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Affordance based human behaviour model for group path finding

Lokesh Patil
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Affordance based human behaviour model for group path finding

By

Lokesh Patil

A Thesis

Submitted to the Faculty of Graduate Studies

Through the School of Computer Science

In Partial Fulfillment of the Requirements for

the Degree of Master of Science at the

University of Windsor

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2014

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May 16, 2014

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ABSTRACT

Many advanced models are developed to predict human behaviour that explains human actions in some specific environment. This study refers to some of those models, such as work behaviour model which deals with the theory of purposeful work behaviour by agents in a work environment. Some behaviour models include cognitive, emotional and social aspects of human behaviour such as PECS model. Some models deals with affordance theory which focuses on the relation between agent, his actions and his observations. All these models offer suitability towards the formation of a new computational model which identifies human behavioural aspects individually. Our new model provides an opportunity to observe human behaviour in social activity, such as migration and solves path prediction problem. The model is expected to resolve various hypothetical relations between the included behavioural aspects, which affect human actions in making path choice decisions. An agent based simulation on migration activity of artificial human societies is developed to test the applicability of the model. Some mobility patterns are calculated using this implementation on a known study area and validated.

DEDICATION

I dedicate my work to my parents, my brother, my sister in law, my grandparents and the
new member who is soon going to join us in the family

ACKNOWLEDGEMENTS

I would like to thank my supervisor Dr. Kobti for all his guidance and efforts, It was very hard for me to maintain the quality of research required, but his faith in me and his constant encouragement and cool attitude made me continue my work independently and without any pressure. I owe him thanks for giving me this opportunity.

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Finally big thanks to my family for letting me pursue this and believing in me. With the promise to everyone that I will make you all proud one day, I wish every student can get to work with such good team, and great opportunity in life.

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CHAPTER 1. INTRODUCTION

1.1. Introduction

1.1.1. Multi Agent Simulation

A Multi Agent Simulation is an artificial simulation model comprising several artificial agents. These agents are autonomous entities that observe and react in an artificial environment. An agent can be described as an abstract functional system. According to Ferber, (2004) an agent can be a physical and virtual entity in any artificial environment communicating with other agents; an agent is an autonomous entity having skills to achieve its goals and tendencies. Such agents interacting together form a multi agent system. A multi agent system contains an environment, objects and agents, relation between all these entities and also a set of actions, combinely performed by all these entities. A relation between these entities in multi agent system depends on the kind of environment scientist want to study. Multi agent simulation is preferred to enhance the knowledge in biology, sociology, and commerce. MAS are used to create artificial environment that could be used as study area for artificial actors. One of the most significant uses of MAS is to study human behaviour during many of the social activities. Social simulation model is a collection of heterogeneous agents that resembles a network of any artificial population. Hence social simulation gives the opportunity to explore dynamics in social systems without affecting the real life of humans.

A multi agent model of artificial societies requires study of an entire social model. The model includes different aspects that make up human behaviour and various decision making states of humans. It is stated by many researchers that, human behaviour is immensely affected by individual needs and environmental systems. Study of human

behaviour is the observation of human actions during various challenges for survival. Human's social behaviour is the study of human actions, while he is a part of society and his actions affect whole dynamics of the society. Some of the social challenges faced by prehistoric human societies are leader selection, social warfare, trading etc. Among them, this research focuses on migration.

1.1.2. Migration

Migration in the prehistoric era is a large scale human movement from their relative settlements to somewhere far. Migration among historians is considered as one of the reasons for all the present demographic diversities in the present world. Migration is also the basis for the development of various trade networks from prehistoric eras. The reasons behind migration vary from era to era and region to region but the ultimate goal is same and that is to find a region with better survival conditions.

In multi agent modelling, migration is considered as one of those social activities where individuals can capture global regularities in the behaviour of heterogeneous actors. It is as common as warfare and trade.

1.2. Current Research Motivation

Primary Motivation behind this research is to come up with a model that helps us explain the hypothesis that human behaviour is a decisive tool during human migration. To do so, the affordance concept proposed by Gibson, (1977) is implemented (explained in chapter 2), that defines a relation between human activities under the effect of environmental variables. In search for an event driven and geospatial cost optimized

solution to the path selection problem, many human behavioural models are referred. Some of them are based on affordance theory; those are discussed in next chapter.

