



UNIVERSITY OF NAIROBI
SCHOOL OF COMPUTING & INFORMATICS

**"MULTI AGENT BASED EXTENSION SUPPORT SYSTEM FOR
HORTICULTURE"**

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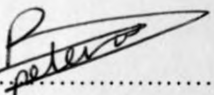
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Declaration

This project, as presented in this report, is my original work and has not been presented for any other institutional award.

Signature: 

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This project has been submitted as part fulfillment of the requirement for Masters of Science in Computer Science with my approval as the University Supervisor

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Dedication

I dedicate this research project and all the work that has gone into it to my beloved wife
Mercyline Sikasa.

Abstract

Most of the medium- and small-scale horticultural farmers rely on public extension service providers while large-scale farmers depend on private extension services. However, the current number of extension service providers is inadequate to meet the needs of horticultural farmers. HCDA offers limited specialized extension services for export crops and only in specific high-concentration areas. Consequently, high-potential regions and farmers who produce for the local market have not benefited from this service.

The purpose of this project is to address the extension service problem by identifying extension services information required in horticulture, to design and build the Multi agent based extension support system then test and evaluate the build multi agent based extension support system with farmers

The information needs and searches for the farmer are related to 6 stages which were identified as follows: (1) Deciding, (2) Seeding, (3) Planting, (4) Diseases, (5) Harvesting, packing and storing, and (6) Marketing.

The stages were the bases for building the multi agent based extension support system for horticulture. The system uses multi agents to perform search on behalf of the farmers and gives results on the mobile phone.

An agent oriented methodology –Prometheus- was used in the analysis and design of the multi-agent based extension support system for horticulture. The implementation of the multi agents was carried out using JADE and JADE-LEAP agent development kit. This framework opens the way towards any kind of distributed multi agent systems, in which farmer agents may be smoothly running on mobile devices and can communicate wirelessly with agents to access information on extension services.

Test cases were run for the purpose of evaluating the built prototype with farmers. On average 91% of the farmers rated the functionality of the system excellent while on average 77% of the farmers rated the overall system excellent in terms of easy to use.

The evaluation results also revealed that 87% of the farmers were motivated to use the program repeatedly while 75% of the farmers indicated that they would recommend this program to other farmers. Future improvements proposed are inclusion of GIS, data mining and language functionalities.

Acknowledgement

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First, I thank my supervisor, Mr. Elisha Opiyo whose guidelines, ideas, support and corrections made me understand better ways of undertaking the project. In addition, it is worth noting that the solid foundation I got under his tutelage while undertaking Multi agent systems unit proved indispensable.

I would like to acknowledge all the farmers who came in hand in the evaluation process of the multi agent based system for horticulture.

Last but not least I thank Pius Barasa's family, my Msc. computer science-mates who helped with advice knowledge and encouragement when the going got tough. Ultimately to God, the Giver of life, strength and health. To Him be the glory.

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Definition of terms

An agent: is a small, autonomous, or semiautonomous software program that performs a set of specialized functions to meet a specific set of goals, and then provides its results to a customer (e.g., human end user, another program) in a format readily acceptable by that customer (Minh T N et al , 2008)

EurepGAP is a private-sector body which sets voluntary standards for the certification of agricultural products worldwide.

Extension Support: is a service or system which assists farm people, through educational procedures, in improving farming methods and techniques, increasing production efficiency and income, bettering their levels of living and lifting social and educational standards.

Methodology: is a body of methods employed by a discipline (Brian Henderson sellers, Paolo G, 2005). A methodology, thus, essentially acts like a “recipe,” which helps the designer to implement the solution by specifying some of the steps of the process, while leaving others to the creativity of the designer (Magid Nikraz et al, 2006).

Method: is a procedure for attaining something (Brian Henderson sellers, Paolo G, 2005)

Multi-agent System: is a system composed of multiple interacting agents.

Horticulture: Branch of agriculture concerned with the cultivation of garden plants — generally fruits, vegetables, flowers, and ornamentals such as plants used for landscaping (answers.com, 2011)

List of abbreviations

| | |
|--------------|---|
| GDP | Gross Domestic Product |
| HCDA | Horticultural Crops Development Authority |
| NAFIS | National Farmers Information Service |
| TTS | Text to speech |
| MAS | Multi-agent System |
| KFC | Flower Council of Kenya |
| ICT | Information Communication Technology |
| FPEAK | Fresh Produce Exporters Associations of Kenya |
| ISP | internet service provider |

CHAPTER 1: INTRODUCTION

1.0 The Background

Agriculture accounts for about 24% of Kenya's GDP with an estimated 75% of the population depending on the sector either directly or indirectly. Much of the intermittent strength and overall weakness in GDP and income growth in Kenya can be attributed to changes in agricultural performance.

The horticulture sub-sector of agriculture has grown in the last decade to become a major foreign exchange earner, employer and contributor to food needs in the country. Currently the horticulture industry is the fastest growing agricultural subsector in the country and is ranked third in terms of foreign exchange earnings from exports after tourism and tea. Fruits, vegetable and cut flower production are the main aspects of horticultural production in Kenya.

Kenya has a long history of growing horticultural crops for both domestic and export markets. Kenya's ideal tropical and temperate climatic condition makes it favorable for horticulture production and development. The climate is highly varied supporting the growth of a wide range of horticultural crops. Horticulture in Kenya is mainly rain fed though a number of farmers, especially the ones growing horticultural crops for export, also use irrigation. The sub-sector is characterized by a tremendous diversity in terms of farm sizes, variety of produce, and geographical area of production. Farm sizes range from large-scale estates with substantial investments in irrigation and high level use of inputs, hired labour and skilled management to small-scale farms, usually under one acre.

The sub-sector generates over US\$ 300 million in foreign exchange earnings. The total horticultural production is close to 3 million tonnes making Kenya one of the major producers and exporters of horticultural products in the world. Europe is the main market for Kenyan fresh horticultural produce with the main importing countries being United Kingdom, Germany, France, Switzerland, Belgium, Holland and Italy. Other importing countries include Saudi Arabia and South Africa.

The industry has had remarkable growth, with exports climbing steadily from 200.6 thousand tonnes in 1999 to 346.1 thousand tonnes in 2003. The sub-sector earned Kenya Kshs. 36.5 billion in 2003 with cut flowers dominating horticulture exports, followed by a variety of fruits and vegetables. Kenya exported Kshs. 16.5 billion worth of cut flowers, Kshs. 1.8 billion worth of fruits, and KShs 18.2 billion worth of vegetables in 2003. The increase in exports was mainly

attributed to good weather, improved crop husbandry and conducive horticulture export environment, as well as increased markets for fruits and flowers in Europe.

A well-developed and dynamic private sector has profitably marketed a wide range of horticultural products to diverse international markets.

Government intervention in this area has been minimal, mainly facilitating the sectorial growth through infrastructure development, incentives and support services. Structural and macroeconomic reforms, plus the introduction of more liberal trading environment has also provided a major boost to the country's horticultural prospects.

Kenya's horticultural export expansion has also been aided by the country's preferential duty-free access to EU markets under the Lome Agreement, which currently runs through 2008. If this agreement is not renewed, or if other developing countries obtain similar benefits, Kenya can expect to face even stiffer competition in these markets. Kenya currently faces major competition in its horticulture industry from Cote d'Ivoire, Morocco, Zimbabwe, South Africa and Cameroon.

The HCDA is a parastatal established by the Government under the Agricultural Act of 1967 with the aim of developing and regulating the horticultural industry. The organization does this through the provision of technical and marketing services to farmers and other stakeholders in the horticulture industry.

The tremendous performance of the horticulture sub-sector presents an ideal investment opportunity for potential investors with a range of investment opportunities available and with ready markets for their produce.

Horticulture requires specialized extension approach and skills due to its dynamism and industry needs. There are private and public extension service providers in the horticultural industry. Most of the medium- and small-scale horticultural farmers rely on public extension service providers while large-scale farmers depend on private extension services. However, the current number of extension service providers is inadequate to meet the needs of horticultural farmers. HCDA offers limited specialized extension services for export crops and only in specific high-concentration areas. Consequently, high-potential regions and farmers who produce for the local market have not benefited from this service (PKF consulting, 2005).

Apart from the traditional way of relying on extension workers for informational support the farmers also get to access the information through libraries or via websites. Seeking information

from these and other platforms becomes a time-consuming and tedious task for the horticulture farmers as it entails ploughing through many publications or surfing a large number of web-pages. Web-based solutions also bring access challenges because internet infrastructure in Kenya is very sparse. This is especially witnessed in rural areas where most Internet Service Providers (ISPs) have not invested in infrastructure to facilitate the internet connectivity of the areas in question. This limitation locks out many smallholder horticultural farmers who would otherwise have wanted to get extension support on horticulture through web based solution. This category of farmers can therefore only rely on extension support from government-funded extension services that are constrained by a number of factors: (1) an extension worker is assigned a large area and must advise farmer groups who are often sparsely located; (2) extension workers have no reliable transport and so cannot provide good-quality services to all; (3) few extension officers are well versed in the current technical demands of the market, and so are unable to provide relevant information to growers; (4) many extension officers lack business skills and group-management skills, which are basic requirements for managing out-grower farmer groups as viable business enterprises; and (5) services provided through contract farming are unsustainable, particularly when partnerships are severed due to conflicts of interest between and within groups and exporters. When this happens, as it frequently does, growers have to seek new partnerships and services, and the production and/or supply chains crash as a result.

It is, therefore, imperative to develop a viable alternative extension system for smallholder horticultural farmers, to ensure their continued participation in the subsector.

This research overcomes the above challenges by developing a Multi agent based extension support system for horticulture.

1.2 Problem statement

Medium and Small scale horticultural farmers rely on government-funded extension service providers while large scale horticultural depend on private extension services. However there is limited access to extension services in most parts of the country with the National extension staff: farmer ratio standing at 1:1500 (Kenya Development Learning Centre, 2010).

(See Figure 1 below)

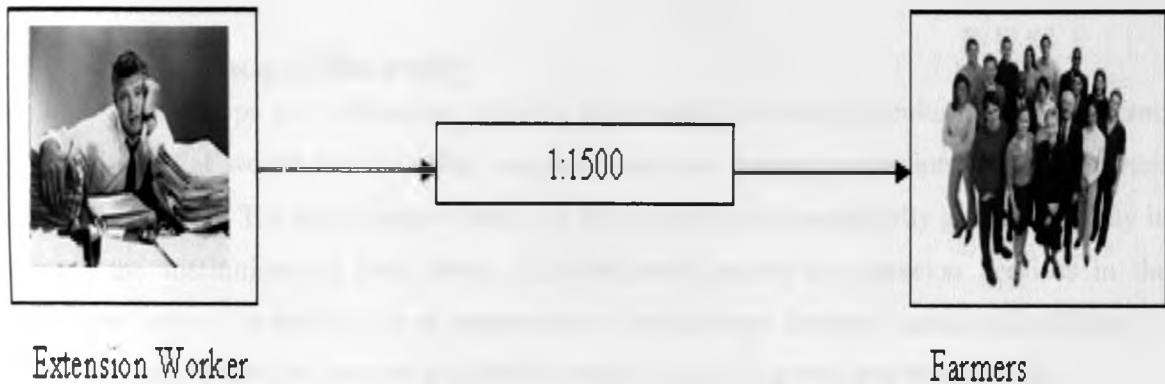


Figure 1: Extension Problem

The government-funded extension services are constrained by a number of factors: (1) an extension worker is assigned a large area and must advise farmer groups who are often sparsely located; (2) extension workers have no reliable transport and so cannot provide good-quality services to all; (3) few extensionists are well versed in the current technical demands of the market, and so are unable to provide relevant information to growers; (4) many extensionists lack business skills and group-management skills, which are basic requirements for managing out-grower farmer groups as viable business enterprises; and (5) services provided through contract farming are unsustainable, particularly when partnerships are severed due to conflicts of interest between and within groups and exporters. When this happens, as it frequently does, growers have to seek new partnerships and services, and the production and/or supply chains crash as a result (Brigitte Nyambo et al, 2009).

Inadequate extension on horticultural crops has also hindered export horticulture. Some crops that used to produce high yields are no longer in production in certain areas; because yields have declined dramatically due to buildup of pests Extension service on flower production for middle sized and small-scale farmers is completely lacking due to the lack of information on floricultural production techniques (Nyangweso P.M. and Odhiambo M.O, 2004).

1.3 Objective of this research

- To identify extension services information required in horticulture.
- To design and build the Multi agent based extension support system.
- To test and evaluate the build multi agent based extension support system

1.4 Significance of the study

The key target groups are horticulture farmers, government funded horticulture institutions and organizations that would like to offer extension services through extension workers to their clients; the farmers. The multi agent system, on being employed successfully goes a long way in assisting the institutions to help them offer unlimited access to extension services in the horticulture sector. In addition it is responsive to horticulture farmers' needs and efficient in service delivery. Therefore farmers are able to benefit production wise and money wise.

The system on adaption and installation helps save on time for physical extension by the institutions and the farmers also acquire extension information at their own pace. In addition, the relevant extension materials according to the horticulture farmers' specifics are availed automatically by the multi-agent support system on request on the mobile phone.

Multi agent extension support system for horticulture farmers adds two-way communication between the extension workers and the farmers and increases the competitive edge and also more in-depth messaging. Furthermore, it widens the scope of extension as well as improves the quality of extension services.

1.5 The Structure of the Report

This report is structured as follows: -

Chapter 1 presents background, problem statement, objective of study and significance of study

Chapter 2 provides a review of literature and related work.

Chapter 3 talks about agent oriented methodology used in the research, it highlights the activities that were done during the research and the techniques of data collection methods which entails data collection, data collection tools and data analysis used

Chapter 4 provides the details of the analysis and design of the multi agent based extension support system for horticulture.

Chapter 5 provides details of building multi agent based extension support system for horticulture.

Chapter 6 discusses the results of the research from the testing and evaluation done by the users on the prototype.

Chapter 7 presents our conclusions and discusses areas which require for further research.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

Basically no research work ever stands on its own. Research is for a large extent the recognition of the validity of previous ideas and its applicability to different settings. This is certainly true for this work. This chapter gives an overview of basic theories and related research areas, to help gain a better understanding of the concepts and ideas.

It is not our aim to give a complete overview of these subjects, but to present the foundations upon which our research is built. Due to the multidisciplinary character of this research, we provide some background on the different disciplines, which may be overkill for practitioners in that field, but which is aimed to help researchers from the other fields to achieve a common understanding of the work in the remainder of this project.

The chapter starts by describing horticulture subsector in section 2.1, the sector which the problem statement of this research emanates from as described in section 1.2. Section 2.2 looks at information systems available that offer extension support for horticulture farmers. In Section 2.3 the main aspects of the agent paradigm are discussed. Work on multi agent systems is presented in section 2.4. Section 2.5 presents discussion on use of Multi-agent system in extension support for horticulture, and its relevance for this project. Section 2.6 Multi agent Systems -based Methodologies, section 2.7 discusses JADE and JADE LEAP. Section 2.8 discusses J2ME and finally section 2.9 gives overview of solution and assumptions.

2.1 Horticulture Subsector

The horticultural sector currently ranks as one of the economy's fastest growing sectors and is ranked the largest foreign exchange earner. This is reflected in a continuous year-to-year expansion in fruit, vegetable and cut flower exports. The growth trend is expected to continue due to a number of positive attributes in the sector.

The Government has made minimal intervention in this sector, thus spurring growth by having private sector participation. The government set up the Horticultural Crops Development Authority (HCDA) under the Agriculture Act in 1967 with the aim of developing and regulating the industry. HCDA offers technical and marketing services to the stakeholders in the horticulture industry.

Currently there are more than 60 companies dealing in fresh vegetables, fruits and cut flowers both for export and domestic consumption. The companies are all privately owned and adhere to very high standards in handling their products.

Through Fresh Produce Exporters Associations of Kenya (FPEAK), the companies assist each other in both technical and marketing aspects of the industry.

The Flower Council of Kenya (KFC) is another members' body that supports and lobbies for particularly the flower growers and exporters.

2.1.1 Production

Kenya having an ideal climate for the production of horticultural produce, produces a wide range of vegetables, fruits and cut flower products for both local and international markets key among them being:

Flowers from Kenya:

| | | |
|-----------------|-----------------|------------------|
| Achillea, | Arum Lillies | Chrysan Cuttings |
| Agapanthus | Aster | Cut Foliage |
| Alstroemeria | Atriplex | Delphinum |
| Amaranthus | Bamboo | Dill |
| AmmiMajus | Bupleurum | Dried Flowers |
| Anthuriums | Carnation | Echinops |
| Arabicum | Carthamus | Eryngium |
| Gerbera | Liatris | Musa Coccinea |
| Gladius | Lilies | Nicola |
| Gypsophilla | Liliums | Orchids |
| Helenium | Lissianthus | Ornithogalum |
| Heliconia | Live Plants | Roses |
| Hypericum | Mixed Flowers | Rudbeckia |
| Kniphofia | Molucella | Seal Girl |
| Solidago | StaticeLimonium | Tuberose |
| Solidaster | Strelitzia | Veronica |
| StaticeBeltaard | Trachelium | |

Table 1: Flowers from Kenya (PKF consulting ltd and International research network, 2005)

Fruits from Kenya:

| | |
|---------------|------------------|
| Apple | Orange |
| Avocado | Passion Fruits |
| Bananas | Pawpaw |
| Betel Nuts | Guavas |
| Bixa | Horned Melon |
| Cashew nuts | Lemon |
| Coconuts | Lime |
| Currants | Litchi |
| Custard Apple | Macadamia Nuts |
| Dried Fruits | Mango |
| Gooseberry | Melon |
| Grapefruit | Nor-Bixin Powder |

Table2: Fruits from Kenya (PKF consulting ltd and international research network, 2005)

Vegetables from Kenya:

| | | |
|-------------|--------------|------------------|
| Arrow Roots | Cabbage | Chillies Short |
| Artichoke | Canned Beans | Chives |
| Asparagus | Capsicums | Chora |
| Aubergines | Carrots | Coriander |
| Baby Corn | Cassava | Courgettes |
| Basil | Cauliflower | Cucumber |
| Beetroot | Celery | Broccoli |
| Bobby Beans | Chevda | Brussels Sprouts |
| Long | Chillies | |

Table 3: Vegetables from Kenya [PKF consulting ltd and International research network, 2005]

extension services to 'contract' out-grower farmer groups on credit, as a way to guarantee the supply of quality produce. The government-funded extension services are constrained by a number of factors as stated in section 1.2 of the problem statement; hence the need for innovative computerized system to address this gap has resulted.

The importance of public extension systems is justified by the realization that government funded extension services can effectively educate and advise farmers. Through public extension, farmers can obtain information that helps them reduce risks in farming. As Rivera & Cary in (Catherine N et al, 2002) pointed out, public extension systems function as coordinating organizations by regulating and providing service to clients who may otherwise not be reached by private organizations. The role of extension can be understood from a study completed in Kenya on agricultural knowledge and information systems (AKIS) by Rees, et al (2000).

The findings by Rees et al (2000) indicate that 40 to 70% of the respondents acknowledged the importance of the Ministry of Agriculture within which extension services are housed as an important source of information. However, farmers and extension personnel expressed their dissatisfaction with the quality and frequency of their interactions. Although 16 to 33% of the farmers reported receiving technical information; most of them indicated that information flow in this category was particularly deficient. Management of diseases in crops, acquiring certified seeds and appropriate varieties among other related practices were some subject matter areas of concern to farmers. The authors conclude that information problems in extension are constraints which if not addressed will continue to make government extension systems ineffective.

To the extension officer who works closely with the farmer, adequate technical knowledge is needed to help solve the farmer's problems. Reliable and easy to access information sources become crucial, especially when the extension agent in contact with the farmer is not knowledgeable in a given subject. The extension administrator responsible for implementing agricultural development policy also needs sufficient information in order to make informed decisions. How to obtain information to meet the educational objectives of the extension organization is, therefore, a long-term commitment (Catherine N et al, 2002). Having a sustainable information system requires that information sources are reliable, offer practical alternatives and be an ongoing activity. To keep up with farmers' needs, extension systems need to be continuously updated with viable alternatives.

