suited place for intelligent agents constructed on their ability to learn from environment as well as train from predefined situation.

Categories of agents are outlined based on their functionality *i.e.* simple agents who have predefined processing rules and self activated on condition arises. Agents are self-governed with no intervention from external resource (users). For example, when call is made, bell rings and after a defined duration, call will be transferred automatically to the answering machine.

An agents are followed by goal-oriented approach and sense the environment constantly and perform autonomously own controllable action if any changes are detected, without intervention of humans with the help of other agents interaction to complete the task. On top of the distinctiveness has been attested that an agent as component, which activates them self by sensing the environment. Software development has enriched to adopt new technique which is increasing intricacy to improve quality and adaptability of system in different environment on multi platforms.

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The agent is relatively related to object and component, which is based on system, follows the concept of object oriented development. Agent is active object contrasting object act passively in object oriented paradigm. Agent component has autonomous and reactivity property furnishes potency diverse in different environment. Many metrics are proposed metrics for object and component based systems are not adequate. Dumke et al. [3] projected for the entire stages of the object-oriented systems. Lee et al. [4] clarified metrics for class coupling and cohesion. Gill and Balkishan [5] proposed metrics for interaction complexity for component based systems. Gill and Grover [6] interface complexity metrics measure for component includes interface signature, constraints, packaging and configurations. Arun et al. [7] measure the quality of component systems by using suitable metrics. AHP is method used to assess the multifaceted result. In this method first problem is crumbled into hierarchy of sub-problems. First, each sub-problem is evaluated individually. In next step this sub-problems help to evaluate the upper level. AHP is used in this paper to identify quality. We also use AHP to measure the autonomy of the agent based system.

**Various significant complexity issues have come across on the nature of agent :**

- Agent Communication
- Process time
- Receptiveness of resources for an agent in surroundings
- Time to grasp surroundings
- Switching time from one environment to another
- Action taken by agents
- Number of unpredictable changes in environment
- Interoperability among agents
- belief and reputation

Accordingly, additional Software metrics are entailed to certain the quality of agent based systems, measure the quality of the systems.

## **2. RELATED WORK**

Metrics are measured for software to maintain the quality of system which serves as purpose comparison, cost estimation, fault predictions and forecasting. For quantitative evaluation, software process and product metrics are used that facilitate software industry to closely judge the efficacy of software by the accomplishment of process for projects and procedure followed. Analyse and compared the means of basic quality and productivity data with the past and get the conclusion for progress have cropped up. Metrics too get through the isolate tricky parts to facilitate the remedies which can be do up for software process improvement. The judgement of software must be quantitative rather subjective. With quantitative evaluation, trends (either high-quality or bad) have been marked to make a better assessment and accomplished true enhancement over time.

Sivakumar et al. [8] presented a metric to measure quality of software for an Agent Oriented System. For this, a tool is proposed to measure the quality. Hoa Khanh Dam et al. Dam [9] worked on maintenance phase with the help of agents. Inconsistencies are repaired using event-triggered plans. Barber and Martin [10] discussed autonomy in terms of identification of goals, role of each decision making agent and declaration of decisions. The degree of autonomy is derived from the proposed model.

Fernando [11] evaluated autonomy with the help of structural complexity, Behavioral complexity, Executive message ratio, state update capability and occurrence of state updation. Further results are normalized in terms of 0 and 1 where 0 means poor and 1 means good. Marcus [12] proposed model for measurement of autonomy with the help of pragmatic interpretation based on social aspects of agent. Social dependence lined up task accepted, assigned and depend upon other agents for completion. Lei Li et al. [13] worked on the social behavior of agent for trust. A dynamic control mechanism is generated to synchronize the behavior in societal system to keep away from pessimistic group behavior. Abdelhay Haqiq et al. [14] proposed method for behavioural specification and verification of agents which is based on decisional aspect of agent.

### Hitch in established metrics aimed at number of deduces.

- Agent has individual thread of control due to autonomous nature.
- On account of autonomous nature agent will decide action by self. It perceives new things from environment.
- Agents are social in nature. Single agent cannot do all activities. They need cooperation of other agents to complete the task.
- Agents communicate with other agent with the help of their own interface. Each agent has independent interface to communicate with other agent.
- Agents are proactive to achieve their goal. They set their goals and wait for achievement.
- Agents have to communicate with different environment with different type of agents. That's why they are dynamic in nature.
- Agents are active objects unlike the object in object oriented systems.
- Each agent communicates with other agent through interface without knowing the details of others.

The autonomy of the agent based system is evaluated in this paper. Agents are distinguished from objects because of their autonomic behavior. They are not call up, sometimes jobs may be allocated. We found that success of agent based systems also pivot around autonomy. We focused on evaluation on autonomy that can be measured with the help of attributes *i.e.* pro-activity and behavior with in organization, which further aligned with multiple roles, negotiations, communications, failure analysis and subordinate position, task sharing. We further relate these attributes with architectural and component level design metrics. Ivan [15] et al. put forwarded metrics suite to measure agent oriented architectures. The respecting quality attributes are getting on with metrics: extensibility, modularity and complexity. We calculated autonomy with the help of metrics suite defined.