Earlier in the research, general path finding algorithms were used for such task, but this algorithm offers certain limitations. It is extremely important to define the limitation of general path finding algorithm. At its core, a general path finding algorithm searches a graph from a fixed point by exploring possibilities to move until a destination is reached and then out of the entire path, the least cost path is selected. The significance of such approaches is in determining the heuristics for cost calculation of the paths. This cost could be the shortest distance from one point to other. When cost scale for migration on any region is to be determined using spatial details of the regions, the topology of the region and elevation could be taken as the parameters to start the calculation. According to the theory of affordance by David, Jonietz, Wolfgang Schuster, and Sabine Timpf, (2013) in case of human, he always evaluates the suitability of all environmental factors for his specific actions. This paper expects the same from him in the path selection process. According to David, Jonietz, Wolfgang Schuster, and Sabine Timpf, (2013) affordance is:

“Theory of visual spatial perception, describing how the human actions are manipulated considering environmental properties and the persevering organisms”

While working for Village Eco-dynamics project in collaboration with University of Washington, we extensively observed affordance behaviour in early Anasazi settlers. These ancient settlers in the Colorado area of south western part of America migrated 1300 years ago to another land area, some hundred miles away from their initial

settlement. This project emphasizes various social activities in this region, of which migration is one. Hence the project provides a good test area to test the approach.

1.3. Thesis Contribution

This model shows a relation between affordance and various aspects affecting human behaviour. This study assumes that the utilization of environmental elements changes with the application area and also the extent of exploitation of environmental resources. General hypothesis behind this research is that, even with all the knowledge of environmental variables there are some aspects of human behaviour that restrict a human to fully utilize the resources. In this research, a model is given that assumes a general understanding of the relation between behavioural aspects and affordance. It is believed that such relation could provide a reasonable approach to study various human actions. To confirm our hypothesis and relation theory, an algorithm is developed that implements some extra constraints on the application area using an already defined algorithm.

1.4. Thesis Outline

In the beginning of the thesis, some hypotheses are presented that speak of a relation between human behaviour and various aspects. In the first part of the introduction, a brief explanation is given to advocate the need of behaviour models and simulation model in the research. The model is organized in a way to map each component of the model with the different aspect of human behaviour in migration process. Identification of such aspects and implementation of the model using agent based simulation is presented. In chapter 1, an introduction to the research work is

presented, that explains relation to our study and computer science. In chapter 2, a brief literature review on the entire topic is covered. Chapter 3 contains the description of the proposed model with all assumed aspects of human behaviour. Chapter 4 presents a study and partial application of the proposed model in an artificially created leader election environment among groups. The chapter discuss all the results and observations taken during the entire dynamics of the leader selection system. Further, an explanation for the need of this experiment before applying the model to the migration study, is presented. A brief explanation of the test area and the purpose for selection of this test area is given in chapter 5. Chapter 6 presents experiment setup with implementation details. Results and discussion on migration process are presented in chapter 7 followed by the concluding remarks on the entire research with brief explanation of limitation of the model.

CHAPTER 2. LITERATURE REVIEW

This chapter presents the works that were referred to build an elementary architecture for our research in the field of affordance, social dynamics, human behaviour and path finding algorithms, as this research deals with all these terms. The study defines a definite role of each term in shaping the present architecture of the proposed model.

2.1. David and Sabine's Introduction to Affordance

David, Jonietz, Wolfgang Schuster, and Sabine Timpf, (2013), in their research extend the concept of affordance proposed by (Gibson, 1977). They propose a framework that supports the idea of artificial agent having “spatial suitability” in an environment. In the model, human actions are the central element that acts as a utilization function on sensory observations. According to affordance, human perception in any environment is a combination of various behavioural properties of the perceiving organism.

Human's utilization of sensory observation and perception at any instance can be explained as, how a human derives a purposeful meaning out of his observations. (In this research, visual information is considered as only sensory observation). (Gibson, 1977) developed this idea of affordance in his words.

“The affordance of the environment is what it offers the animal, what it provides or furnishes, whether for good or ill” (Gibson, 1977).