2.2 Information Systems

In our review, we found that Extension Support system application development is an evolving field and hence there are few success stories about it. Some of them are explained in the following section.

The development of the National Farmers Information Service – NAFIS, a voice-based service is one such initiative of an information system. It is a comprehensive information service, intended to serve farmers' needs throughout the country including the rural areas where internet access is limited. The service comprises of a detailed website that is easily updated by Extension officers and a Voice-Based Service which contains summarized information which farmer's access using mobile phones. The Voice-Service is available both in English (Kenyan Local dialect) and Kiswahili (Mucemi G et al, 2009). The application resides and runs on a server, is a web-based application/web service and was built using C/C++, Python programming languages (MMIX NAFI, 2008)

Another voice information delivery system is the Banana Information Line a project of the Local Language Speech Technology Initiative (LLSTI), produced in partnership with National Agriculture and Livestock Extension Programme (NALEP) of the Kenyan Ministry of Agriculture (local language speech technology initiative Nalep, 2006). The text-to-speech (TTS) telephone line provided farmers in Kenya with information in either English or Kiswahili, related to how to plant, grow, and harvest bananas. It ran as a pilot for several months in 2006, but has now been superseded by the NAFIS information line, launched in April of 2008, which covers a wider range of crops and livestock.

Communication Strategies: The key strategy in the Banana Information Line was the use of its automated TTS system that allows users to access the information in either Kiswahili or English. According to the organizers, because anyone with a land line or mobile phone could access the information line, communities that were more difficult to reach by traditional means could more easily access the agricultural information they needed to more efficiently grow their crops. A TTS line bypasses the need for literacy, as well as the problem of reaching farmers living in very remote areas. Farmers are able to call the line any time of day, every day, thereby allowing them to get information when they need it, and when it is most convenient for them (Mucemi G et al, 2009).

E-learning websites for basic skills, agricultural education and video-based approaches are currently available to offer extension support. Such an initiative is INFONET, a web-based service promoting organic farming which is supplemented by *The Organic Farmer* publication.

Infonet- Bio Vision is a farmer information platform that provides information to farmers and rural communities in topics such as sustainable agriculture, livestock and human health promotion and environmentally safe technologies and approaches. The information platform is used as a resource pool for disseminating information inside and outside the internet through active cooperation with partner organizations and local farmer and women's groups and through ICTs.

It has no feedback function and no built-in option for sending text to voice messages from the website to mobile phones (Mucemi G et al, 2009).

Seeking information from these and other platforms becomes an onerous task for the farmers as it entails ploughing through many publications or surfing a large number of web pages. Web-based solutions also bring access challenges because internet infrastructure in Africa is still very sparse.

Extension services based on mobile phone and database monitoring, success stories have not yet bore fruits as the projects are still active. Such a project is Kenya Agricultural Commodities Exchange (KACE) MIS Project that was initiated by KACE, in collaboration with CTA. KACE collects, processes, updates and disseminates market information daily to farmers and other market intermediaries through the MIS. Market information includes prices of commodities in different markets, and commodity offers to sell and bids to buy, as well as short extension messages.

Web-based solutions also bring challenges because internet infrastructure in Africa is still very sparse. Nevertheless, these are very useful resources and all that is needed is to provide an easy way for the farmers to navigate them. With the widespread use of mobile phones, voice and SMS solutions should find more use as they offer easy accessibility. However, they also face the following challenges: the SMS carries only a limited amount of information and requires a basic level of literacy.

Voice-based solutions are complicated to develop for they require machines to produce natural speech, or in technical terms, good speech synthesis. They also do not offer detailed information such as pictorial illustrations as in web solutions.

2.3 Agent Paradigm

Intelligent agents are a new paradigm for developing software applications and are currently the focus of intense interest on the part of several fields of computer science and artificial intelligence (Jennings N. Wooldridge M, 1998). Agents have made it possible to support the representation, coordination, and co-operation between heterogeneous processes and their users. A growing number of researchers and organizations are using agents in an increasingly wide variety of applications. Current 'real world' agent applications, cover several domains in industry, commerce, health care and entertainment, and range from comparatively small systems such as e-mail filters to large, open, complex, mission critical systems such as air traffic control. The future of computing will be 100% driven by delegating to, rather than manipulating computers (Bill Ackar et al, 2009)

2.3.1 What is an Agent?

An agent is a small, autonomous, or semiautonomous software program that performs a set of specialized functions to meet a specific set of goals, and then provides its results to a customer (e.g., human end user, another program) in a format readily acceptable by that customer (Minh et al, 2008).

The definition exhibits the following basic properties of software agents:

- (i) **Autonomy:** agents have some degree of control over their actions and can work without intervention of humans;
- (ii) **Social ability:** agents can coordinate their actions and cooperate with other agents to achieve their goals, using a common language to communicate with each other;
- (iii) **Reactivity:** agents can perceive their environment and respond to environmental changes;
- (iv) **Proactiveness:** agents can act on their own initiative to achieve their goals instead of simply reacting with the environment.

2.3.2 Agent Architectures

Agent architectures are design solutions, which describe agent's modules and capabilities, and how these operate together. An agent architecture helps to explain and to predict the agent behaviour, that is, it helps to understand how an agent's internal state affects its decisions, and how perceptions affect the agent's internal state. Furthermore, an agent architecture may support the design of multi-agent systems, by providing tools and methodologies for designing agents

and their interactions. Maes in (Antonio Jesus Monteiro de Castro, 2006) defines agent architecture as follows:

“An architecture proposes a particular methodology for building an autonomous agent. It specifies how the overall problem can be decomposed into sub problems, i.e., how the construction of the agent can be decomposed into the construction of a set of component modules and how these modules should be made to interact. The total set of modules and their interactions has to provide an answer to the question of how the sensor data and the current internal state of the agent determine the actions (effectors outputs) and future internal state of the agent. Architecture encompasses techniques and algorithms that support this methodology.”

Concerning the implementation of agents, several architectures have been proposed that can be roughly classified into the following types (Jennings N. Wooldridge M, 1998), increasingly less abstract:

- Logic-based agents: reasoning and decision making are realized through logical deduction
- Reactive agents: in which decision making is implemented as some direct mapping from situation to action
- Belief-desire-intention (BDI) agents: decision making depends on the manipulation of some representation of the beliefs, desires and intentions of the agent
- Layered agents: decision making is realized via several software layers, each explicitly reasoning about the environment at different levels of abstraction.

Of the above architectures, we want to pay special attention to the BDI architecture. On the one hand, this architecture has become a de facto standard for agent models and is at the basis of namely the FIPA standard, and, on the other hand, it is generic enough to enable the modeling of both natural as artificial agents (Virginia Dignum, 2003).

Being a generic architecture, BDI provides the best approach to this requirement.

The BDI model has its roots in the philosophical tradition of understanding practical reasoning in humans. Practical reasoning involves two important processes: deciding what goals to achieve (deliberation), and how to achieve those goals (means-ends analysis). The process starts by analyzing the options available, which depend on the agent's beliefs and desires, and deciding which ones to choose. These chosen options became the agent's intentions, which then determine its actions. Intentions play a crucial role in the practical reasoning process, as they lead to action

In summary, agents have a set of beliefs, which are based on their perception of the environment. Beliefs and intentions are used to determine the current options (desires) available to the agent. A deliberation process determines the agent's intentions based on its beliefs, desires and intentions. Intentions are the current focus of the agent: the states it is committed to bring about, and for which the agent will specify a plan on how to reach them. Finally, an action selection function, determines which action to perform based on the current intentions.

2.4 Multi agent Systems

Multi agent is a system composed of multiple interacting agents. Multi-agent environments extend single-agent architectures with an infrastructure for interaction and communication. Ideally, MAS exhibit the following characteristics (KP Sycara, 1998): – Are typically open and have no centralized designer; – Contain autonomous, heterogeneous and distributed agents, with different 'personalities' (cooperative, selfish, honest, etc.); – Provide an infrastructure to specify communication and interaction protocols. Agents in MAS are expected to coordinate by exchanging services and information, to be able to negotiate and agree on commitments, and to perform other complex social operations (Virginia Dignum, 2003). Coordination and communication are therefore extremely important issues of MAS, but not really relevant in the case of single-agent systems. In MAS agents have to be able to find each other, announce their possibilities and pose questions or requests.

2.5 Why Multi agent Systems for Extension Support?

When we disaggregate stages of information needs and searches for Horticulture extension support the breakdown looks as follows. The farmer has information needs and searches for information related to 6 stages: (1) Deciding, (2) Seeding, (3) Planting, (4) Diseases, (5) Harvesting, packing and storing, and (6) Marketing.

All the above stages need agents to search information in the information base from different farmer's needs. Agent-based models for knowledge management use agents as autonomous entities (like employees in a company) that are endowed with certain behaviors, and the interactions among these entities give rise to complex dynamics. In this context, agents can be defined as 'one that acts or has the power or authority to act' or 'one that takes action at the instigation of another'. The concept of agent in this sense is not new, nor restricted to software.

- The system specification phase focuses on identifying the basic functionalities of the system, along with inputs (percepts), outputs (actions) and any important shared data sources.
- The architectural design phase focuses to use the outputs from the previous phase to determine which agents the system will contain and how they will interact.
- The detailed design phase looks at the internals of each agent and how it will accomplish its tasks within the overall

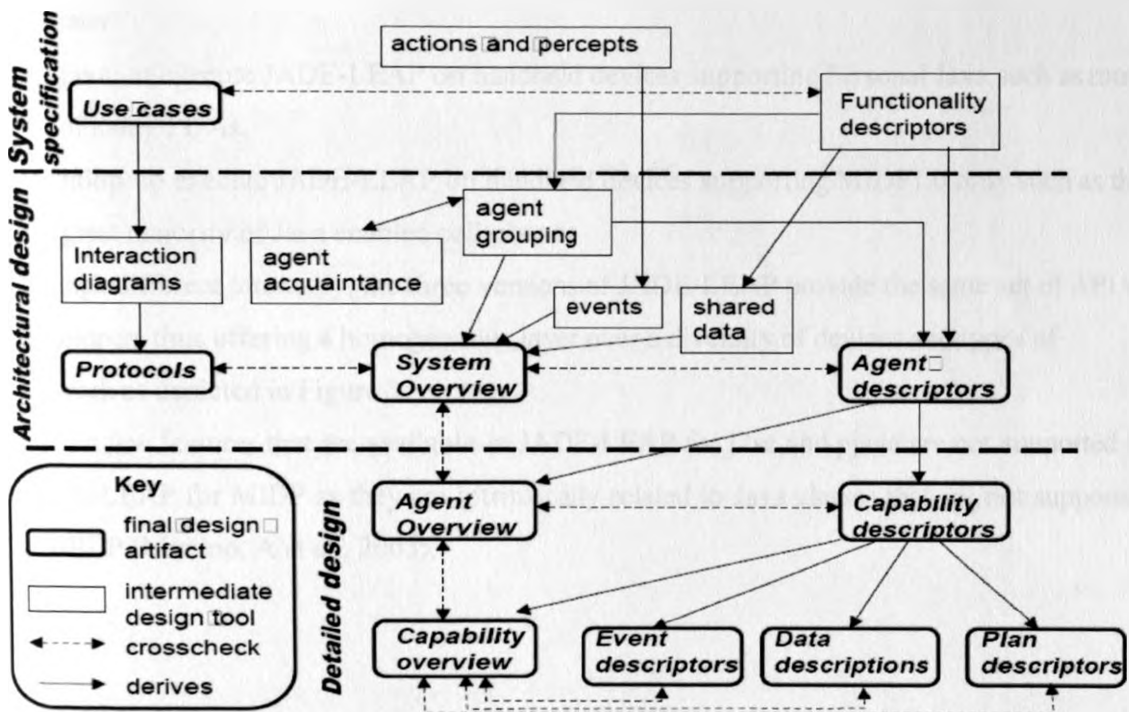


Figure 2: Prometheus Design Phases

2.7 JADE LEAP & JADE

2.7.1 JADE

JADE is a software platform that provides basic middleware-layer functionalities which are independent of the specific application and which simplify the realization of distributed applications that exploit the software agent abstraction (Wooldridge and Jennings, 1998). A significant merit of JADE is that it implements this abstraction over a well-known object-oriented language, Java, providing a simple and friendly API.

2.7.2 JADE LEAP.

JADE is a set of Java classes that allow a developer to build a FIPA-compliant multi-agent system quite easily. It provides a set of graphical tools that facilitate the complex task of implementing a multi-agent system. A few months ago an add-on to JADE, called LEAP, was released. This add-on replaces some parts of the JADE kernel, creating a modified environment called JADE-LEAP, which allows the implementation of agents in mobile devices with limited resources. It provides three modes of work to adapt to different circumstances:

- **j2se**: to execute JADE-LEAP on PC and servers in the fixed network running JDK1.2 or later
- **java**: to execute JADE-LEAP on handheld devices supporting Personal Java such as most of today PDAs.
- **midp**: to execute JADE-LEAP on handheld devices supporting MIDP1.0 only such as the great majority of Java enabled cell phones

Though different internally, the three versions of JADE-LEAP provide the same set of API to developers thus offering a homogeneous layer over a diversity of devices and types of network as depicted in Figure 3.

Only a few features that are available in JADE-LEAP for j2se and pjava are not supported in JADE-LEAP for MIDP as they are intrinsically related to Java classes that are not supported in MIDP (Moreno, A et al., 2003).

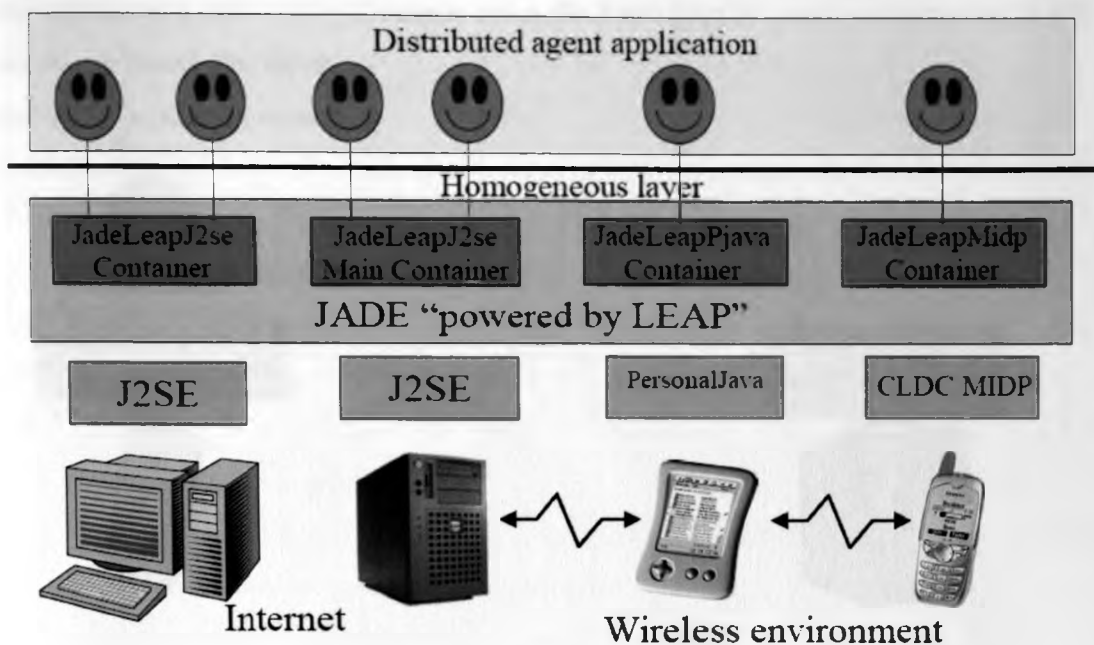


Figure 3: The JADE-LEAP runtime environment

2.7.3 Execution Modes

The JADE-LEAP runtime environment can be executed on a handheld device in two different ways.

The **“Stand-alone”** execution mode where a complete container is executed on the hand held device.

The **“Split”** execution mode where the container is split into a Front End (actually running on the handheld device) and a Back End (running on a J2SE host) linked together through a permanent connection (see Figure 5). This execution mode is particularly suited for resource-constrained and wireless devices since:

- The Front End is definitely more lightweight than a complete container.
- The bootstrap phase is faster.
- Less bytes are transmitted over the wireless link.

It is important to remark that the developer does not have to care in any way about the fact that an agent will run on a stand-alone container or on the Front End of a split container as the APIs they provide are exactly the same.

a) "Stand-alone" execution mode

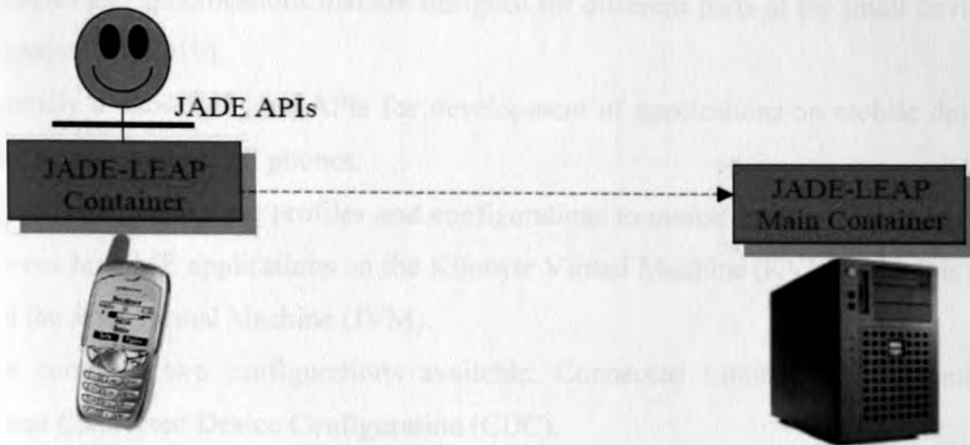


Figure 4 "Stand-alone" execution mode

b) "Split" execution mode

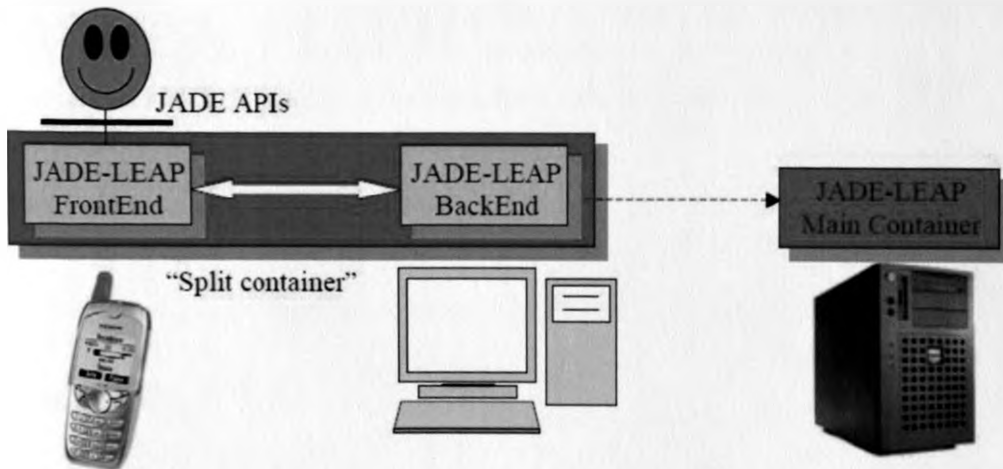


Figure 5: "Split" execution mode

2.8 J2ME

Java Platform, Micro Edition (Java ME), previously known as J2ME, was developed by Sun Microsystems. It is a subset of the Java platform aimed at mobile devices

Java Platform, Micro Edition (Java ME) was developed by Sun Microsystems and is a collection of technologies and specifications that are designed for different parts of the small device market (Sun Microsystems, 2010).

It is essentially a subset of Java APIs for development of applications on mobile devices with limited resources, such as cell phones.

Java ME was designed to use profiles and configurations to enable devices of varying ability to be able to run Java ME applications on the Kilobyte Virtual Machine (KVM), which is the micro version of the Java Virtual Machine (JVM).

There are currently two configurations available: Connected Limited Device Configuration (CLDC) and Connected Device Configuration (CDC).