### 3. MEASUREMENT OF AUTONOMY

Agents should function with no involvement of outer elements (either human or agent). Agents have control on their own behaviour and internal states. Pierpaolo et al. [16] discussed that Autonomy pivot on pro-activity and autonomy within the organization. Pro-activity further lies on four aspect *i.e.* multiple roles, negotiations, communications and failure analysis Autonomy depends upon that whether agent is doing work of another subordinate agent and sharing the task with another agents. We have also used the above mentioned factors to measure the autonomy shown in Figure 1.

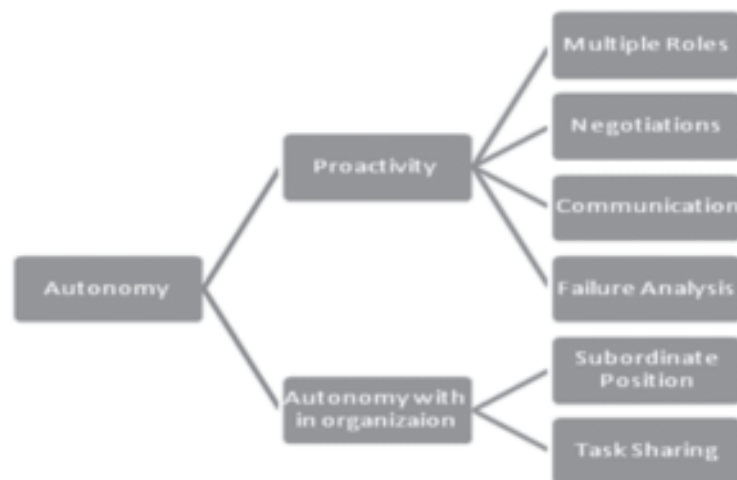


Fig. 1. Framework for Autonomy.

Some of the above mentioned factors are related with modular design in software engineering. If agent is able to perform multiple roles in a system, it is said to be cohesive system. If agent does not depend on other agents for achieving the goal then it is said that cohesion is high. So if agent is able to perform multiple roles then it can be relate with cohesion. Negotiation is the form of communication among agents to achieve the goal. Negotiation is

done with the help of communication can be evaluated with average number of communications. Communication is sum of incoming and outgoing communication is evaluated with the help of fan-in and fan-out. Failure analysis is assessed i.e. 1 if agent is capable, 0 if not capable. Subordinate Position is also assessed i.e. 1 if agent is capable, 0 if not capable. If agent shares the task among agents then it shows the dependency on other agents. It can be said that agent based system supports the coupling property. Task sharing is related to dependency on other agent in terms of knowledge or controlling the behavior of another agent. We used metrics suite to calculate coupling, cohesion, fan-in, fan-out and average number of communications defined by Ivan [15].

Agent based systems are not so much popular in software industry around. To set up these evidences as authentic exercise, we conducted a survey on small group with different age groups, profession i.e. students, faculty and software professionals. We discuss with them about an hour: what is agent based system, life cycle, intelligent behavior etc. We provide them material for study of agent, agent based system. After that we have query session to solve queries. This process is done at 2 different times in group of 17.

The answers obtained from survey are analyzed using Analytical Hierarchy Process (AHP) approach. AHP is a method that sustains decision makers in constructing complex resolution, quantifying vague factors, and estimate alternatives in multi-objective judgment state. It is ample and logical decision-making structure that offers a dominant methodology for establishing comparative significance amongst a position of aspects. AHP is mainly appropriate for multifaceted results that occupy the relationship of decision aspects which are complicated to compute. MS-Excel is used to evaluate the generated data.

The weight values of each sub-characteristic are ranging between 0 to 1 shown in Table 1. The summation of all weight values is 1. The table shows that communication plays important role for agents toward achieving the goal. Least preference is given to play multiple roles because if agent will perform multiple roles complexity. However all characteristic participate when autonomy is evaluated. The parent characteristic value is calculated with the summation of weight values of sub-characteristics under a characteristic.