From many years this concept of affordance served as the theoretical basis for research in the development of cognitive simulation models. Warren, (1984) applied this concept on the practical problem while investigating the abilities of an agent in climbing.

David, Jonietz, Wolfgang Schuster, and Sabine Timpf, (2013) are convinced that, this research is able to explain the interconnection between the environment and agent properties. Using a case study of pedestrian route choice as an example, it confirms the presence of a complex dependency relationship between an agent and his environment. David et al. desired a need of adding an attributed relation to pedestrian movement by calculating an agent's stamina during walk.

According to Vukmirovic, (2010) even in a general walk, it makes a difference for choice of suitability for different age groups, as adult pedestrian agents are characterized by often experiencing reduction regarding their physical abilities. While an unexperienced walker is more prone to security threats, it could be possible that their choice of path selection is different from the experienced ones.

2.2. Human Behaviour simulation using affordance-based model

Kim, N., Joo, J., Rothrock, L., Wysk, R., & Son, Y. J. (2011) proposed a new agent based simulation modeling of human behaviour using affordance concept. They propose a novel way to capture the natural manners in a system and enhance the simulation quality by incorporating cognitive intent into human behaviour simulation.

Decision making has been studied in various domains such as cognitive science, psychology, and decision science. Their definition of affordance in environment is that "While a certain human action, whatever is offered by the environment, if ease towards his goal then such a help can be called as affordance".

Kim, N., Joo, J., Rothrock, L., Wysk, R., & Son, Y. J. (2011) uses a state transition function with finite automata on human life events to calculate human perception. A

fundamental approach to calculate affordance before calculating human behaviour is proposed.

According to Kim, N., Joo, J., Rothrock, L., Wysk, R., & Son, Y. J. (2011), in a system theoretic perspective a human can be considered as a re-predictable entity, and that theory gives researchers enough space to include perception-based behaviour of human in events like social dynamics.

The simulation developed by (Kim, et. al. 2011) contains a human agent representing each human in a system. An environmental agent considers almost all environmental elements of the system which may affect human decision. As the test case for their study they studied the evacuation problem during fire outbreaks. Their definition on these term as – “The perspective control is concerned with the future events, usually interpretable as goals”. (Turvey, 1992)

Kim, N., Joo, J., Rothrock, L., Wysk, R., & Son, Y. J., (2011) claim their model is a perception-based model. This itself creates a sense how a human and his perception can be integrated in a model. The algorithm generates all possible evacuation plans for a human agent trapped in a warehouse fire. Each agent, on the basis of his own observation and capabilities, chooses his own path, and rescues himself. The algorithm is able to execute all “perception based decision making plans” (Kim, N., Joo, J., Rothrock, L., Wysk, R., & Son, Y. J., 2011) claimed by psychologists.

Kim, N., Joo, J., Rothrock, L., Wysk, R., & Son, Y. J., (2011) mentioned some other human attributes like social psychology, emotions, culture and knowledge for their future research and also speak about an urgent need to define some sets of validation on the simulation for suitable tasks as for example migration etc.

2.3. Natural Movement as an agent-based system

When Turner, Alasdair, and Alan Penn, (2002) started working on the theory of affordance, very few researchers had ever considered relation between human perception and environmental variables as serious. Hence (Turner, Alasdair, and Alan Penn, 2002) are among the firsts, who exploited this theory to an extent that, now almost every multi-agent system involves a separate structure for agent versatility and capability in the simulation. What makes it crucial is from very long time and from the birth of artificial intelligence; the challenge for researchers is to come up with an algorithm that enable cognitive behaviour in agents.

Large scale simulation has been investigated from some time on agent based pedestrian models. Hoogendoorn S P, Bovy P H L, Daamen W, (2002) categorize such pedestrian models into three types.

First the macro simulation level involves differential flow equations. It gives a researcher proper independence to construct a flow model of events which occurred during HAZZ on pedestrian situations (AlGadhi, Saad AH, and H. Mahmassani, 1991).

Second the meso-scopic level is more suitable for traffic modelling and for urban level simulation. “Meso-scopic level simulation model combines a set of origin and destination points with route –choice behaviour to simulate journeys within the system”.