The most common profile is the Mobile Information Device Profile (MIDP), which is aimed at mobile devices such as cell phones. Currently MIDP 1.0 and MIDP 2.0 are available, while MIDP 3.0 is being developed. Java ME applications developed for an MID Profile are called MIDlets.

2.9 Multi agent Based Extension Support Solution

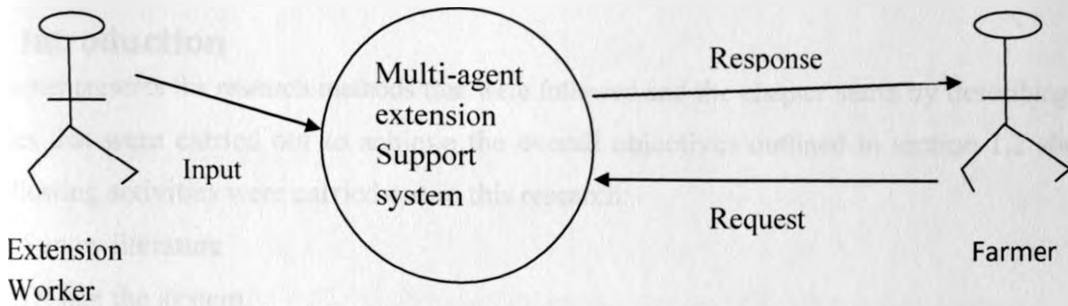


Figure 6: Multi agent Based Extension Support Solution

The above diagram acts as guiding principle in the design and implementation of the system. For more information see figure 10 system overview- technological infrastructure.

Assumptions and Limitations

- All farmers own mobile phones that can be used to query extension information.
- Not all Horticulture crops will be supported by the developed system only flowers and Tomatoes will be handled.
- The net bean javafx emulator will represent the real phone in the case of running the system.
- Trust and delegation limitations. Both individuals and organizations have to be confident that agents will work on their behalf. The process of learning to trust an agent and to learn how to delegate tasks to an agent takes time.
- Careful personalization limitations. Profiles that an agent makes of its user must be comprehensive, accurate, require minimal user input, and enforce privacy issues. Furthermore an agent must know its limitations and be trustworthy.

CHAPTER 3: METHODOLOGY

3.0 Introduction

This chapter presents the research methods that were followed and the chapter starts by describing the activities that were carried out to achieve the overall objectives outlined in section 1.2 above.

The following activities were carried out in this research:

1. Survey literature
2. Design the system
3. Implement prototype
4. Run some test and Evaluating the results
5. Discuss results
6. Data Collection

3.1 Survey Literature

The study employed a literature review survey as a means to understand horticulture extension as documented. Basically no research work ever stands on its own. Research is for a large extent the recognition of the validity of previous ideas and its applicability to different settings. This is certainly true for this work. The Survey goes further to justify and give a clear glimpse of multi agent system. In addition this was a more appropriate approach because the study is both exploratory and descriptive. It also intends to investigate and unearth original information to understand the phenomena at hand. From this information a requirement specification document was produced. Finally the problem being examined has a significant social, economic impact on a vast horticultural farmer's population

3.2 Design the System

The research design was guided by the Prometheus methodology, reviewed in section above

The methodology was adopted in designing the multi-agent extension support system for horticulture. The following activities were carried out:

- The system specification phase focused on identifying the basic functionalities of the system, along with inputs (percepts), outputs (actions) and any important shared data sources.
- The architectural design phase used the outputs from the previous phase to determine which agents the system will contain and how they will interact.

- The detailed design phase we will look at the internals of each agent and how it will accomplish its tasks within the overall system.

3.3 Implementation of Prototype

The implementation of multi agent extension support system for horticulture has been done using JADE-LEAP toolkit (Fabio L et al, 2007) (Moreno et al, 2003).

The Graphical user interface for the mobile phone has been developed using Java 2 Micro-edition (J2ME) (D.A. Tauber, 2011). The extension workers web interface –the server side was built using PHP.

3.4 Running some Test and Evaluating with farmers

The program was tested on a java emulator, which is in build in net beans. The system was run to farmers who later filled the questionnaires for evaluation purposes.

3.5 Discussion of Results

The discussion of the results activity was done after analysis of farmers' evaluation questionnaires which they filled.

3.6 Data Collection Methods

3.6.1 Sources of Data

The Study utilized both secondary and primary data to help in generating new depth on the subject. The primary data was collected through observation and interviewing of the area residents in the study area to get a better insight of the whole situation and by use of Evaluation questionnaires.

Secondary data has been researched from published books and unpublished works, academic papers, journals, internet, media and special reports.

3.6.2 Data Collection Tools

Questionnaires and interview schedule were the major research instruments used in this study. The questionnaire contains structured questions. The study targets a sample of thirty farmers thus we used thirty questionnaires.

3.6.3 Data Analysis

The study employed quantitative data analysis. The data in the questionnaire forms was edited, coded, entered and analyzed using statistical package for social scientists (SPSS). Frequency tables will be generated and used in the final presentation of findings on the general perception of respondents.

CHAPTER 4: ANALYSIS AND DESIGN OF THE EXTENSION SYSTEM

4.0 Introduction

The research analysis and design was guided by the Prometheus methodology, reviewed in section above. The methodology was adopted in designing the multi-agent extension support system for horticulture.

The chapter is organized as follows: section 4.1 describes the system specification which entails initial system description, goal diagram, actors, use case scenarios, percepts/actions and functionality of the system. Section 4.2 introduces architectural design which describes agent overview, agent descriptor, system overview diagram and interaction diagram. coordination frameworks for agent societies. In section 4.3 detailed design is presented finally.

4.1 System Specification

The system specification activities are as follows: identifying the basic functionalities of the system, along with inputs (percepts), outputs (actions) and any important shared data sources.

4.1.1 Initial System Description

The farmer has information needs that requires extension information related to 6 stages that are followed when farming: (1) Deciding, (2) Seeding, (3) Planting, (4) Diseases, (5) Harvesting, packing and storing, and (6) Marketing

The first stage farmers get information to decide on what crop to grow in a particular region. Secondly farmers need to either purchase seeds or prepare their own seeds based on the crop they have earlier decided to grow. They also require information on how to prepare a seed bed. On planting stage farmers require information on how to plant and transplant. Firth stage farmers need information about diseases that affect horticulture crops, their symptoms, prevention techniques, causes of the disease and the treatment of the same. The Sixth stage farmers have to find harvesting procedures, tips, regulations and packaging, if at all, depending on the horticultural crop. Finally farmers require market information on both Local Markets and Overseas Markets. They also get information on potential markets and current prices in both markets.

The extension worker on the other hand receives sms and updates the data base using a web interface.

4.1.2 Goal Diagram

The system parent goal is farmers need to access extension services on horticulture and the subsidiary goal include diseases, planting, seedling, harvesting& packing and deciding services. The subsidiary goal contributes to the achievement of the parent goal

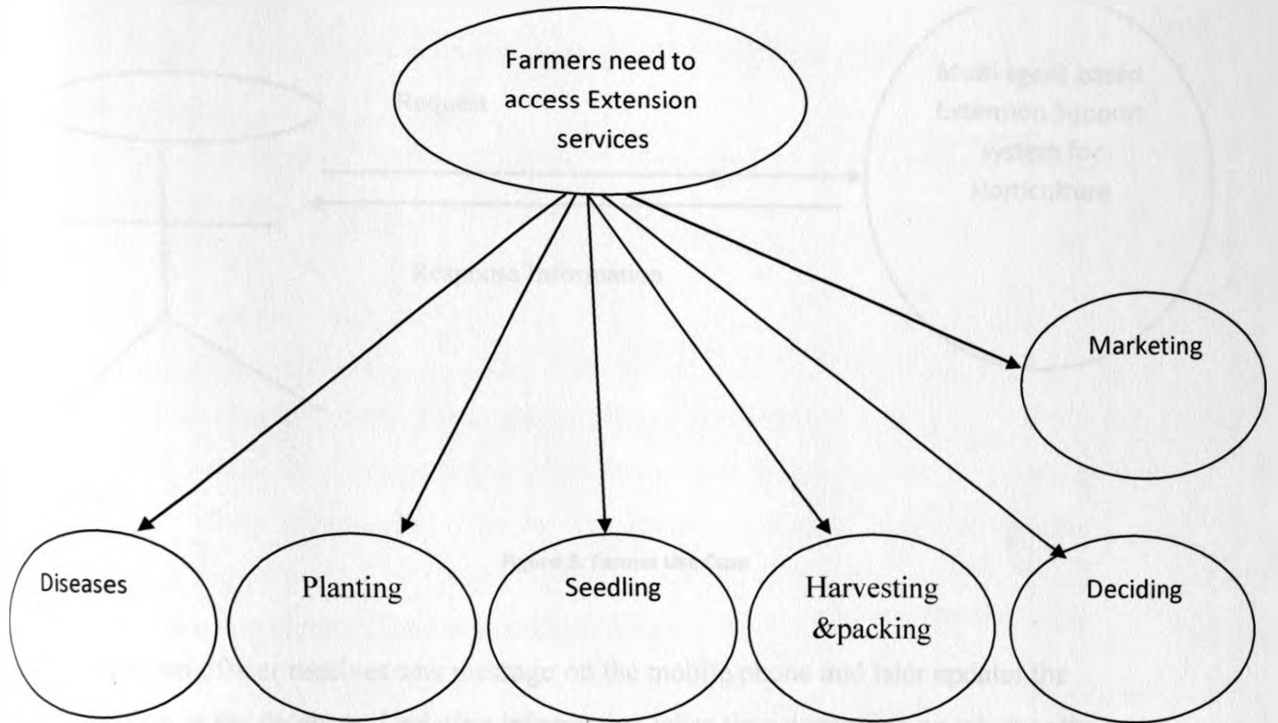


Figure 7: Goal Diagram

4.1.3 Actors

The main actors in the multi agent based extension support system for horticulture are as follows:-

a) Farmer

The farmer accesses extension information using a mobile phone. The information accessed is on diseases, decisions, harvesting& packaging, planting and seedlings

b) Extension Worker

The extension worker inputs missing information in the data base after receiving a message that the information was not available in that database.

4.1.4 Use Case Scenarios

A farmer requests for extension information from the extension support information for horticulture. The farmer then receives reply to his/her mobile phone as response information.

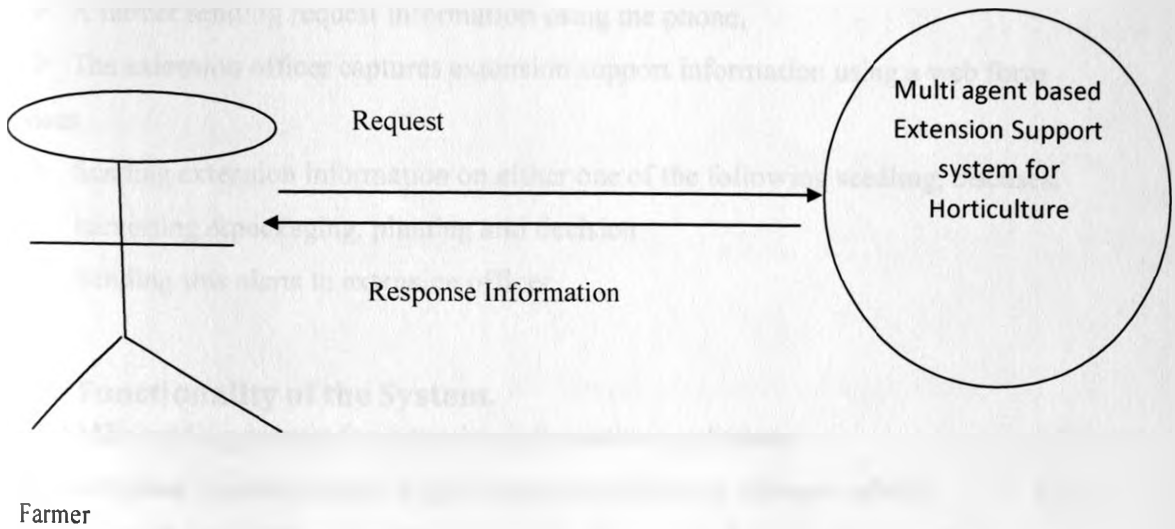


Figure 8: Farmer Use Case

An extension officer receives sms message on the mobile phone and later updates the information in the database. Updating information takes time depending on whether the extension worker has an instant answer or whether it requires further research.

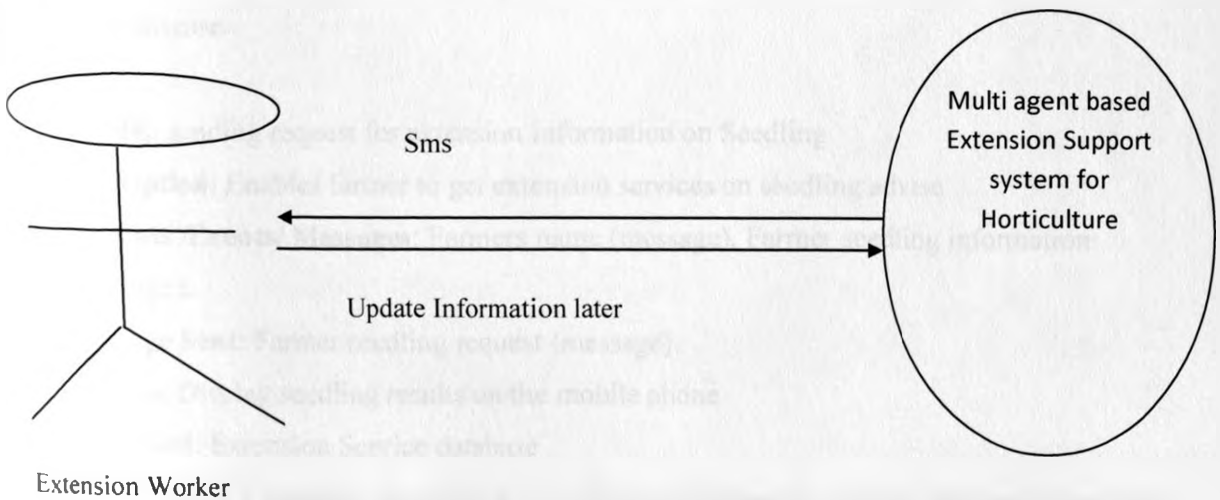


Figure 9: Extension Worker Use Case

4.1.5 Percepts/Actions

Analysis of the above scenarios point out the need for the following percepts/actions:-

Percepts

- The farmer selecting the items from dropdown menu on the phone.
- A farmer sending request information using the phone.
- The extension officer captures extension support information using a web form

Actions

- Sending extension information on either one of the following seedling, diseases, harvesting & packaging, planting and decision
- Sending sms alerts to extension officer

4.1.6 Functionality of the System.

NAME: sending request for extension information on diseases

Description: Enables farmer to get extension services on diseases advise

Percepts /Events/ Messages: Farmers name (message), Farmer disease information (message).

Message Sent: Farmer diseases request (message)

Actions: Display results diseases on the mobile phone

Data used: Extension Service database

Interactions: Extension via disease (Via Farmer information request, diseases information)

Goal: disease

NAME: sending request for extension information on Seedling

Description: Enables farmer to get extension services on seedling advise

Percepts /Events/ Messages: Farmers name (message), Farmer seedling information (message).

Message Sent: Farmer seedling request (message)

Actions: Display seedling results on the mobile phone

Data used: Extension Service database

Interactions: Extension via seedling (Via Farmer information request, seeding information)

Goal: Seedling

NAME: sending request for extension information on marketing

Description: Enables farmer to get extension services on marketing advise

Percepts /Events/ Messages: Farmers name (message), Farmer marketing information (message).

Message Sent: Farmer marketing request (message)

Actions: Display marketing results on the mobile phone

Data used: Extension Service database, marketing

Interactions: Extension via seedling (Via Farmer information request, marketing information)

Goal: marketing

NAME: sending request for extension information on harvesting &packaging

Description: Enables farmer to get extension services on harvesting &packaging advise

Percepts /Events/ Messages: Farmers name (message), Farmer harvesting &packaging information (message).

Message Sent: Farmer harvesting &packaging request (message)

Actions: Display harvesting &packaging results on the mobile phone

Data used: Extension Service database, harvesting

Interactions: Extension via harvesting &packaging (Via Farmer information request, harvesting &packaging information)

Goal: harvesting &packaging

NAME: sending request for extension information on deciding

Description: Enables farmer to get extension services on deciding advise

Percepts /Events/ Messages: Farmers name (message), Farmer deciding information (message).

Message Sent: Farmer deciding request (message)

Actions: Display deciding results on the mobile phone

Data used: Extension Service database, deciding

Interactions: Extension via harvesting &packaging (Via Farmer information request, deciding information)

Goal: deciding

4.2 Architectural Design

4.2.1 Agent Overview

Multi agent based extension support system for Horticulture involves 8 types of agents: (Farmer Agent, Extension Agent, Seedling Agent, Planting Agent, Diseases Agent, Harvesting and Packaging Agent and Marketing Agent.

The Farmer search Agent has been developed using LEAP which is an add-on of JADE. It has been implemented on mobile devices which the user possesses like the mobile or smart phone. It accepts selection from dropdown menu about diseases, marketing, advice, planting, and seedling and so on. This agent gets connected with the Extension Agent and retrieves the information about the subject requested by farmer based on search criteria and returns the data to the user on his/her mobile device.

This agent gets connected with the Extension Agent, the extension agent on receiving the request from farmer agent starts search process by requesting any of the following agents depending on the criteria selected: Seedling Agent, Planting Agent, Diseases Agent, Harvesting and Packaging Agent and Marketing Agent.

4.2.2 Agent Descriptor

Name: Extension Agent

Description: Receives requests from the farmer agent, starts search process by issuing the request to a particular agent that information is needed from by the farmer, logs query in the database, forwards results to the farmers mobile phone, sends sms to extension worker ,receives responses from the seedling, planting, diseases, harvesting and packaging and marketing agent.

Cardinality: one/ Extension Service Database

Lifetime: Instantiated when receives request from other agents.

Initialization: starts search process by issuing the request to the concerned agent.

Demise: Forwards results to the farmer's mobile phone.

Functionality: Receives requests from the farmer agent, starts search process by issuing the request to a particular agent that information is needed from by the farmer, logs query in the database, forwards results to the farmers mobile phone, sends sms to extension worker ,receives responses from the seedling, planting, diseases, harvesting and packaging and marketing agent.

Uses Data: Extension Database

Produces Data: Extension information to farmer, Sms to extension worker.

Goals: To avail extension information required by the farmer.

Events responded to: Farmers agent request

Actions: Sends farmers request queries to other agents, Sends sms message query to extension worker after not finding information from the database tables and logs query in the database, forwards results to farmer's mobile phone.

Interacted with: Farmer request protocol, Harvesting and Packaging Agent, Marketing Agent, deciding agent, seedling agent, diseases agent

Name: Seedling Agent

Description: Receives messages from Extension Agent, Searches Seedling information in the database, Sends results to extension agent

Cardinality: one /Seedling

Lifetime: Instantiated when the Jade container is run.

Initialization: Receives request from extension agent, Reads seedling table from the Extension Database.

Demise: Gets information from table and sends to extension agent and Closes open database connection.

Functionality: Receives messages from Extension Agent, Searches Seedling information in the database, Sends results to extension agent

Uses Data: Seedling information from seedling table

Produces Data: Seedling information.

Goals: To avail extension seedling information required by the farmer.

Events responded to: Extension agent request

Actions: Seedling info, farmer queries

Interacted with: Extension agent.

Name: Disease Agent

Description: Receives messages from Extension Agent

Searches diseases in the database

Sends results to extension agent

Cardinality: one /diseases

Lifetime: Instantiated when the Jade container is run.

Initialization: Receives request from extension agent, Reads disease table from the Extension Database.

Demise: Gets information from table and sends to extension agent and Closes open database connection.

Functionality: Receives messages from Extension Agent, Searches diseases information in the database and Sends results to extension agent

Uses Data: Diseases information from diseases table

Produces Data: Diseases information.

Goals: To avail extension diseases information required by the farmer.

Events responded to: Extension agent request

Actions: Diseases info, farmer queries

Interacted with: Extension agent.