**Table 1. Weight values of Sub-characteristic**

<i>Characteristic</i>	<i>Sub-characteristic</i>	<i>Weight Values</i>	<i>Sum</i>	<i>Grand Total</i>
Pro-activity	<b>Multiple Roles</b>	.110	.70	1.0
	<b>Negotiation</b>	.122		
	<b>Communication</b>	.360		
	<b>Failure Analysis</b>	.112		
Autonomy within organization	<b>Subordinate Position</b>	.120	.30	
	<b>Task Sharing</b>	.180		

**Following is the formula to evaluate the autonomy:**

$$A = w_p P + w_o O$$

Where  $w_p$  and  $w_o$  are the weight values for the proactivity (P) and autonomy within organization (O):

$$P = w_m M + w_n N + w_c C + w_f F$$

Where  $w_m$ ,  $w_n$ ,  $w_c$  and  $w_f$  are the weight values for the multiple roles (M), negotiation (N), number of communications (C) and failure analysis (F):

$$O = w_s S + w_t T$$

Where  $w_s$  and  $w_t$  are the weight values for the subordinate position (S) and task sharing (T):

#### 4. EVALUATION OF AUTONOMY

Three agent based systems are used for evaluating the autonomy *i.e.* Book Trading, Party and Security System. Book Trading and Party agent based systems are developed in JADE [17]. A case study based evaluation is done on security system having three agents: Home agent, Call agent and Alarm agent. Home agent resides in the environment and sensing for unauthorized activity. As soon as unauthorized activity is identified, signal is send to call and alarm agent.

#### 4.1. Book Trading System

Book trading system is software developed in java agent development environment. This system consists of two agent buyer agent and seller agent. One interface is provided to add the book in catalogue by the user. Bookbyuer agent does:

- Search all seller agent
- Receive all proposals from Seller Agent
- Send the Purchase Order or Book already sold
- Search the book title with all Seller Agent
- Find the best one

#### Bookseller agent does

- User can add book in catalogue
- Queries of buyer agent
- Receive purchase order of buyer agent
- Register book selling service
- Send Book Price
- Seller replies on Purchase Order

The autonomy evaluated for Book Trading System is shown in Table 2:

**Table 2. Results of Book Trading System**

<i>Characteristic</i>	<i>Sub- characteristic</i>	<i>Value</i>	<i>Value</i>	<i>Autonomy</i>
Pro-activity	<b>Multiple Roles</b>	1	3.831	2.731
	<b>Negotiation</b>	4		
	<b>Communication</b>	9		
	<b>Failure Analysis</b>	0		
Autonomy within organization	<b>Subordinate Position</b>	0	.104	
	<b>Task Sharing</b>	.58		

#### 4.2. Party System

Party System is also developed in JADE having two types of agent i.e. host agent, guest agent. Host agent invites the guests in party and tells the rumour to guest. Host agent selects other two guests and introduced

- Count the guests who heard rumour
- Announce guest that party is over if all guests heard rumour
- Receive the request to introduce from guest
- Receive notification from guest after listening rumour

The autonomy result of Party System is shown in Table 3:

**Table 3. Results of Party System**

<i>Characteristic</i>	<i>Sub- characteristic</i>	<i>Value</i>	<i>Value</i>	<i>Autonomy</i>
Pro-activity	<b>Multiple Roles</b>	2	5.646	3.992
	<b>Negotiation</b>	6.2		
	<b>Communication</b>	13		
	<b>Failure Analysis</b>	0		
Autonomy within organization	<b>Subordinate Position</b>	0	.135	
	<b>Task Sharing</b>	.75		

### 4.3. Security System

The security system consists of three agents' home agent, call agent and alarm agent. Home agent is overall responsible to detect objectionable activities and send signal to activate call and alarm agent. Call agent made a call to security and as well to other authorities according to category of risk. Alarm agent raises alarm for the attention in particular area.

1. Detection of objectionable entity depends upon perceiving the environment,
2. Sending signal to alarm agent and call agent further depends upon detection of objectionable entity

The results of autonomy of Security System are shown in Table 4:

**Table 4. Results of Security System**

<i>Characteristic</i>	<i>Sub- characteristic</i>	<i>Value</i>	<i>Weight Values</i>	<i>Value</i>	<i>Autonomy</i>
Pro-activity	<b>Multiple Roles</b>	1	.110	2.510	1.811
	<b>Negotiation</b>	2	.122		
	<b>Communication</b>	6	.360		
	<b>Failure Analysis</b>	0	.112		
Autonomy within organization	<b>Subordinate Position</b>	0	.120	0.180	
	<b>Task Sharing</b>	1	.180		

## 4. CONCLUSION

Agents based development is promising technique for development of complex and distributed system. Technology is accumulative intricacy of software hence Agents are acquainting with as a paradigm in software engineering. Agents are centred on societal opinion of computations and assistance by the sensors that are the reason after their continuous environment sensing.

Autonomy is one of the important features of an agent which further inclined towards pro-activity and autonomy within the organization. Autonomy feature differentiate agent from the object in object oriented system. The innovation of this paper is that autonomy is calculated with the help of pro-activity and autonomy in organization with the help of AHP. AHP is the technique which helps to analyse complex decisions which is based on psychology and mathematics. We relate multiple roles with cohesion (dependency on other agent is low), negotiation with average number of communications (communication to achieve goal), Communication is sum of both incoming and outgoing i.e. fan-in, fan-out, failure analysis and subordinate position is assessed in form of 0 and 1 i.e. capable and not capable, Task sharing with coupling (shows dependency on other agent). With the help of these features, we have calculated the autonomy.

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