The third one micro-simulation is about applying multi-agent simulation on life like emergent phenomenon using predetermined directional paths. One of the best examples of such movement is fire evacuation models. Turner, Alasdair, and Alan Penn, (2002) present a study of agent movement which is built on a hypothesis that:

“When engaging in natural movement, a human will simply guide him or herself by moving towards further available walkable surface. The existence of walkable surface will be determined via the most easily accessed sense, typically his or her visual field”.

Turner, Alasdair, and Alan Penn, (2002) were the first to present a systematic study on the affordance model in human movement (Figure 1). A thorough study on this model, which was used by both Kim, Joo, Rothrock, Wysk, & Son, (2011) and Jonietz, David, Wolfgang Schuster, and Sabine Timpf, (2013) This model discusses EVA (exosomatic visual architecture) agent- decision process. This model is self- explanatory but the transition of actions in those steps is important for the research.

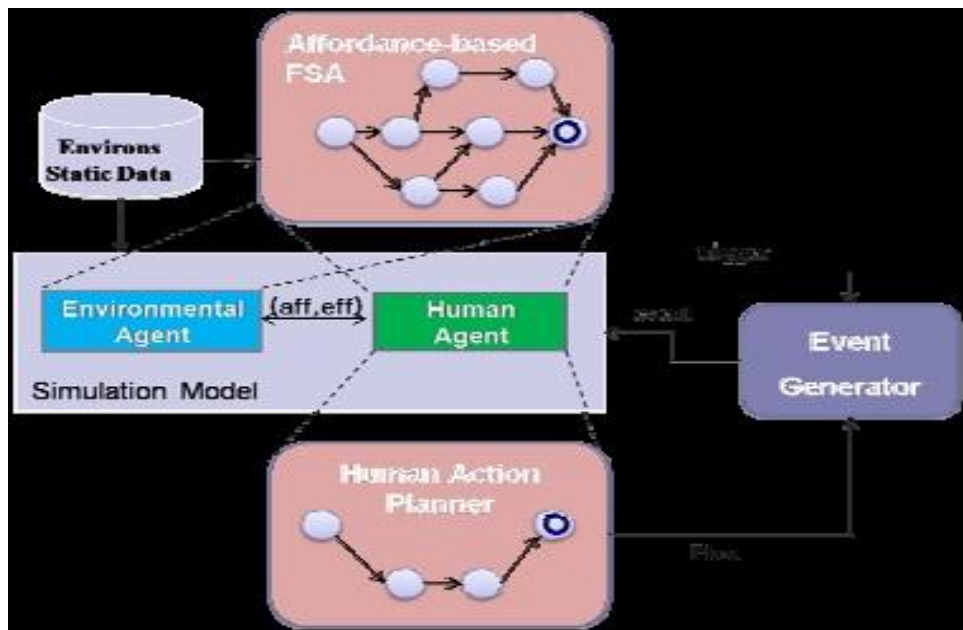


Figure 1 Affordance Model (Turner, Alasdair, and Alan Penn, 2002)

2.4. Murray's Work behaviour model

According to Barrick, Michael, and Ning, (2013)

“The theory of purposeful work behaviour derived from behaviour integrates higher order implicit goals with principles derived from the five factor Model of personality and the expanded job characteristics model to explain how traits and jobs characteristics jointly and interactively influence work outcomes”.

They further explain that, it is human behaviour that makes him attain a certain goal, under some influence, and when motivation is associated with it, the whole purpose becomes “Motivational purpose strivings” (Barrick, Michael, and Ning, 2013). (Meyer, Dalal, & Hermida, 2010) propose motivation as the resultant of combining attributes and environment. Whereas Barrick, Michael, and Ning, (2013) explanation of work behaviour is that “it is the goal that a person wants to attain that, when and why an individual will be motivated at work”.

In the research, the researchers considered the dynamic nature of influence and both gain and loss of motivation in a working environment. They also propose an integrity theory that focuses on different difficulties in performance at work in order to achieve a goal. This study establishes a dependency of human behaviour on motivation on work behaviour. They based this motivation theory on five human personalities, and they are:

“Extraversion (sociable, dominant, ambitious), agreeableness (cooperative, considerate, trusting), conscientiousness (dependable, hardworking, persistent), emotional stability (calm, confident, secure), and openness to experience (imaginative, adaptable, intellectual).”