Name: harvesting& packing Agent

Description: Receives messages from Extension Agent, Searches Harvesting and Packaging information in the database and Sends results to extension agent

Cardinality: one /Harvesting

Lifetime: Instantiated when on receiving extension request

Initialization: Receives request from extension agent, Reads harvesting table from the Extension Database.

Demise: Gets information from table and sends to extension agent and Closes open database connection.

Functionality: Receives messages from Extension Agent, Searches harvesting& packing information in the database and Sends results to extension agent

Uses Data: harvesting& packing information from diseases table

Produces Data: harvesting& packing information.

Goals: To avail extension harvesting& packing information required by the farmer.

Events responded to: Extension agent request

Actions: harvesting& packing info, farmer queries

Interacted with: Extension agent.

Name: marketing Agent

Description: Receives message from Extension Agent, Searches Marketing information in the information database and Sends results to extension agent

Cardinality: one /marketing

Lifetime: Instantiated when on receiving extension request

Initialization: Receives request from extension agent, Reads marketing table from the Extension Database.

Demise: Gets information from table and sends to extension agent and Closes open database connection.

Functionality: Receives messages from Extension Agent, Searches marketing information in the database and Sends results to extension agent

Uses Data: marketing information from diseases table

Produces Data: marketing information.

Goals: To avail extension marketing information required by the farmer.

Events responded to: Extension agent request

Actions: marketing info, farmer queries

Interacted with: Extension agent.

Name: planting Agent

Description: Receives messages from Extension Agent, Searches planting information in the database and Sends results to extension agent

Cardinality: one /planting

Lifetime: Instantiated when on receiving extension request

Initialization: Receives request from extension agent, Reads planting table from the Extension Database.

Demise: Gets information from table and sends to extension agent and Closes open database connection.

Functionality: Receives messages from Extension Agent, Searches planting information in the database and Sends results to extension agent

Uses Data: planting information from diseases table

Produces Data: planting information.

Goals: To avail extension planting ting information required by the farmer.

Events responded to: Extension agent request

Actions: planting info, farmer queries

Interacted with: Extension agent.

Name: Farmer Agent

Description: Sends Farmers information request to Extension Agent and gets results

Cardinality: one /marketing

Lifetime: Instantiated when farmer inputs name and send request

Initialization: Farmers enter name and

Goals: To avail extension information required by the farmer.

Events responded to: Extension agent information by displaying

Actions: farmer queries

Interacted with: Extension agent.

| Agent Type | Responsibilities |
|--------------------------------|--|
| Farmer Agent | Sends Farmers information request to Extension Agent Gets results |
| Extension Agent | Receives Requests from the farmer agent Starts search process Logs Query in the database Forwards results to the farmers mobile phone Sends SMS to Extension worker Receives Responses from the seedling, planting, diseases, Harvesting and packaging and marketing agent. |
| Seedling Agent | Receives messages from Extension Agent Searches Seedling information in the database Sends results to extension agent |
| Planting Agent | Receives messages from Extension Agent Searches planting information in the database Sends results to extension agent |
| Diseases Agent | Receives messages from Extension Agent Searches diseases in the database Sends results to extension agent |
| Harvesting and Packaging Agent | Receives messages from Extension Agent Searches Harvesting and Packaging information in the database Sends results to extension agent |
| Marketing Agent. | Receives message from Extension Agent. Searches Marketing information in the information database. Sends results to extension agent. |

4.2.3 System Overview Diagram

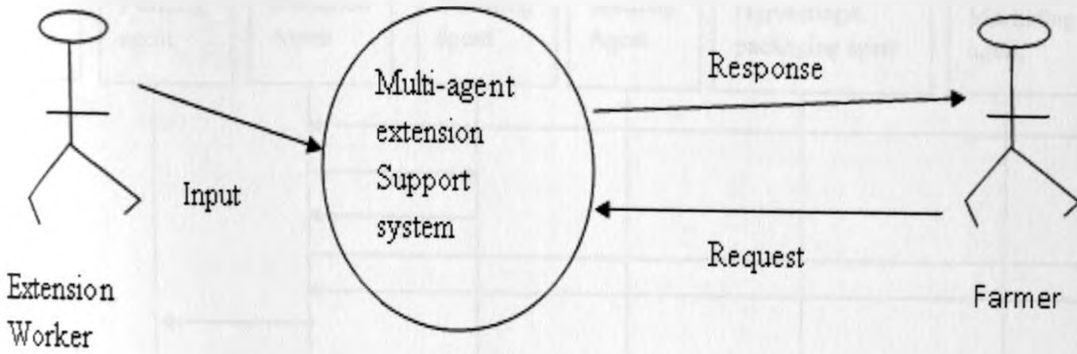


Figure 10: System Overview

4.2.4 Technological Infrastructure: System Overview Diagram

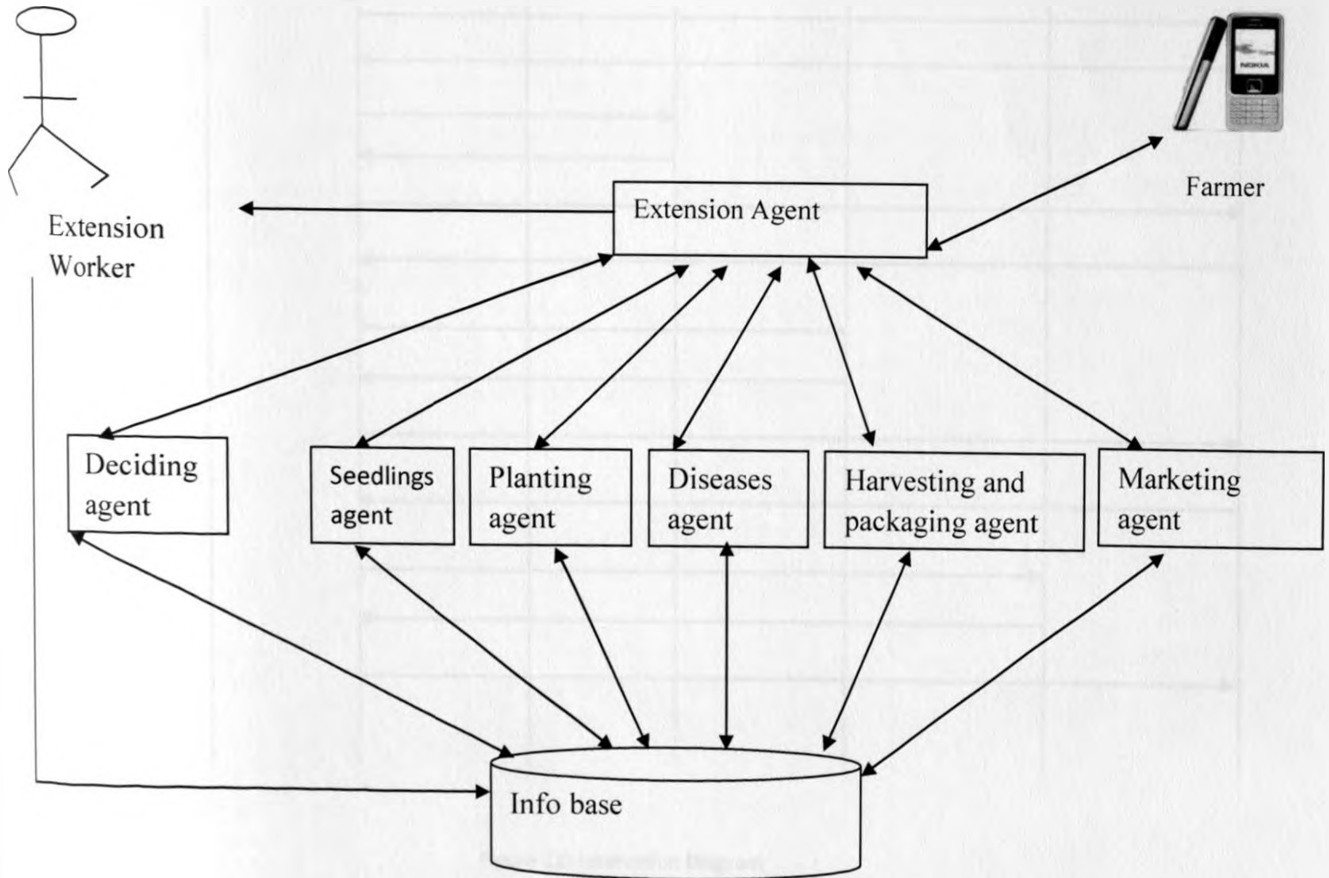


Figure 11: Technological Infrastructure System overview

4.2.5 Interaction Diagram

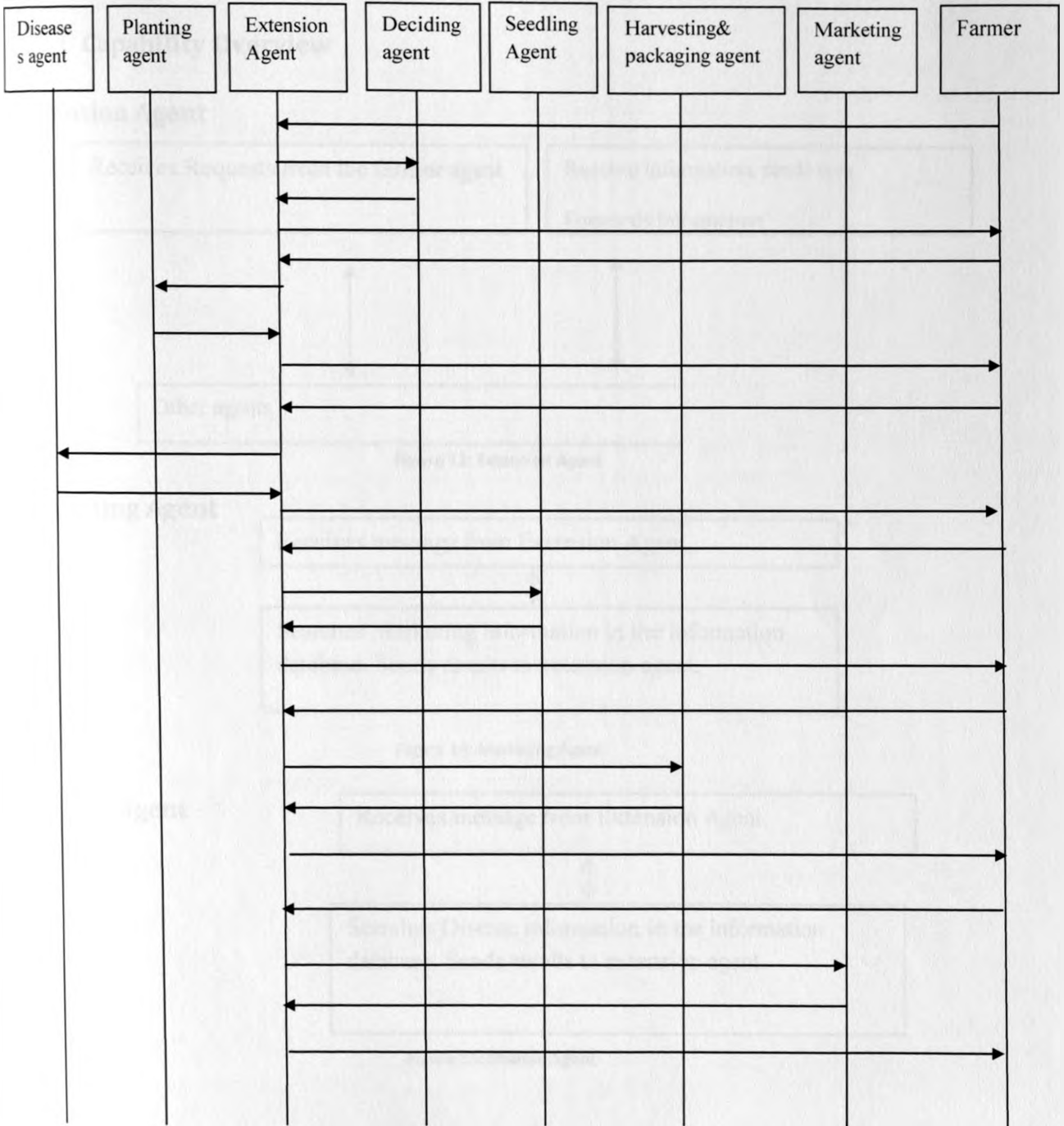


Figure 12: Interaction Diagram

4.3 Detailed Design

4.3.1 Capability Overview

Extension Agent

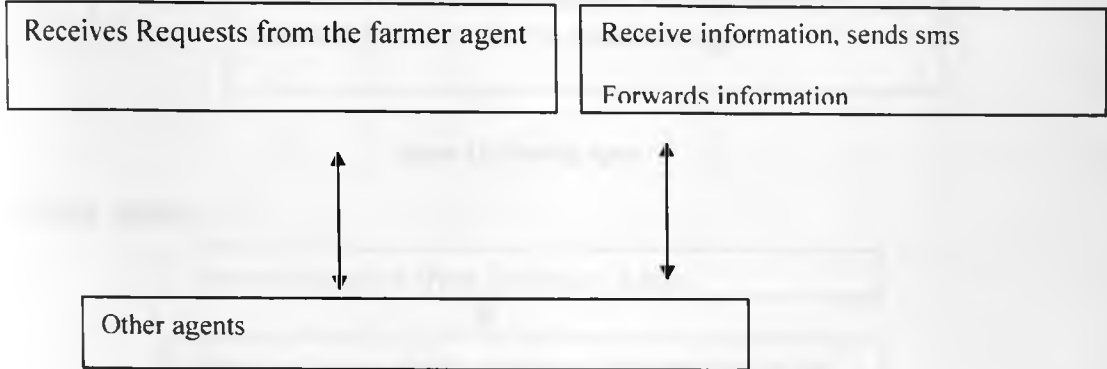


Figure 13: Extension Agent

Marketing Agent

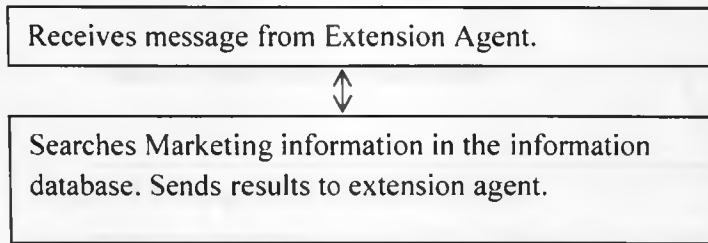


Figure 14: Marketing Agent

Disease Agent

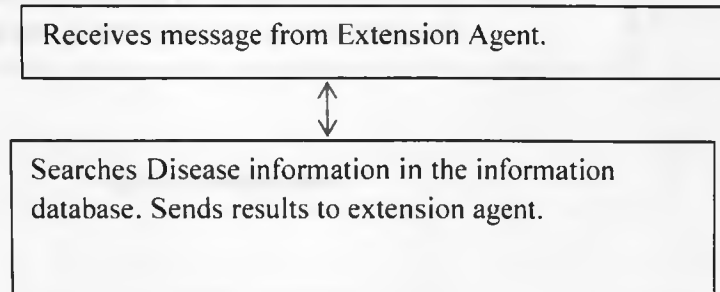


Figure 15: Disease Agent

Deciding Agent

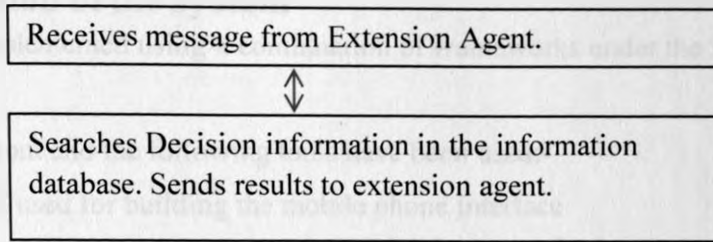


Figure 16: Deciding Agent

Harvesting Agent

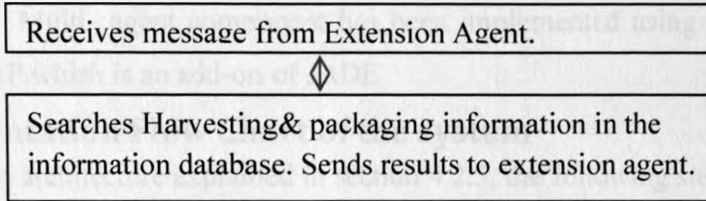


Figure 17: Harvesting & packaging Agent

Seedling Agent

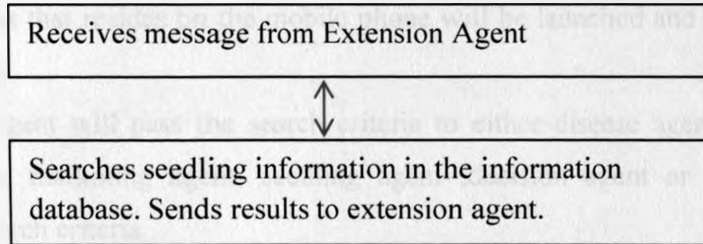


Figure 18: Seedling Agent

Farmer Agent

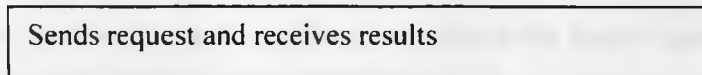


Figure 19: Farmer Agent

CHAPTER 5: IMPLEMENTATION

5.0 Implementation of the system

The system has been implemented using a combination of frameworks under the Java Enterprise Edition i.e.

- (i) For the front end the following tools have been used:-
 - ✓ J2ME used for building the mobile phone interface
 - ✓ PHP used for building the web interface
- (ii) The back end has been implemented using the enterprise java beans, following the Java Persistence (JPA) framework.
- (iii) The Multi agent component has been implemented using JADE and JADE – LEAP which is an add-on of JADE

5.1 Implementation Flow Chart of the system

Based on the design architecture explained in section 4.2.5, the following steps were followed in development.

- ✓ Farmers first inputs Name and then search criteria on graphical user interface from the mobile phone and submit request.
- ✓ The farmer Agent that resides on the mobile phone will be launched and pass request to Extension Agent.
- ✓ The Extension agent will pass the search criteria to either disease agent, harvesting& packaging agent, marketing agent, seedling agent ,decision agent or planting agent depending on search criteria
- ✓ The agent that receives the search criteria request from extension agent retrieves the information according to the search criteria from the database.
- ✓ The agent which be either disease agent, harvesting& packaging agent, marketing agent, seedling agent ,decision agent or planting agent inform the Extension agent what information was retrieved from the extension service database
- ✓ The extension agent upon receiving the information informs the farmer agent which in turn displays the information on the screen of the mobile phone.
- ✓ If the results were not found the Extension Agent automatically sends a query sms to several extension officers in order for them to know what needs to be updated.

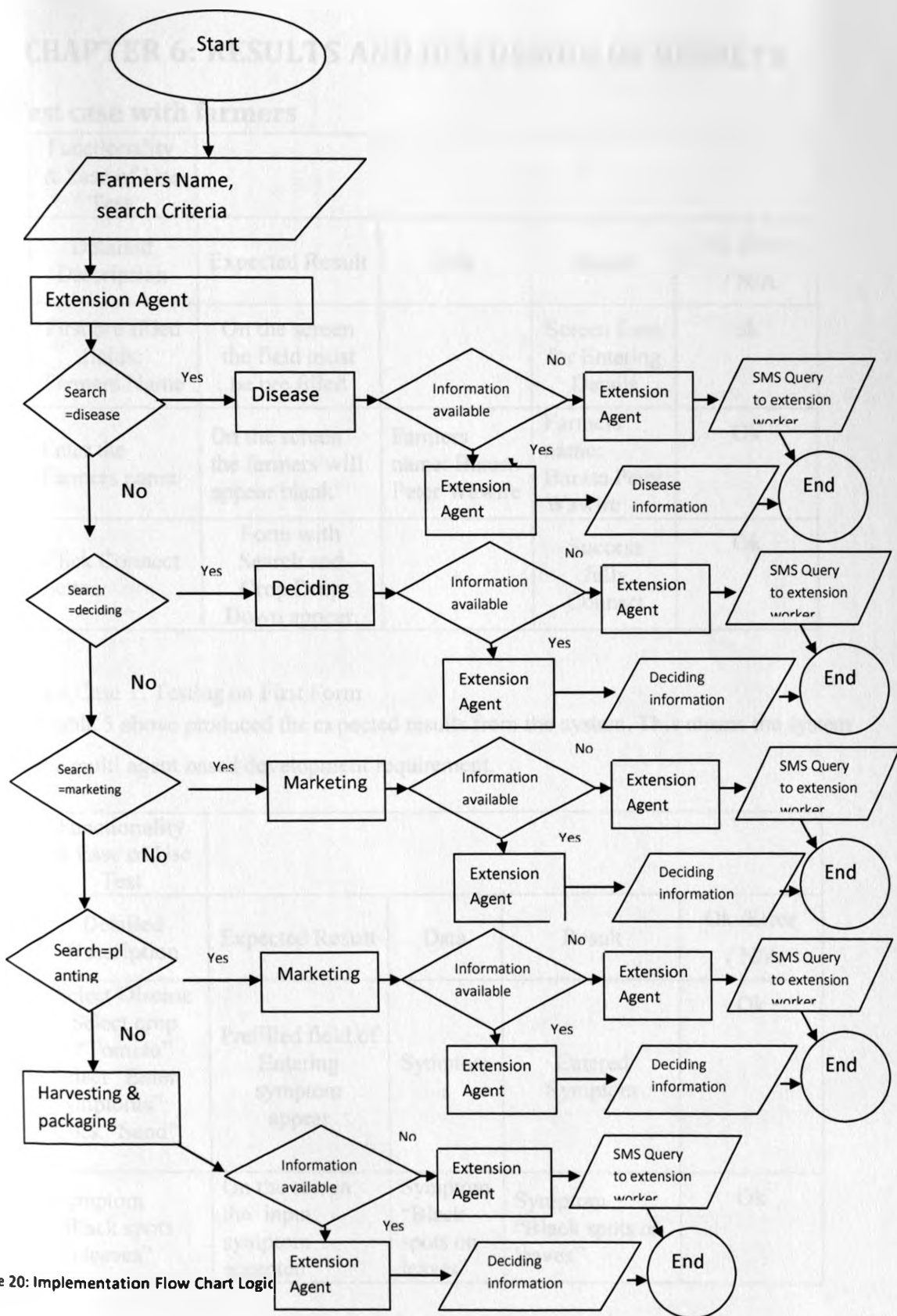


Figure 20: Implementation Flow Chart Logic

CHAPTER 6: RESULTS AND DISCUSSION OF RESULTS

6.1 Test case with farmers

| Case 1 | Functionality & Ease of Use Test | | | | |
|--------|--|---|-----------------------------------|-----------------------------------|-----------------|
| Seq. | Detailed Description | Expected Result | Data | Result | Ok /Error / N/A |
| 1 | First pre filled fields: Farmers Name | On the screen the field must be pre filled | - | Screen form for Entering Details | ok |
| 2 | Enter the Farmers name | On the screen the farmers will appear blank | Farmers name: Barasa Peter Wawire | Farmers name: Barasa Peter Wawire | Ok |
| 3 | Click Connect button | Form with Search and Crop Drop Down appear. | - | Success fully Connect | Ok |

Table 5: Test Case 1: Testing on First Form

The test in table 5 above produced the expected results from the system. This means the system achieved the multi agent based development requirement.

| Case 2 | Functionality & Ease of Use Test | | | | |
|--------|---|--|---------------------------------|---------------------------------|-----------------|
| Seq. | Detailed Description | Expected Result | Data | Result | Ok /Error / N/A |
| 1 | Select Disease Select crop "Tomato" Select "Enter Symptoms" Click "Send" | Prefilled field of Entering symptom appear | Symptom s | Entered Symptom | Ok |
| 2 | Symptom "Black spots on leaves" | On the screen the input symptom accepted | Symptom "Black spots on leaves" | Symptom "Black spots on leaves" | Ok |

| | | | | | |
|---|---|--|---|---|----|
| 3 | Click "Send" | Possible Diseases matching the symptoms. | - | Late Blight: Early Blight: Powdery Mildew: Bacterial Spot: Tomato Spotted wilt | Ok |
| 4 | Select Back Button Select search "Diseases" Crop "Tomato" Disease "Late Blight" Option Select "Treatment" Click Send | Treatment of Late Blight | | Recommended are copper products based on either copper hydroxide or oxychloride. Copper fungicides are formerly accepted in organic farming provided that the number of applications is strictly followed and a proper soil amendment is observed to prevent copper accumulation in the soil, and can still be accepted with permission from the certifying authority (other fungicides based on Sulphur (e.g. Thiovit) are being tested by CIP).;wet weather fungicide sprays should be applied as soon as the disease is observed or as soon as local experience suggests that weather conditions are favourable for disease development. | Ok |

Table 6: Test Case 2-Testing Diseases Form on disease treatment

The test case in table 6 achieved its expected results as it's shown. There were no errors in the system

| Case 3 | Functionality & Ease of Use Test | | | | |
|--------|---|--|--------------------|--|-----------------|
| Seq. | Detailed Description | Expected Result | Data | Result | Ok /Error / N/A |
| 1 | Click back button display of diseases | Form with Search and Crop Drop Down appear again | - | Form with Search and Crop Drop Down appear again | Ok |
| 2 | Select Disease Select crop "Tomato" Select "Enter Symptoms" Click "Send" Enter unavailable Symptom "Vomiting" | Message on screen of mobile phone stating not found. Sms query to several farmers | Symptom "Vomiting" | No results found. But Our extension officers are working on it to ensure the necessary information is availed. Please check with us later SMS query to Extension officers: Disease from diseases WHERE crop=Tomato. AND MATCH(symptoms) AGAINST (- Vomiting-) | ok |

Table 7: Test Case 3- Testing Diseases Form on SMS functionality

The test case in table 7 achieved its expected results as it's shown. There were no errors in the system. The farmers were happy that whatever is not found while searching a sms query is send to the extension worker to alert. The extension workers can the add information.

| Case 4 | Functionality & Ease of Use Test | | | | |
|--------|--|--|------------------------------------|--|-----------------|
| Seq. | Detailed Description | Expected Result | Data | Result | Ok /Error / N/A |
| 1 | Select Disease Select crop "Tomato" Select "Enter Symptoms" Click "Send" | Prefilled field of Entering symptom appear | Symptoms | Entered Symptom | ok |
| 2 | Symptom "Black spots on leaves" | On the screen the input symptom accepted | Symptom "Black spots on leaves" | Symptom "Black spots on leaves" | ok |
| 3 | Click "Send" | Possible Diseases matching the symptoms. | - | Late Blight: Early Blight: Powdery Mildew: Bacterial Spot: Tomato Spotted wilt | ok |

Table 8: Test Case 4 - Testing Disease Form on matching of input symptoms to diseases

The test case in table 8 above achieved its expected results as it's shown. There were no errors in the system. The farmers were happy that the symptoms input would be able to match the equivalent possible diseases. The farmers can then be able to counter check the symptoms by accessing information on each disease, suggested by the system individually.

| Case 5 | Functionality & Ease of Use Test | | | | |
|--------|---|--|---|------------------------------|-----------------|
| Seq. | Detailed Description | Expected Result | Data | Result | Ok /Error / N/A |
| 1 | Click Back Button Select Search "Decision" Select crop "General" Select "Enter Region" Click "Send" | Crop that can be planted in the region | Naivasha | Rose Flower | ok |
| 2 | Click back button Select search "Decision" Crop "Rose Flower" Options "Requirement" Click Send | Requirement for Rose flower | Select decision Rose flower, requirement | Requirements of rose flower. | ok |

Table 9: Test Case 5- Testing decision Form

| Case 6 | Functionality & Ease of Use Test | | | | |
|--------|--|--------------------------------------|---|--|-----------------|
| Seq. | Detailed Description | Expected Result | Data | Result | Ok /Error / N/A |
| 1 | Click Back Button Select Search "marketing" Select crop "General" Option select "How TO" Click "Send" | General information on How to market | Naivasha | ->Get agent contacts and give them your details -> Get more information | ok |
| 2 | Click back button Select search "marketing" Crop "Rose Flower" Select Get "Potential markets" Click Send | Potential markets | Marketing, rose flower, potential markets | Potential markets displayed. | ok |

Table 10: Test Case 6- Testing marketing Form

| Case 7 | Functionality & Ease of Use Test | | | | |
|--------|--|--|--|---------------------------------------|-----------------|
| Seq. | Detailed Description | Expected Result | Data | Result | Ok /Error / N/A |
| 1 | Click Back Button Select Search "Harvesting & packaging" Select crop "Rose flower" Select Options "Harvesting Procedures" Click "Send" | Display of Harvesting procedures on the screen | Selection of: Harvesting & packaging, Rose Flower, Harvesting Procedures | Harvesting procedures for Rose Flower | ok |
| 2 | Click back button Select search "Seedling" Crop "Rose Flower" Options "Preparation" Click Send | Requirement for Rose flower | Select :seedling, Rose flower, Preparation | Display of preparation of seedling | ok |

Table 11: Test Case 7- Testing harvesting & packaging and seedling Form

6.2 Evaluation results after running test cases with farmers

Table 12: Percentages and Means of Farmers Rating in Ease of Use Evaluation

| Ease of Use | Percentages of Rating (%) | | | | | Means |
|-------------------------|---------------------------|------|------|-----------------|----------------|-------|
| | Excellent | Good | Poor | Does Not Exist? | Not Applicable | |
| | 3 | 2 | 1 | 0 | NA | |
| 1. Is it simple to use? | 80 | 17 | 3 | 0 | 0 | 2.77 |
| 2. Is it user friendly? | 70 | 23 | 7 | 0 | 0 | 2.63 |
| 3. Is it Flexible? | 80 | 17 | 3 | 0 | 0 | 2.77 |
| Total Means | 77 | 19 | 4 | 0 | 0 | 2.72 |

Table 12 above reveals three evaluation items of the system in terms of ease of use. The rate mean is quite high at 2.72. Based on the evaluation survey results, it is deduced that overall screen layout and window design, overall interface operation method, overall configuration of colours and background contributed to ease of use high rating mean. Simplicity and flexibility of interface operation both scored highly with 80% of farmer respondents ranking it as excellent.

A Bar Chart on Ease of Use Evaluation of Multi agent Based Extension Support System

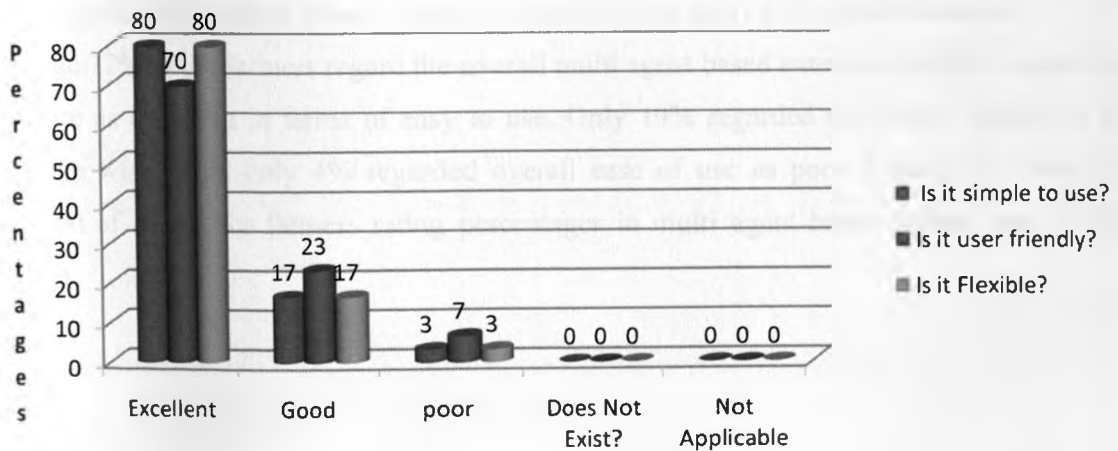


Figure 21: A Bar Chart on ease of use evaluation of the multi agent based system for horticulture

A Bar Chart of Means for Farmers Rating Percentages in Ease of Use Evaluation



Figure 22: The distribution of means for farmers rating in System ease of use evaluation

80% respondents rated the system as excellent in terms of ease of use and flexibility, while 70 % of the respondents rated the system excellent in term of being user friendly. 17% of respondent rated the system as good in terms of ease of use and flexibility, while 23% of respondents rated the system good user friendly wise. Figure 20 shows the bar chart with this information.

On average 77% of the farmers regard the overall multi agent based extension support system for horticulture as excellent in terms of easy to use. Only 19% regarded the overall system to be good usage wise while only 4% regarded overall ease of use as poor. Figure 21 shows the distribution of means for farmers rating percentages in multi agent based system ease of use evaluation.

Table 13: Percentages and Means of Farmers Rating in Functionality Evaluation Aspects

| Functionality | Percentages of Rating (%) | | | | | Means |
|---|---------------------------|------|------|-----------------|----------------|-------------|
| | Excellent | Good | Poor | Does Not Exist? | Not Applicable | |
| | 3 | 2 | 1 | 0 | NA | |
| 1. Is Feedback Effective and appropriate? | 90 | 10 | 0 | 0 | 0 | 2.9 |
| 2. Does it offer in depth messaging of information? | 93 | 7 | 0 | 0 | 0 | 2.93 |
| 3. Does it meet farmer's needs? | 90 | 7 | 3 | 0 | 0 | 2.87 |
| Total Means | 91 | 8 | 1 | 0 | 0 | 2.9 |

Table 13 shows the results of three evaluation items surveyed for the five major functional areas. The build system was able to offer access to extension services on diseases, planting, seedling, and harvesting & packing, marketing and deciding information services. 3% of the farmer respondents do not regard the system as meeting all the needs of the farmers because information on pests and fertilizers was not available.

The result reveals the system still needs further improvement, this may be reason for low appraisal (mean=2.87) of this particular function by farmers, but we find a mean of above 2.9 for the other aspects of functional evaluation. Hence, the functional aspects of this multi agent based extension support system for horticulture should be able to meet the needs of the farmers by providing in depth effective and appropriate messaging. Figure 22 shows a bar chart for functionality evaluation aspects.

On average, 91% of the farmers rated the overall functionality of the system as excellent and 8% regarded the build system as good. Only 1% regarded the system as in appropriate. Such results reveal that the major functions of the multi agent based system have met the needs of the farmers very well. There is much more room for improvements such as improving the automatic mining of data to the database from different information sources on the internet so that farmers receive

all the information they need. Figure 23 shows the distribution of means for farmers rating percentages in system Functionality evaluation

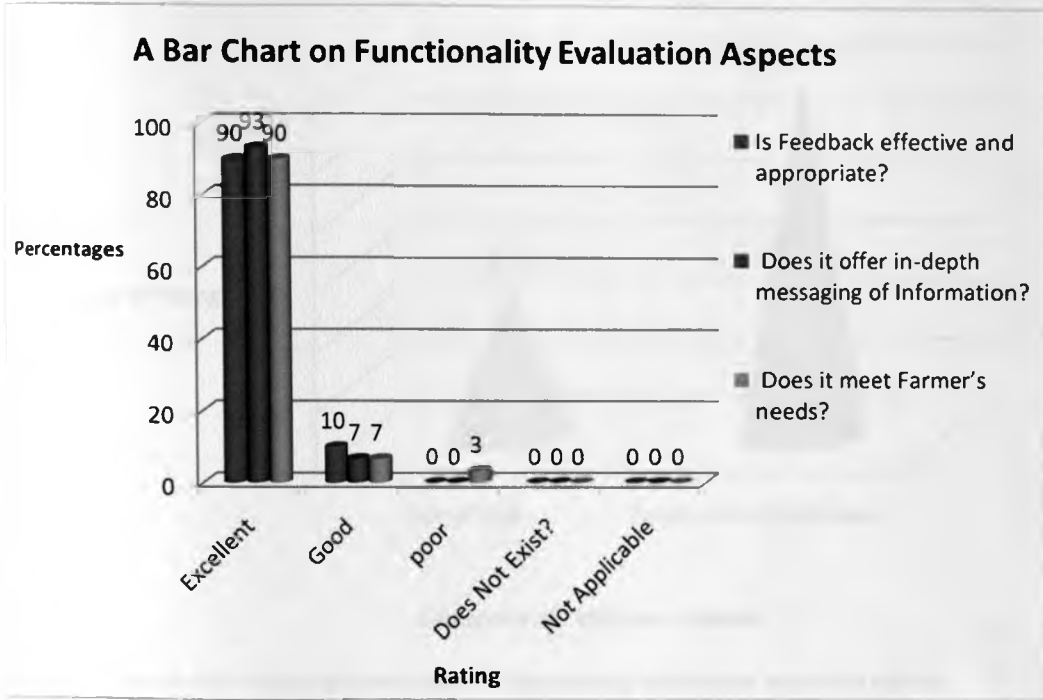


Figure 23: A bar chart for functionality evaluation aspects

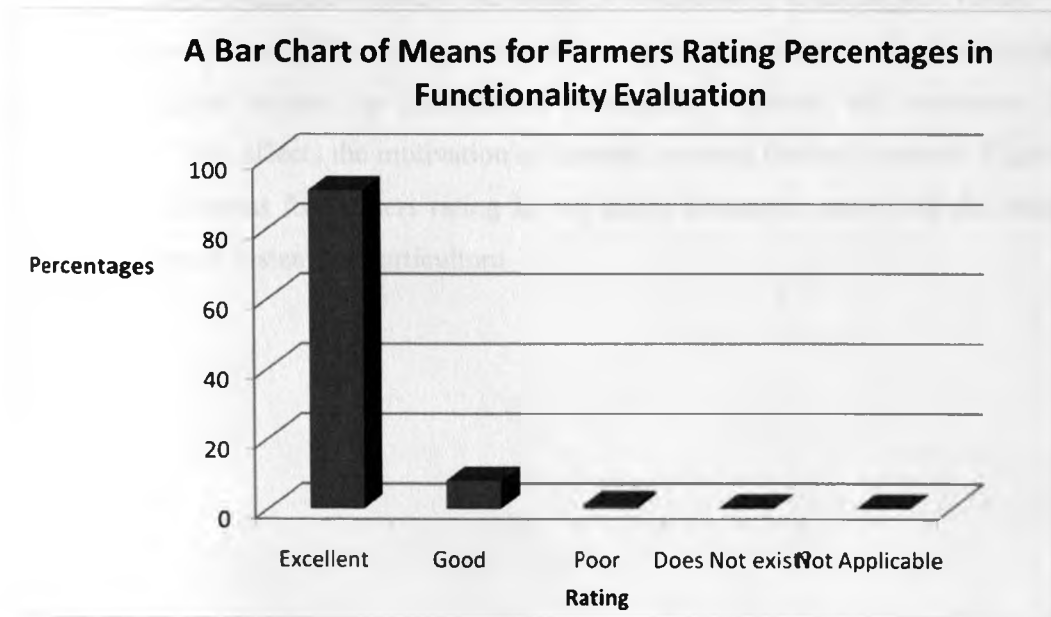


Figure 24: The distribution of means for farmers rating percentages in Functionality evaluation

Distribution of means for farmers rating in two major evaluation aspects

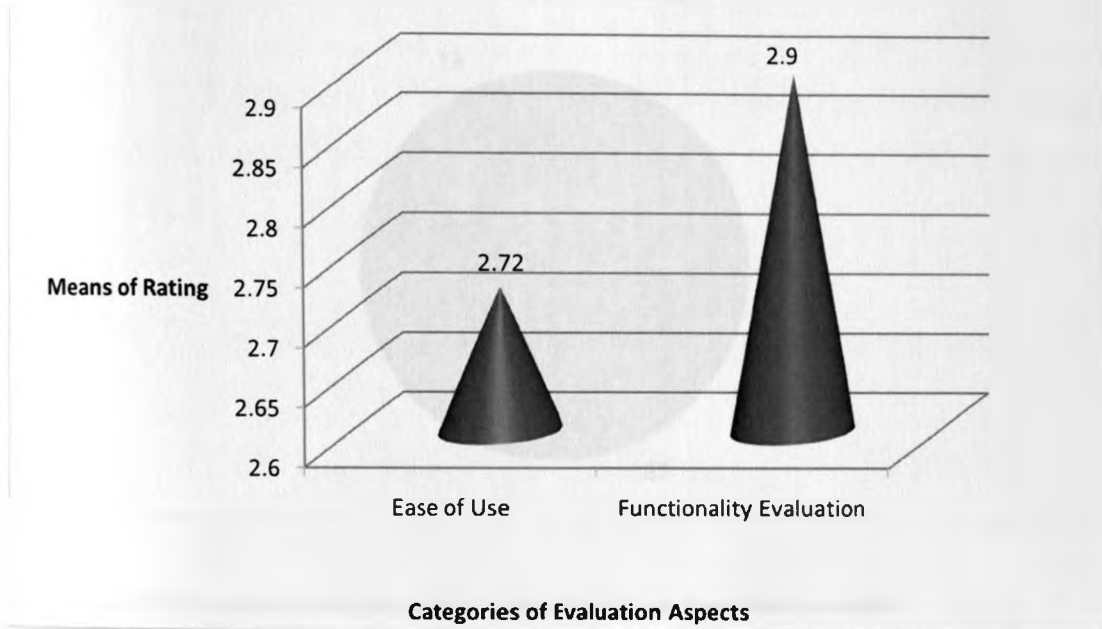


Figure 25: A bar chart for functionality evaluation for farmers rating in two major evaluation aspects

Of the two major evaluation aspects, the rating of functionality is the highest (mean = 2.9) and ease of use follows (mean = 2.72). This reveals that in spite of having an excellent multi agent based extension support system for horticulture functionally, farmers still encounter difficulties in practical use. This affects the motivation of farmers in using the build system. Figure 24 show the distribution of means for farmers rating in two major evaluation aspects of the multi agent based extension support system for horticulture.