-Barrick, M. R., Stewart, G. L., & Piotrowski, M. (2001), Judge & Ilies, (2002)

Barrick, Michael, and Ning, (2013) further propose a model integrating personality and motivational factor during work for individual in order to attain meaningfulness at work(figure 2). The model can be describes as:

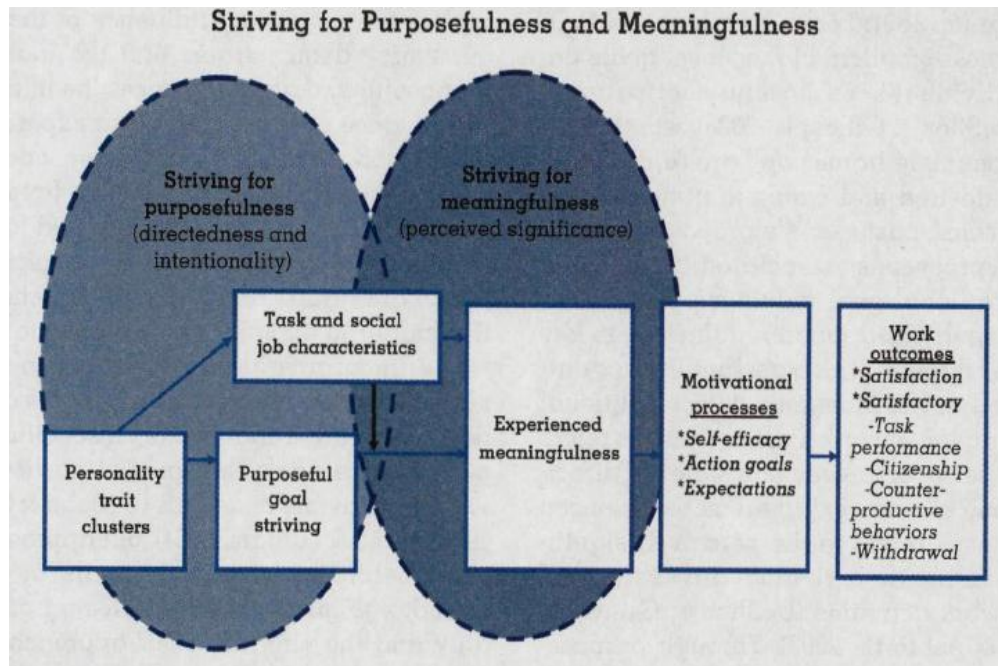


Figure 2 Work Behaviour Model (Barrick, Michael, and Ning, 2013)

FFM personality traits: Barrick, Michael, and Ning, (2013) use Funder's description of personality as "An individual characteristic patterns of thought, emotion and behaviour, together with the psychological mechanisms hidden or not, behind those patterns" (Funder, 2001:2)

Higher Order implicit goal: These components reflect the importance of goal in worker's behaviour, as a basic assumption is the human need goal to achieve purposefulness in his work as described by Barrick, Stewart, & Piotrowski, (2001), Locke, & Latham, (2004).

Task and Social characteristics: “Theoretical and empirical research have long recognized that, any job consists of test and social characteristics varying in a degree to which they are intrinsically motivating, influences the job performance” (Hackman and Oldham,1976).

Striving for purposefulness and experienced meaningfulness: Barrick, Michael, and Ning, (2013) state that purposefulness and meaningfulness are clearly related, and when we need a notion “achieving a state of well-being is referred as meaning fullness and purposefulness of our actions”.

Barrick, Michael, and Ning, (2013) establish a relation between agent’s personality traits and agent’s actions in a working environment, in case of any particular job characteristics. This relation becomes one of the fundamental concepts for any human behavioural model.

2.5. PECS reference model

PECS, basic model was first introduced by Bernd Schmidt in Schmidt, (2002). PECS stands for (P) physical condition, (E) emotional state, (C) cognitive capabilities and (S) social states. The PECS model defines a different approach to affordance in social systems. In PECS model an environment represents a social system (figure 3). The model specifies emergent human behaviours as the events occur with time. This model lays path for new system modelling that completely relies on human’s perceptions for decision making. To fully understand the human action transitions we studied the structure of PECS’s agent. The structure is divided into three components.