Are you motivated to use the program repeatedly?

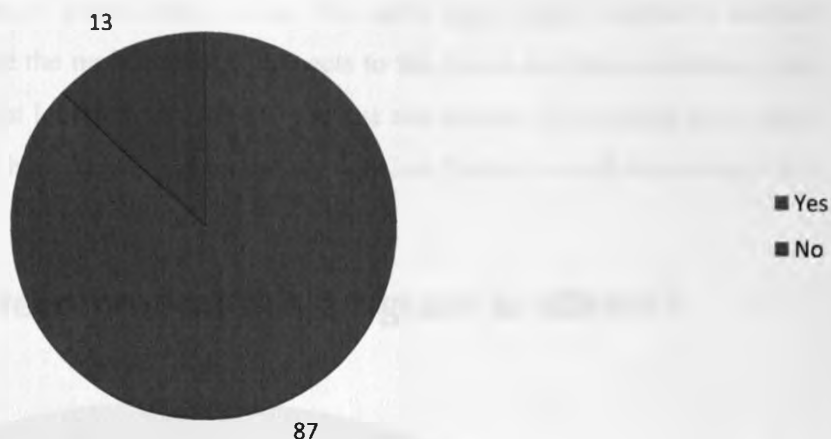


Figure 26: A pie Chart response on whether farmers are motivated to use the system repeatedly?

Once the system was evaluated on functionality and ease of use, we obtained valuable opinions and suggestion from the farmers.

Their responses to questions of "whether they are motivated to use the system repeatedly" indicate that 87% of the respondents were motivated to use the program repeatedly because the program is much flexible when you move back wards. For example after the system giving the farmer the possible diseases matching the symptoms, the farmer is able to move backwards using the back button and view symptoms in full. Only 13% of the farmers respondents had their opinion as No. Figure 25 show the pie chart response on whether farmers are motivated to use the system repeatedly.

When asked "would you recommend this program to others" and "If you were to recommend this program, what positive aspects would you stress?" 75% of the farmers indicated that they would recommend this program to other farmers. The farmers feedback opinion suggested that the overall screen layout and window design, overall interface operation method, overall configuration of colours and background were positive aspects (See appendix 3). The other positive aspects that farmers recommended is that farmers can be able to access extension information anywhere any time using the mobile phone as long as they have installed system, the extension information offered starts from the first stage of deciding , then seedlings, planting,

diseases, harvesting & packaging and marketing. The farmers also noted that search information not found is send to several extension officers as sms to their mobile phones. The extension officers have an interface to upload the information through a computer which can later be accessed by the same farmers. It's not costly to use the multi agent based extension support system for horticulture because the mobile phone connects to the server computer wirelessly and that several farmers in different locations are able to request and access information at the same time. Figure 26 shows a pie Chart showing response on whether farmers would recommend this program to others?

Would you recommend this program to others?

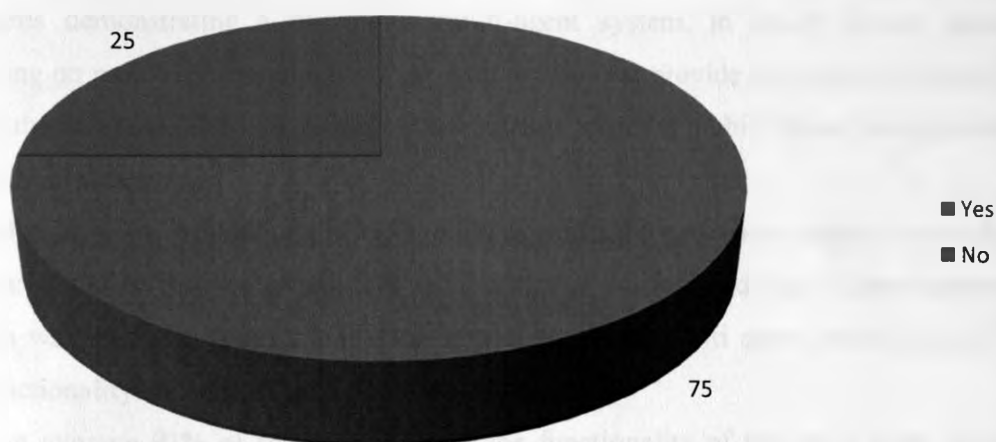


Figure 27: A pie Chart showing response on whether farmers would recommend this program to others?

25% of the farmer respondents indicated that they would not recommend the build multi agent based extension support system for horticulture to others. When asked, "Are there any weaknesses with the program?" and "If so, what are they?" they indicated that build system has got weakness. The feedback suggested weaknesses that farmers who are only Kiswahili literate and mother tongue literate cannot read the information provided by the multi agent based extension support system for horticulture. Another weakness is that the multi agent based extension support system would only run on mobile phones that are java enabled phone. This means farmers need to own certain mobile phone.

CHAPTER 7: CONCLUSION AND FUTURE WORK

7.1 Conclusion

The multi agent based extension support system for horticulture application targeted the agriculture industry; where we normally employ a human agent (the extension officer) to pass extension information to the farmers. However in such a mobile environment we can employ multi agents which can replicate the job of the extension officer. The research focused on adding value to accessing extension information by farmers using multi agent based technology with the aid of a mobile phone.

This work has also successfully demonstrated agent oriented development approach applicability in solving the horticulture extension problem. Using JADE and JADE LEAP frameworks opened the way towards demonstrating a distributed multi-agent system, in which farmer agents smoothly running on mobile phone communicate with agents that provide extension information available from the database. The integration of multi agents with the mobile phone development technology J2ME was seamless.

The purpose of testing and evaluating the build multi agent based extension support system for horticulture was to ensure that the system attained its original purpose and goal of development. The evaluation was meant to provide understanding of the build multi agent based system in terms of its functionality and ease of use.

As many as on average 91% of the farmers rated the functionality of the multi agent based extension support system for horticulture excellent while on average 77% of the farmers rated the overall multi agent based extension support system for horticulture as excellent in terms of easy to use.

The evaluation results also revealed that 87% of the farmers were motivated to use the program repeatedly while 75% of the farmers indicated that they would recommend this program to other farmers.

It was revealed that the built prototype system had positive aspects of enabling several farmers to access extension through the mobile phone hence it meets its original design purpose. The results also revealed that there is still room for improvement in spite the fact that it has shown excellent rating in functionality and ease of use.

7.2 Limitations

The agent oriented technology still has limitations on the development of better and user friendly interfaces. Security is still a limitation not only for agent technologies but other technologies as well. Another limitation is that the project focused on English leaving out Kiswahili which is more familiar to majority of the farmers. The system also requires editing information from different sources and entering into database. The system is also not able to get the location of the farmer to enable follow up services by the farmer

7.3 Future Work

The following improvements can be added to the multi agent based extension support system for horticulture:

- Data mining functionality. Integration of data mining and multi agent technology will enable mining of current extension information from the internet and automatically storing the information in the extension service data base.
- Geographical information system (GIS) functionality. Integration of GIS with multi agent will enable the system to store the location of the farmers farm to enable follow up by the extension officer if need arises.
- Language functionality. The multi agent based extension support system should in future be able to give extension information in Kiswahili language.

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APPENDIX

Appendix A: Multi-agent based Extension Support for Horticulture Evaluation Form

| | | | | | |
|---|----------|---|-------|---|----|
| Evaluator's Name: | | | | | |
| Date of Evaluation: | | | | | |
| A. Ease of use | | | | | |
| 1. Is it simple to use? | 3 | 2 | 1 | 0 | NA |
| 2. Is it user friendly? | 3 | 2 | 1 | 0 | NA |
| 3. Is it Flexible? | 3 | 2 | 1 | 0 | NA |
| (Max total of 9) Total Section A | + | + | + | = | |
| Rating Key 3 = Excellent 2 = Good 1 = Poor 0 = Does Not Exist NA = Not Applicable | | | | | |
| B. Functionality | | | | | |
| 4. Is Feedback effective and appropriate? | 3 | 2 | 1 | 0 | NA |
| 5. Does it offer in-depth messaging of Information? | 3 | 2 | 1 | 0 | NA |
| 6. Does it meet Farmer's needs? | 3 | 2 | 1 | 0 | NA |
| (Max total of 9) Total Section B | + | + | + | = | |
| Are you motivated to use the program repeatedly? | Yes..... | | No... | | |
| Would you recommend this program to others? | Yes..... | | No... | | |
| If you were to recommend this program, what positive aspects would you stress? | | | | | |
| Are there any weaknesses with the program? If so, what are they? | | | | | |

Appendix B: Sample code of the Implementation of the system

Extension Agent: Farmer Vocabulary

```
public class Extension Agent extends Agent implements
farmerExtensionVocabulary {
//Registering Content Languages and Ontologies with an Agent
public Codec slCodec = new SLCodec();
public Ontology exOntology = extensionOntology.getInstance();

@Override
protected void setup() {
System.out.println ("Agent" + getLocalName() + " of " + getClass() + "
running...");
getContentManager().registerLanguage(slCodec);
getContentManager().registerOntology(exOntology);
addBehaviour(new receiveRequests(this));
addBehaviour(new receiveResponses(this))
}
}
```

Extension Agent: Forward Results

```
classForwardResults extends OneShotBehaviour {
privateACLMessage mess;
publicForwardResults(Agent a, ACLMessage message) {
super(a);
mess = message;}
@Override
public void action() {
//throw new UnsupportedOperationException("Not supported yet.");
myAgent.send(mess);
} }
```

```

String[] message = msg.split("::");//received message is split for parsing
    String agent = message[0] + "_Agent";
    String params = message[2];
    String table=message[3];
    String conditions = message[1];
    String extra[] = params.split(",");
if (extra.length == 2) {
conditions += " AND " + extra[1];
params = extra[0];
    }

```

```

myAgent.addBehaviour(new StartSearchProcess(params + " <> " + conditions+"<>" +table, new
AID(agent, AID.ISLOCALNAME), requestor)) }}

```

Extension Agent: Receive Responses

```

classreceiveResponses extends CyclicBehaviour {
private Ontology ontology = extensionOntology.getInstance();
private Codec language = new SLCodec();
private Modem md;
publicreceiveResponses(Agent a) {
super(a);
}
@Override
public void action() {
try {
ACLMessage result =
myAgent.receive(MessageTemplate.MatchPerformative(ACLMessage.INFORM)
);
if (result == null) {
block();
return;
}
ACLMessage forward = new ACLMessage(ACLMessage.INFORM);

```

Extension Agent: Start Search Results

```
class StartSearchProcess extends OneShotBehaviour {
    public Codec slcodec = new SLCodec();
    public Ontology extontology = extensionOntology.getInstance();
    public String searchCriteria;
    private AID receiver;
    private String requesta;
    public StartSearchProcess(String criteria, AID recep, String requestor) {
        searchCriteria = criteria;
        receiver = recep;
        requesta = requestor }
    @Override
    public void action() {
        SendMessage(searchCriteria, ACLMessage.REQUEST, receiver, requesta);
    }
}
```

Extension Agent: Receive Requests

```
class receiveRequests extends CyclicBehaviour {
    public receiveRequests(Agent a) {
        super(a) }
    @Override
    public void action() {
        ACLMessage receivedMsg =
        myAgent.receive(MessageTemplate.MatchPerformative(ACLMessage.REQUEST));
        if (receivedMsg == null) {
            block();
            return;
        }
        String msg = receivedMsg.getContent();
        String requestor = receivedMsg.getSender().getLocalName();
        receivedMsg = null;
    }
}
```

```

String[] message = msg.split("::");//received message is split for parsing
String agent = message[0] + "_Agent";
String params = message[2];
String table=message[3];
String conditions = message[1];
String extra[] = params.split(",");
if (extra.length == 2) {
conditions += " AND " + extra[1];
params = extra[0];
}

```

```

myAgent.addBehaviour(new StartSearchProcess(params + " <> " + conditions+"<>" +table, new
AID(agent, AID.ISLOCALNAME), requestor)) }}

```

Extension Agent: Receive Responses

```

class receiveResponses extends CyclicBehaviour {
private Ontology ontology = extensionOntology.getInstance();
private Codec language = new SLCodec();
private Modem md;
public receiveResponses(Agent a) {
super(a);
}
@Override
public void action() {
try {
ACLMessage result =
myAgent.receive(MessageTemplate.MatchPerformative(ACLMessage.INFORM)
);
if (result == null) {
block();
return;
}
ACLMessage forward = new ACLMessage(ACLMessage.INFORM);

```

```

ContentElementmessageContents
myAgent.getContentManager().extractContent(result);
if (messageContents instanceof Result) {
    Result results = (Result) messageContents;
    if (results.getValue() instanceof SearchResults) {
        SearchResults sr = (SearchResults) results.getValue();
        System.out.println(myAgent.getLocalName() + ": Results Received:->" +
            sr.getFrom() + "->" + sr.getReceipient() + "->" + sr.getContent());
        String data = sr.getContent();
        if (data.equals("No results found.\nBut Our extension officers are working on it to
            ensure the necessary information is availed.\nPlease check with us later")) {
            System.out.println();
            if (null == md)
                md = new Modem("COM4", "", "Safaricom Modem", "Huawei",
                    "E160", "0.0", 115200, null, "0735616893", sr.getQuery());
            else
                md.sendSMS("0704519019", sr.getQuery());
            myAgent.addBehaviour(new logQueryInDB(myAgent, sr.getReceipient(),
                sr.getQuery()));
        } else {
            String[] dat = data.split(";");
            String[] a = sr.getFrom().split("_");
            data = a[0] + " Search Results\n";
            for (int j = 0; j < dat.length; j++) {
                data += "\n->" + dat[j];
            }
        }
        forward.setContent(data);
        //myAgent.getContentManager().fillContent(forward,
        messageContents);
        forward.addReceiver(new AID(sr.getReceipient(), AID.ISLOCALNAME));
        myAgent.addBehaviour(new ForwardResults(myAgent, forward));
    }
}

```

```

    }
    } else {System.out.println("Whatever was received wasn't results"); }
    } catch (CodecException ex) {
Logger.getLogger(receiveResponses.class.getName()).log(Level.SEVERE, null,
ex);
    } catch (UngroundedException ex) {
Logger.getLogger(receiveResponses.class.getName()).log(Level.SEVERE, null,
ex); } catch (OntologyException ex) {
Logger.getLogger(receiveResponses.class.getName()).log(Level.SEVERE, null,
ex); } } }

```

Appendix C: Demo Session

For our research purpose, we created seven (7) agents which are Decision agent, Disease agent, Extension agent, Harvesting& packaging agent, marketing agent and seedlings agent. We also have basic management agents defined by FIPA (DF, AMS and RMA which manage the GUI of the JADE platform). All the agents discussed above communicate using messages; the messages passed between the agents are FIPA ACL Messages. All the agents in the system are implemented to conform to the FIPA Agent Standards. The conformance of the agents to these standards ensures and guarantees agent interoperability. The fact that this system has more than one agent working together to solve the problem of extension support for horticulture farmers, means the system is a multi-agent system.

All the above seven agents are running in the main container created in the JADE environment as shown in figure 28 below

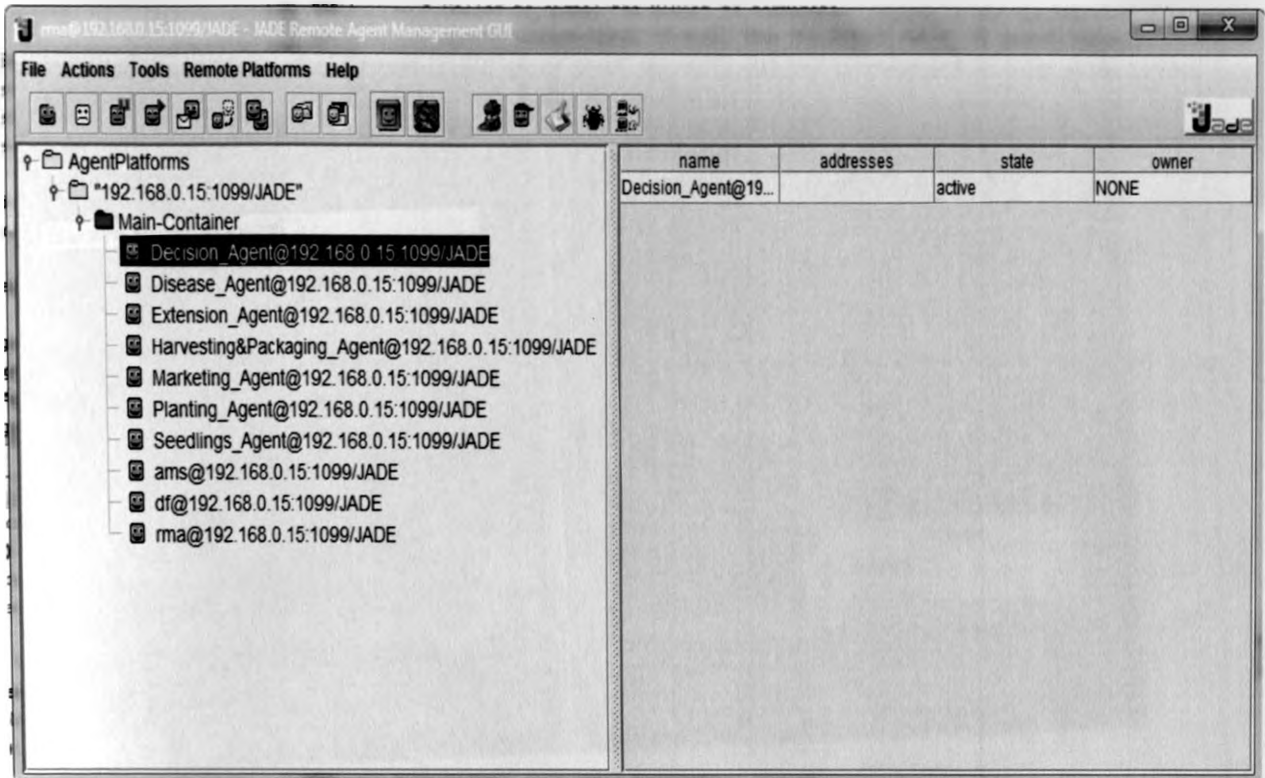


Figure 28: Seven Extension Support Agents

This GUI above in Fig 28 is actually provided by a JADE system agent called the Remote Monitoring agent (RMA) and allows a platform administrator to manipulate and monitor the running platform. It should be noted that the use of the RMA GUI, and all other graphical tools, can negatively impact system performance.



Figure 29: Farmer Requirement one: Name



Figure 30: Immediate Next-Click Connect

The First requirement is for the farmer to specify the name as shown in the above fig. 29 and then on the menu selects connect as shown in fig 30. On selecting connect; the mobile phone holds another container of the same platform. called BE-198.168.0.15_1099-1, in which the farmer agent is running. The container is created and is visible in jade as shown in the figure 31 below

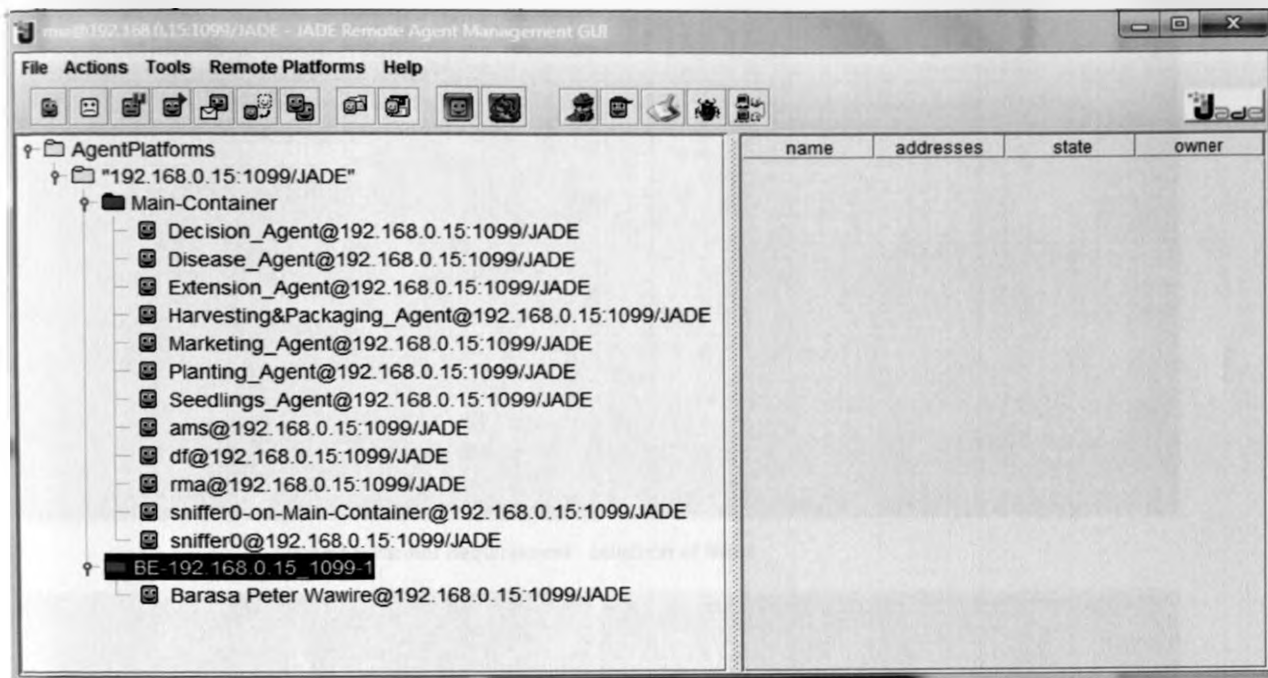


Figure 31: Container: BE-192.168.0.151099-1 Container

The farmer specifies the criteria like which search does he/she wants to perform it may be an extension need on any of the following: diseases, marketing, planting, seedlings and Harvesting & packaging. See fig: 32 below.

The extension agent exhibits autonomy, and social ability as in it communicates and negotiates with other agents in pursuit of goals, the disease agent, marketing agent, harvesting & packaging agent, deciding agent and seedlings agent exhibit the multi agent property of being goal oriented.



Figure 32: Farmer Requirement - Selection of Need

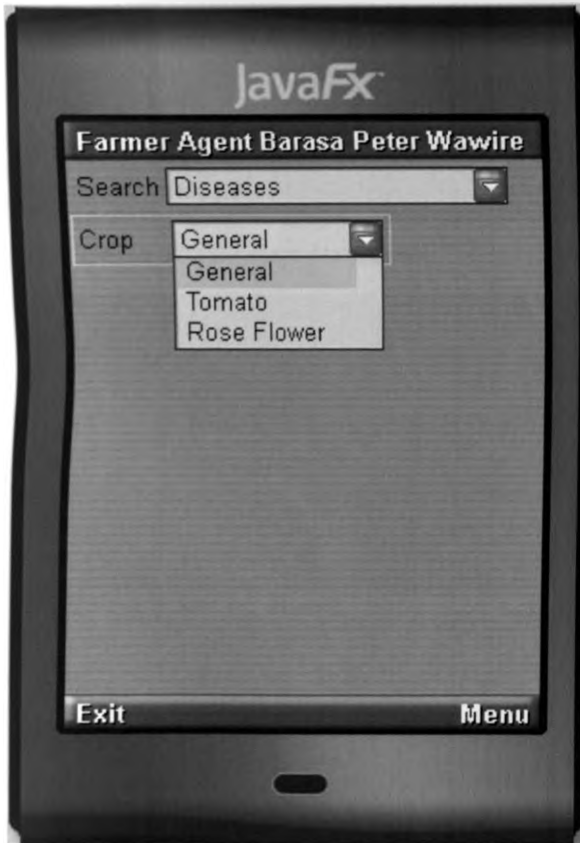


Figure 33: Farmers- Select Crop

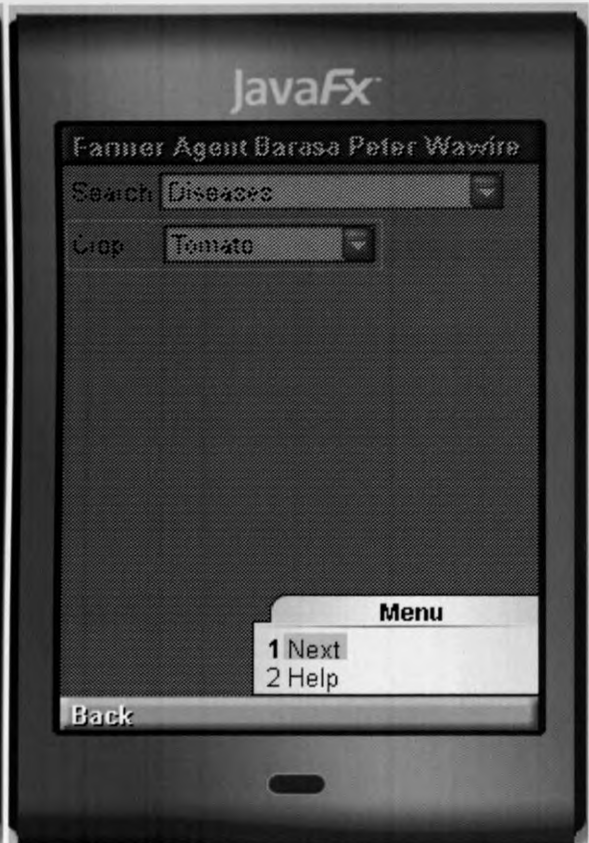


Figure 34: Farmer Requirement- GUI to Movement

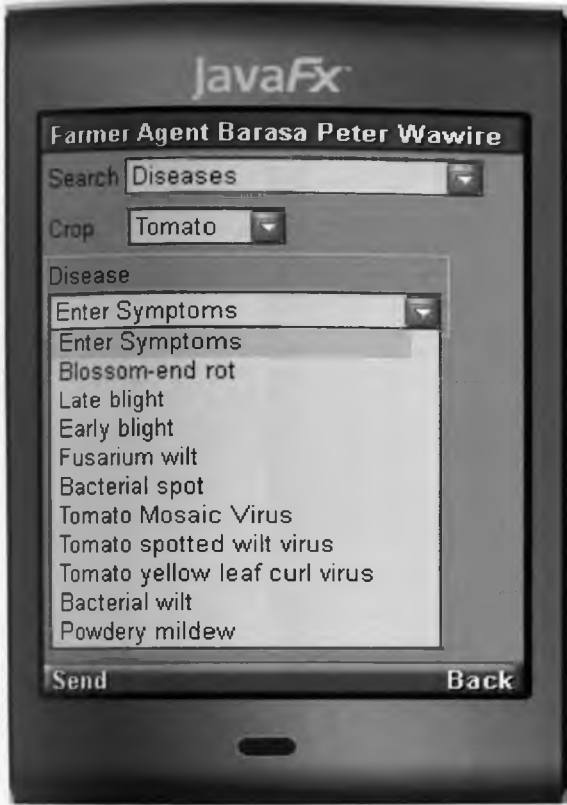


Figure 35:Farmer Requirement -Make Choice



Figure 36: Farmers Clicks Send on Marketing Choice

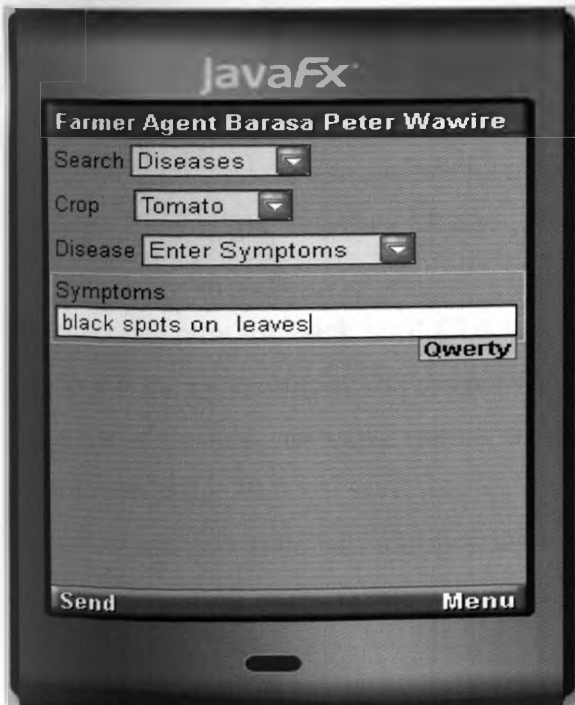


Figure 37: Farmer Requirement- symptoms

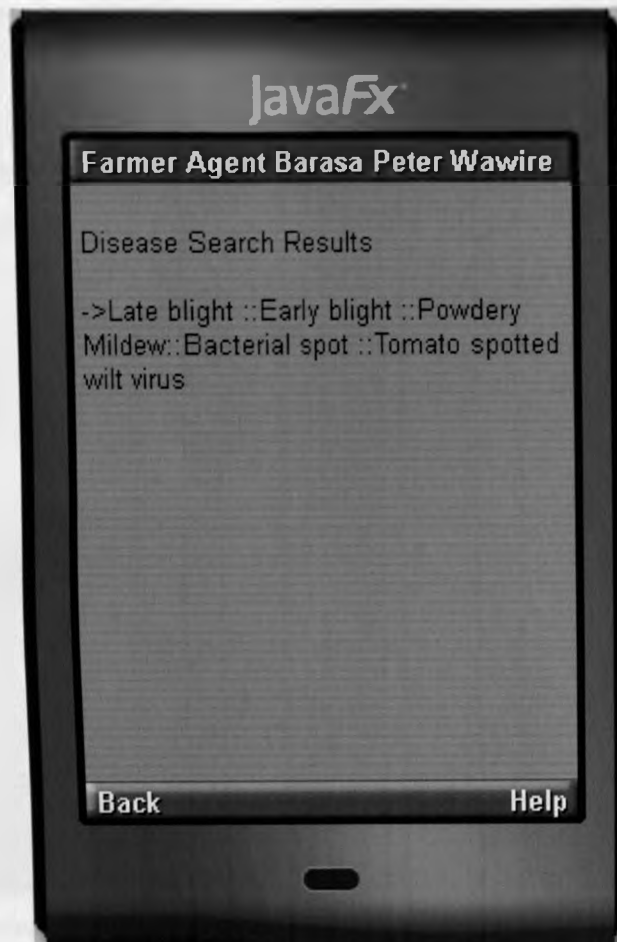


Figure 38: Farmer Results: Possible Diseases Affection Tomato Crop

The disease agent possess intelligence to retrieve diseases with black spots on leaves which are Late blight, Early blight, Powdery Mildew, Bacterial spot and Tomato spotted wilt virus . This is shown in fig. 38 above.

The farmer can now use back until GUI where the diseases are listed. Then the farmer selects from options the symptoms of the diseases and counter checks with the symptoms on the crop. The farmer is also able to select causes, treatment and prevention techniques from that menu. This is shown in fig. 39.

The options are very good because they allow the farmer to zero down and confirm the diseases symptoms before they check for their treatment, causes and prevention techniques.

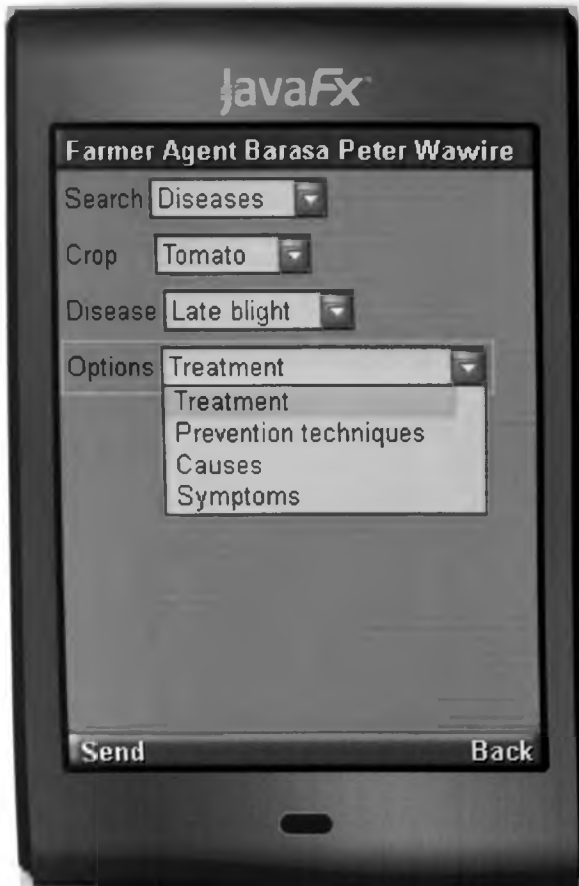


Figure 39: Farmer Requirement: Select Options.

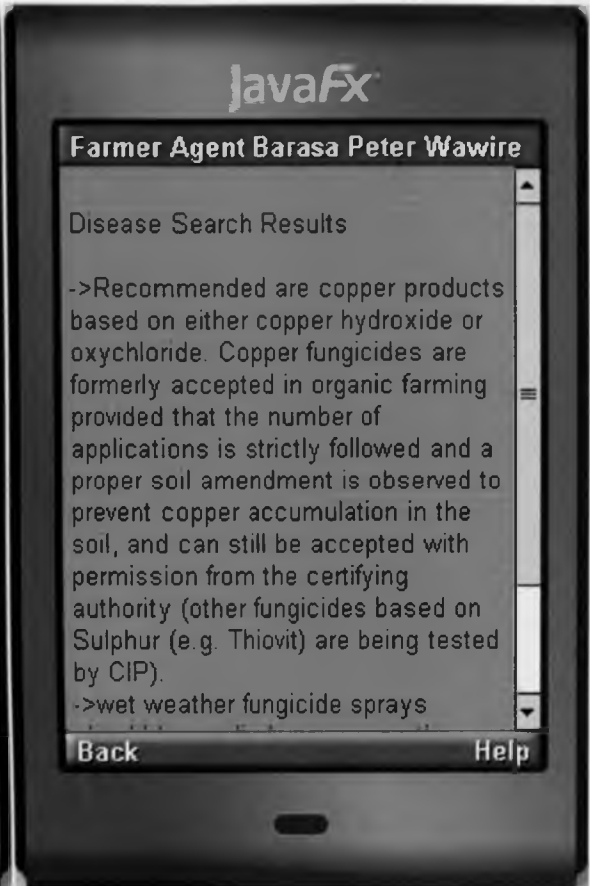


Figure 40: Farmer Results- Treatment of Late Blight

Fig. 40 above shows the results on search of information on treatment of Late Blight, the farmer is able to read through information provided by the disease agent via Extension Agent. Therefore the farmer gets direct support from the system without the need of the extension expert which are very few as depicted in the problem statement.

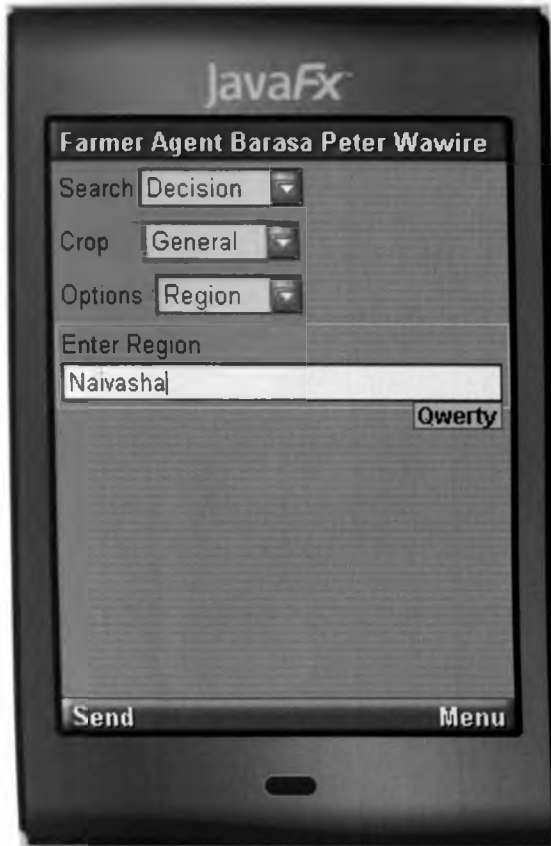


Figure 41: Farmer Requirement- Advice

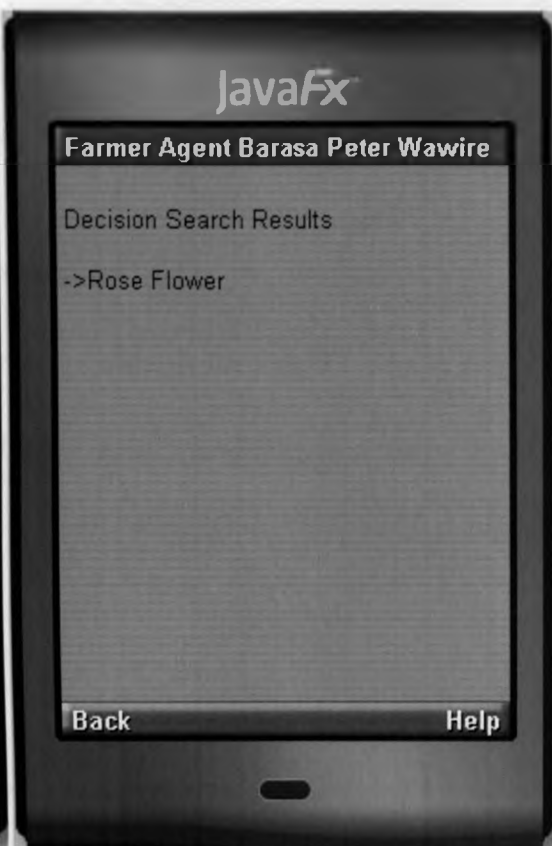


Figure 42: Farmers Results on Decision

Consider another search scenario with different search criteria to search for information on what kind of horticultural crop should be grown in a particular region. The decision agent finds the appropriate horticultural crop that is grown in the specified region. The decision agents possess intelligence to select the crop grown with closest match as shown in fig. 42 above. The farmer usually enters the search criteria as shown above in fig. 41 above. The region entered is not fixed and may vary from region to region.