Upper level: the upper level comprises the perception and sensors block. Sensors block is one which is responsible for acquiring sensory data, where an agent takes input from environment and passes it to perception block. The perception block is responsible for establishing relation between those inputs on the basis of an agent's state on middle level.

Middle Level: The middle level contains components like social status, cognition, emotions and physics. This layer passes status of an agent on social, cognitive, emotional and physical level by using some state transition functions.

The bottom component contains behaviour block and actor block, where calculated perception is transferred as an action using state transition function. These actions collectively represent agent behaviour, which is then passed to the actor to act, and that is how an agent's behaviour is calculated. This process is repeated again as the input information changes dynamically with the social according to situation.

This model defines a clean relation between motives desires and actions. Reiss, (2000) used 16 different desires that motivate a human behaviour and personality.

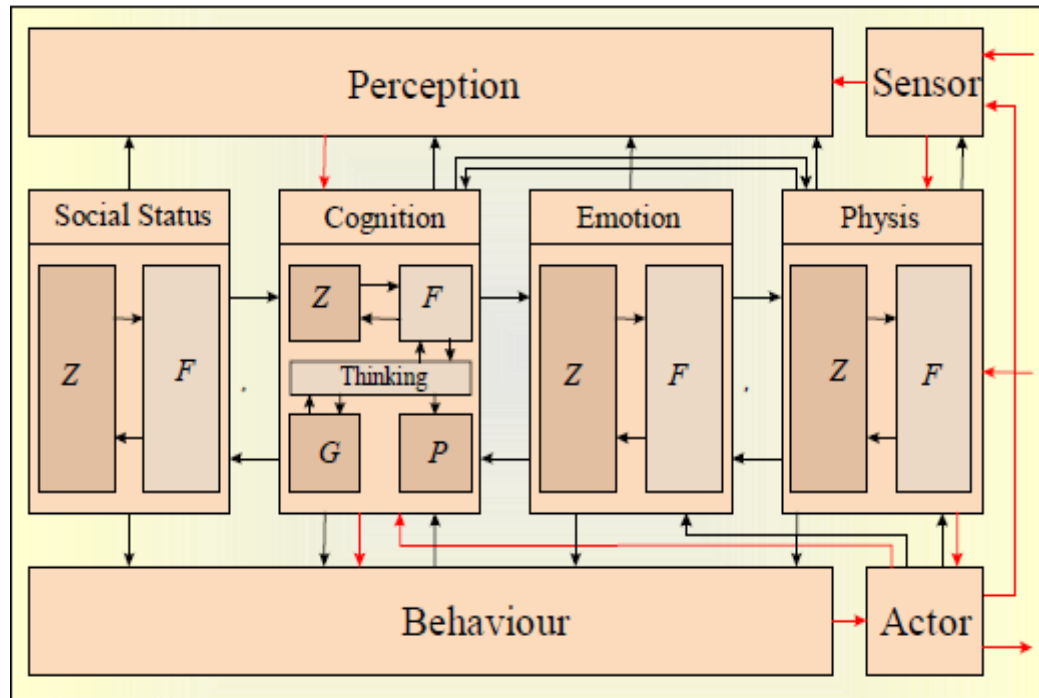


Figure 3 PECS Model (Schmidt, Bernd., 2000: 2002).

2.6. Geospatial Modelling: Devin A White

Various GIS path finding models have been created till this time, many of them are sophisticated enough that can be employed to trace human movements to various geographic locations on long scales. These GIS's models use information about specific origins and destinations, which is very necessary to model path networks. White (2012) proposes a method that overcomes the limitation for pre-knowledge of starting and stopping positions. He termed this method as FETE i.e. from everywhere to everywhere. FETE generates path networks using information about topology and land cover of the region.

White, and Sarah, (2012) describe that FETE involves complex graph building approach "The end results of a fete process is a travel probability surface, with some processing resembles a circulatory system or road network. FETE method extends the

grid technique proposed by Whitley, and Lacey, (2003). This grid technique uses a grid of regular spaced points to calculate the path from some fixed direction, while FETE employees the same grid technique and instead calculates path in each possible direction only more efficiently.