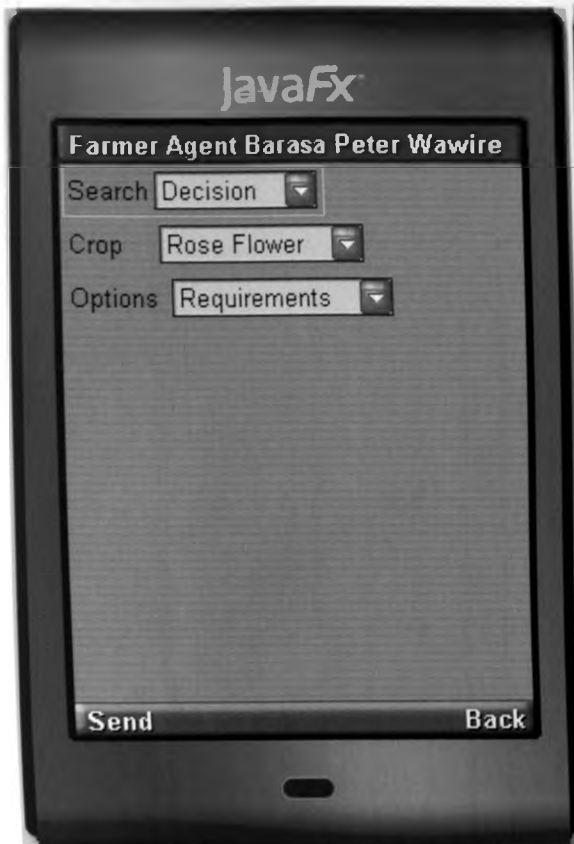


Figure 43: Farmer Requirement: Advice

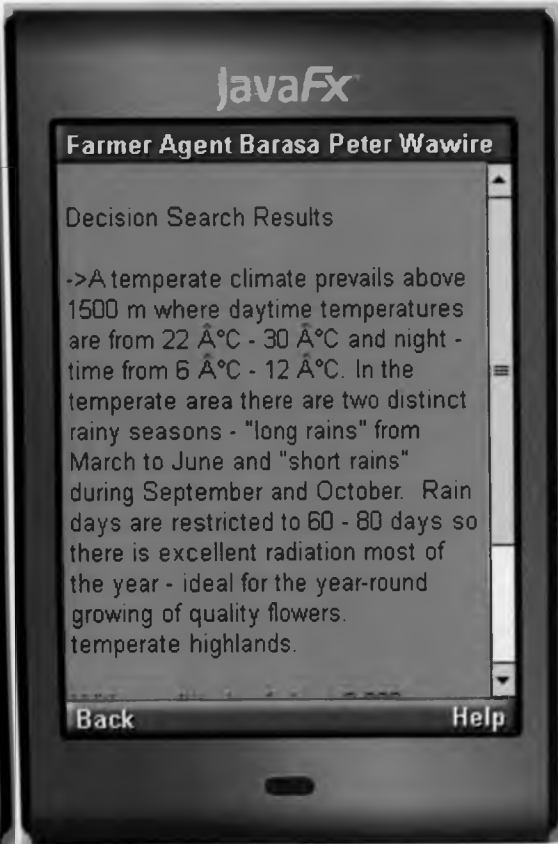


Figure 44: Farmer Results on Decision

Considering another scenario with different selection criteria as shown in fig.43 where the farmer selects options on requirements to grow rose flower. The decision agent receives request from the extension agent and with the intelligence property of being goal oriented it moves into the database and gets information which is send back to the farmer via extension agent as shown in fig. 44 above. The farmer is able to get support extension service on the particular information need without having to wait for one on one extension service.

The multi agent based extension support system offers marketing extension services. it give s general tips and general information on how to markets as shown in fig. 45 and Fig 46 below. Considering this particular scenario on selecting the appropriate from the dropdown menu the results of the information on how to market is shown in fig. 47 below. The marketing agent also gets information on local and overseas market. Of particular concern is current markets, marketing agent and current prices for both the local and overseas market (see figure 48. 49 and 50).

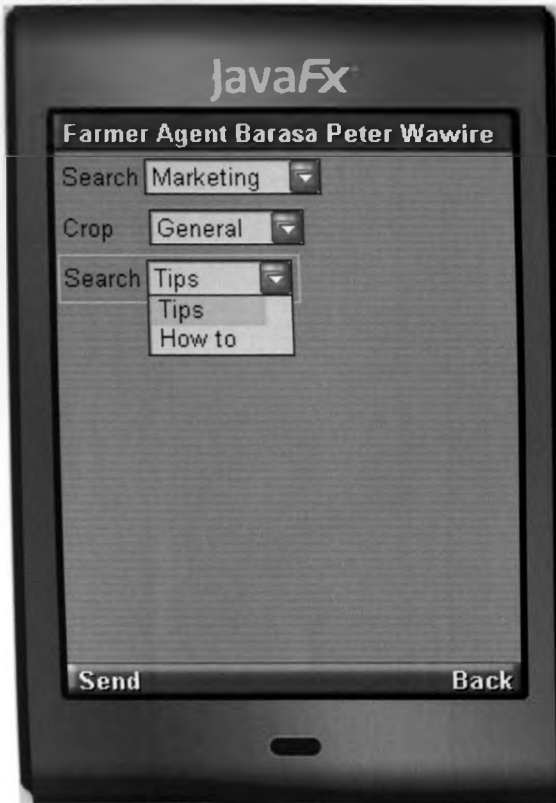


Figure 45: Farmer Requirements: Marketing

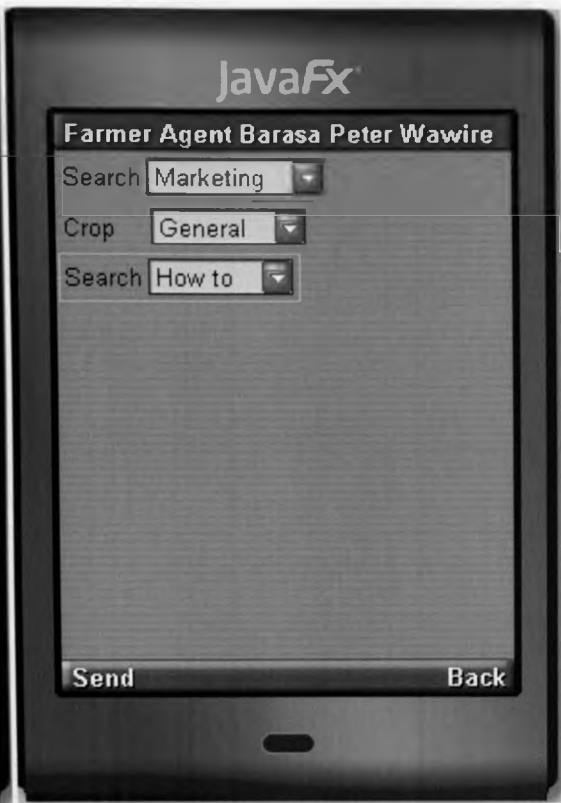


Figure 46: Farmer Requirements: Select How to market.

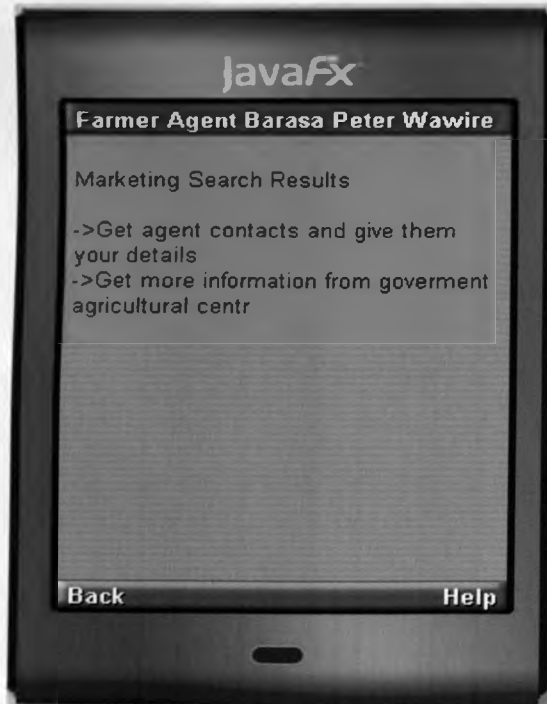


Figure 47: Marketing Agent Results



Figure 48: Farmer User Requirement



Figure 49: Farmer User Requirement-Marketing Agent

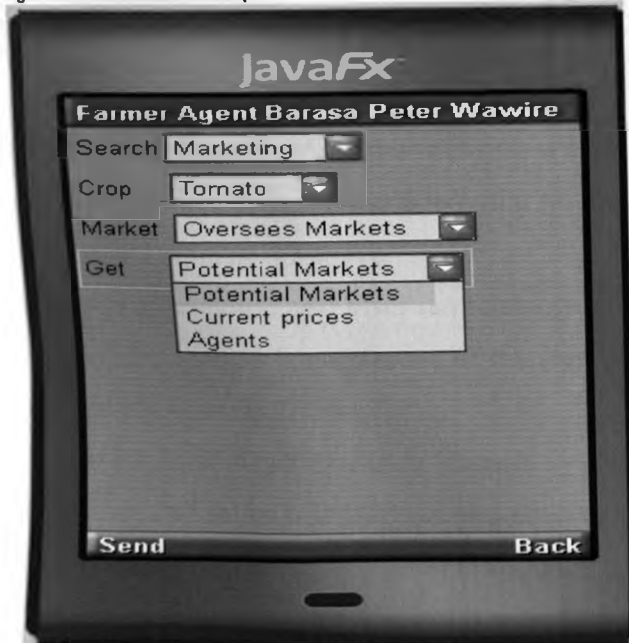


Figure 50: Farmer User Requirement- Marketing Get Options

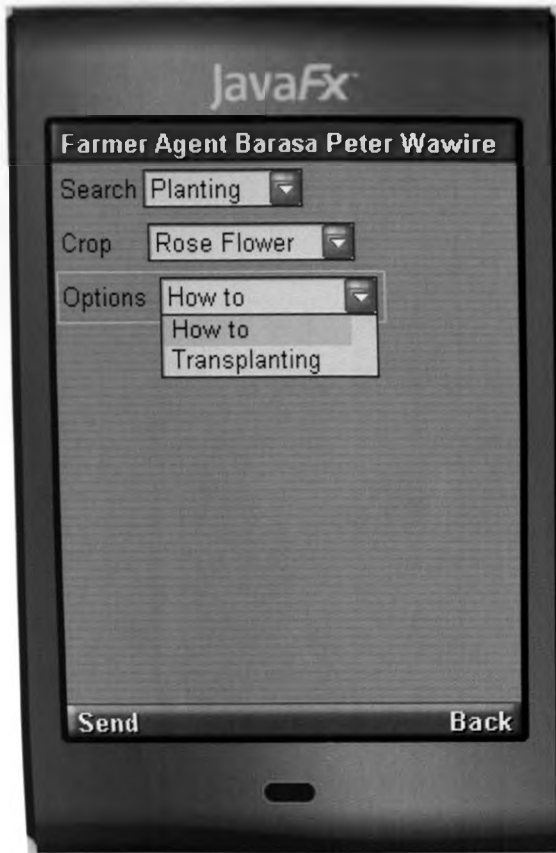


Figure 51: Farmer Requirement- Planting Search

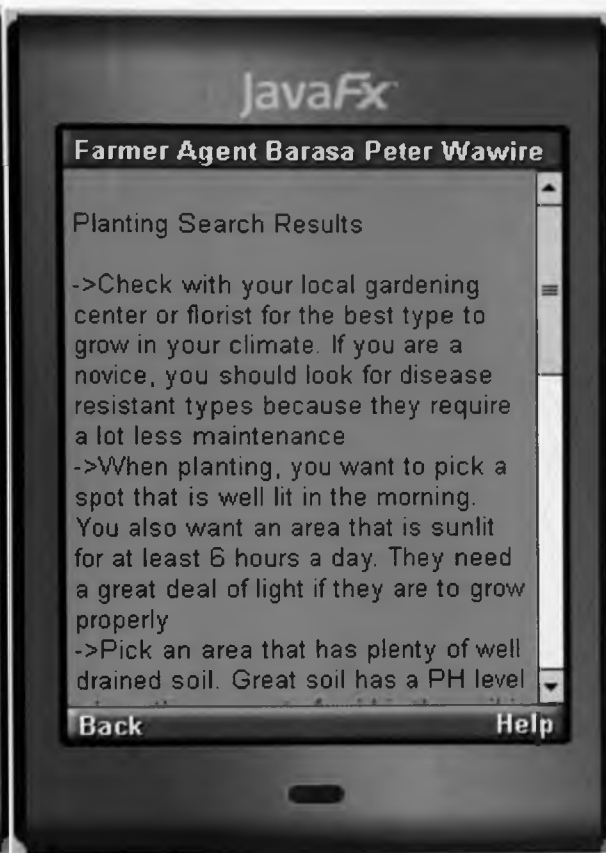


Figure 52: Farmer Results: How to Plant Rose Flower

The multi agent based extension support system for horticulture also avails information on planting procedures and transplanting procedures of horticultural crops as shown in. 51 above.

Considering a scenario where the selection criteria is on planting Rose flowers and the selection criterion is on how to plant rose flower the results of the search from the extension services will be as shown in figure. 52 above.

The system developed also offer farmers with extension information on seedlings of particular concern to the farmer is preparation of the seeds, maintenance of the seeds and where to get the seeds as shown in fig 53 below.

The multi agent based extension support system for horticulture also offers information on harvesting and packaging. Of particular concern to farmer needs is harvesting procedures, tips, regulations and packaging as shown in fig. 54.

The results of packaging and harvesting agent are shown in figure 55 below. The extension agent also sends a message to the extension worker who later updates the database of the information if there is relevant evidence.



Figure 53: Farmer Requirement-Seedling Agent

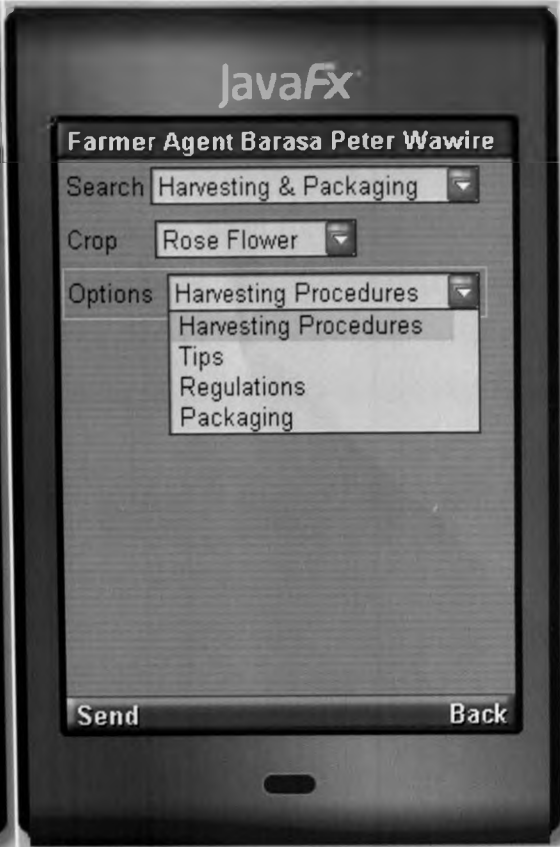


Figure 54: Farmer Requirement- Harvesting Search

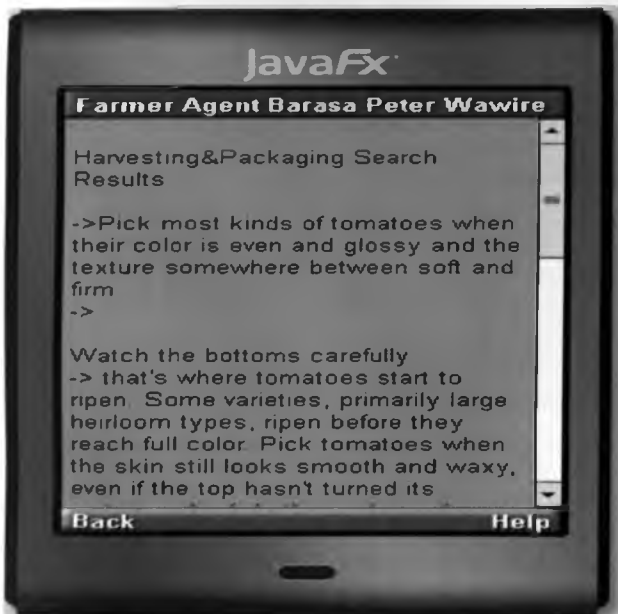


Figure 55: Farmers Results- Harvesting & Packaging Search

A sniffer agent is extensively used for debugging, or simply documenting conversations between agents. The ‘sniffer’ subscribes to a platform AMS to be notified of all platform events and of all message exchanges between a set of specified agents.

Figure 56 below shows the GUI of the Sniffer Agent results of the multi agent extension support system. The canvas below provides a graphical representation of the messages exchanged between sniffed agents, where each arrow represents a message. When we decided to sniff an a group of agents i.e. Decision agent, disease agent, harvesting& packaging agent, marketing agent, planting agent seedlings agent and farmer agent represented by farmers name Barasa Peter Wawire, every message directed to, or coming from, that agent/group is tracked and displayed in the sniffer GUI as shown in the fig 56, below.

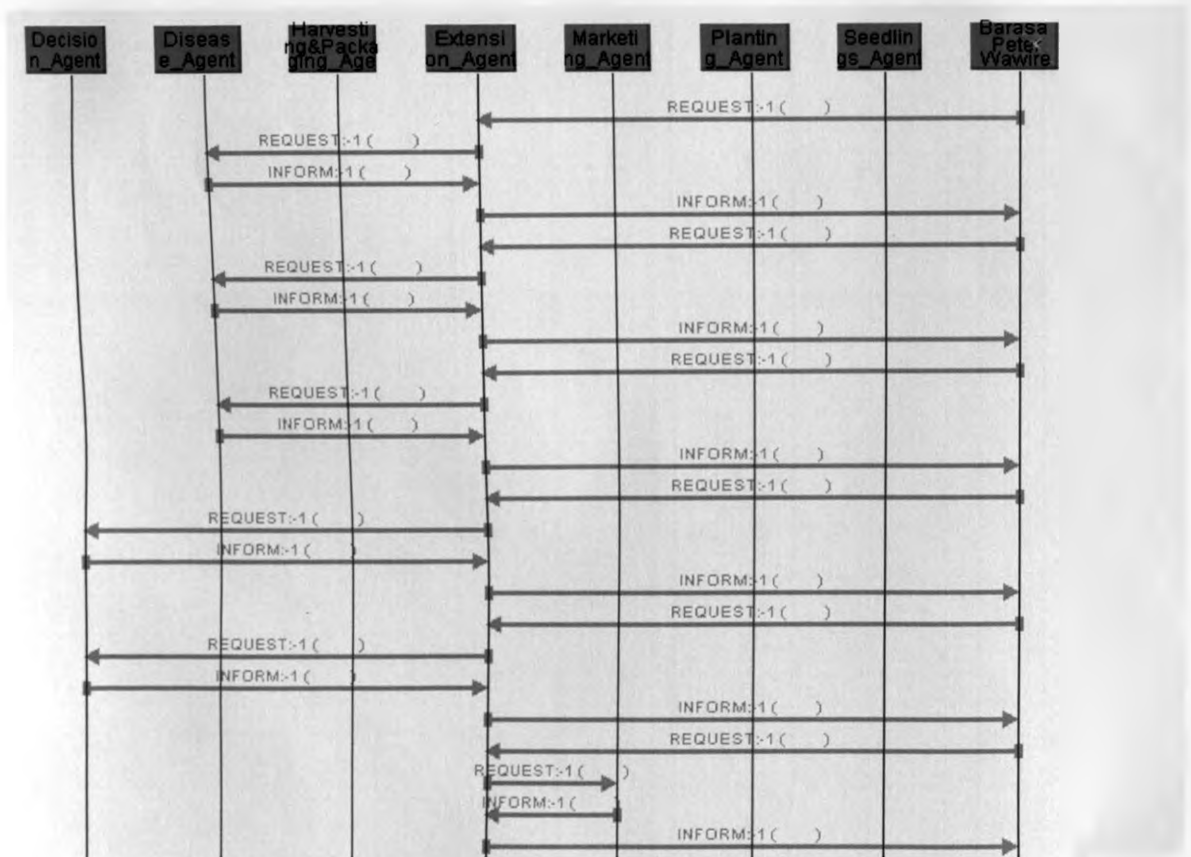


Figure 56: Sniffer Agent Results on Agent Communication

The farmer agent Barasa Peter Wawire sends a request to extension agent for disease information. The extension agent sends the request to disease agent; the disease agent gets information from extension service database and informs the extension agent, the extension agent in turn sends received information to farmer agent represented by farmer’s name.