2.7. Influence in social dynamics

Influence in a social dynamic system prevails in the form of leader of the society. It is the leader who becomes the face of society and is considered as the only actor behind all social actions by the Migration in ancient societies and cause to wars.

According to Fix, (1999) since the beginning of civilization it has always been hard to predict the role of individuals during migration from a society. The co-evolution of society and the social factors are responsible for dynamics in social life of ancient people. The changes in cultural, social and geopolitical life of an agent in a society are complex enough to predict, (Fix, 1999) studies about gene distribution which he considers as to be a cause of migration and other variance in present civilization can be explained on these terms. The author claims that his work is the extension of work done by Boyce, (1984), Crawford and Mieke, (1982), and Mascie, (1988). According to the Fix, (1999), he just extended the work done by previous researchers and gave a suitable hierarchy to distinguish the problem using some patterns which were not given by other researchers. The previous researchers were rendered unable to exemplify their work under the factors of gene distribution and colonization which is explained much better by the author. Fix (1999) claims to have introduced some new ideas and some new patterns in his work. He talks about the relation between the emergence of diverged culture and the demo-

graphical changes based on the data provided by anthropologists working in same area. According to Fix, (1999) there is a common factor which resulted in such a diverse distribution of genes, cultures and populations.

The study claims to have incorporated various domains like anthropology and sociology to explain the effect of migration and colonization on the demography of the present civilization, which started from the ancient society. The author in the paper draws attention towards the next step in the same research area. According to him this is the phase form where the division of Society into various cast, tags, and culture started.

2.8. Predicting Pedestrian routes within a built in environment

Today we see a lot of research in the field of pedestrian safety measures. Researchers have moved their approach towards more logical reasoning to solve such problems. Major problems which are about creating situations with relevant dynamics and making an agent participate towards his security by analyzing the help human has from his environment.

In any unfavourable situation, making an agent more cognitive in his behaviour is the goal behind such research. In addition to all the developments in this area, Nasir, Lim, Nahavandi, & Creighton, (2014) contributed by developing a new cognitive model for an indoor environment under normal conditions. In order to investigate a pedestrian's behaviour under normal circumstances with all his basic attributes, they believe the outcomes could be comparable in other hazardous situations.

“Their main contribution is in the formulation of an on-demand utility function that allows an effective application of dynamic programming to predict a series of

consecutive waypoints with in a built environment” (Nasir, Lim, Nahavandi, & Creighton, 2014)

According to Helbing, (2001) there are generally two categories of modelling pedestrian behaviour research i.e. microscopic and macroscopic scales. In the microscopic scales we have agents with cognitive attributes like needs, intentions and their active participation with other pedestrians. “Macroscopic scales does not consider agent to agent interactions” (AlGadhi, and Mahmassani, 1991: Maldonaldo, Wachowiaz, and Vazquez-Hoehre, 2011: Helbing, 2001)

In a research based model by Zheng, Zhong, & Liu, (2009) considered various heterogeneous characteristics of pedestrians that account for pedestrian’s decision making capabilities. These factors are personnel, trip characteristics and social economic etc. Some of the factors affecting pedestrians as mentioned by Nasir, Lim, Nahavandi, & Creighton, (2014) in their research are travel length, number of turns (Golledge, Reginald G., ed., 1999) personnel factors like age, gender, preferences (Li, Yan, and Tsukaguchi, 2005). Some factors that firms steering behaviour like sense of directions, metal replacements and individual behaviour indices (Padgitt, A. J., & Hund, A. M, 2012).

Model used by Nasir, Lim, Nahavandi, & Creighton, (2014). The following assumptions are considered in the proposed model in order to predict pedestrian’s behaviour:

- The pedestrians are provided with set of routes to choose among.
- All actions of pedestrians are result of utility functions used by pedestrian (agent).
- Pedestrians also have a disutility function that is used in the need of walking distance, discomfort level and fluctuation factor.

- Pedestrian behaviour is rational.
- All agents know their destination.
- A pedestrian is considered as two dimensional points in the environment.

Concluding their research they proved their algorithm is able to generate better results than A* algorithm. They are certain that pedestrians-environment interaction and the impact of the environment on the pedestrian's choice are the major factor in pedestrian's path choice. Nasir, Mojdeh, Chee Peng Lim, Saeid Nahavandi, and Douglas Creighton, (2014) considered in their research a new term, that is the steering behaviour of pedestrian as of utmost importance. (Reynolds, 1999) pedestrian steering activity in path determination emerged as one of the important phase of mobility behaviour. According to Reynolds, (1999) this mobility behaviour is divided into three categories they are action selection, steering, and locomotion (Nasir, Mojdeh, Chee Peng Lim, Saeid Nahavandi, and Douglas Creighton, 2014). Hence the fundamental variables are thus identified as direction duration and security from the above studies.

CHAPTER 3. MODEL DESCRIPTION

For developing an affordance based multi agent model we need a model that establishes a relation between various aspects affecting human behaviour. We are taking six important aspects motivation, influence, individual traits, individual needs, individual expectations, and individual goals. These aspects all together with environmental variables make a valid affordance system.(The model is presented in figure 4.)

Also with relations between these factors, one of the crucial requirements is to define various interdependencies among these factors. Before proceeding further, let us understand the role of each individual factor in an affordance system. These factors are often termed as individual difference variables.

3.1. Individual difference variables

According to psychologists “Individual difference variables are the characteristics that cannot be changed, they vary across the population”. In the model it is assumed that individual traits and individual needs are common for few agents among many. But initial needs are same for all agents. Although individual needs and traits are very broad terms and span a wide scope of factors and attributes of human behaviour, however this approach intends to limit their scope in accordance to the case study used in this thesis.

3.2. Individual Needs

The term “Needs”, in simple words, can be stated as the wants and desires of a person. It is assumed that for mere survival, a basic human need can be food, shelter and water. However in some cases it could be anything ranging across physical, economic and social needs.

In general, need is one of the major driving forces for a human to define a set of achievement in his life. This also goes with the saying that “necessity (needs) is the mother of invention”. The question that we are trying to answer in this research is can we really put needs and goals in a one to one relationship and if we can, then will it be true that any action corresponding to this relationship defines actual human behaviour. Following this, we would like to hypothesize that:

“It’s the needs that make a human declare his goals and it’s the needs that attract reasons for his/her motivations and influence towards the goal”

The above hypothesis seems trivial at first but, we have some supportive arguments in favour to the hypothesis.

“Intrinsic need satisfies on the job will predict both performance ratings and psychological well-being of employees, in line with cross-cultural findings” Deci et al, (2001).

According to autonomy-supportive contents

“Both Social contents and enduring individual differences influences individual’s intrinsic need satisfaction and thus their motivation, performance and adjustment” Deci and Ryan, (1987)

3.3. Individual Behaviour Traits

According to the Five Factor model, individual traits represent the various personalities of an individual in a population. This personality represents the individual difference variable in psychology. Five Factor model gives researchers the space to classify all possible normal and abnormal human behaviour, and that is why it makes an very elementary component of the present research model we have used.

3.4. Motivation

Motivation is the force behind any action that leads one to his/her predefined goal. Motivation has roots in behaviour, cognition and social science. Motivation can be divided into two categories, intrinsic motivation and extrinsic motivation.

Intrinsic Motivation: It is that motivation which is driven from inner need or inner satisfaction for self-interest, pleasure and reward.

Extrinsic Motivation: Extrinsic motivation is the performance of an activity under pressure in order to attain an outcome. This pressure could be a threat for survival or any kind of punishment following inability to behave properly. According to Barrick, Michael, and Ning, (2013)

“Social characteristic on employee motivation and behaviour, separately has given one or the other only cursory treatment”

In our research we see the above mentioned thought from a different angle and try to establish a firm relation between motivation and behaviour.

3.5. Expectation

Expectations are the reason why people give one action more priority over other actions. Every behaviour has expectations associated with it, whereas needs are the driving force behind that behaviour.

Researcher's considers the maximum satisfactory expectation set for an individual as his goal. In much human behaviour research, it is observed that an individual's expectations and actions are dependent on each other. A change in any one of these affects the other. Some psychologists define the relation between motivation and expectation as:

"The motivation behind selection is determined by the desirability of the outcome"

Oliver, Richard L., (1974)

3.6. Influence

The dictionary meaning of influence is the capacity of a person that affects the actions, behaviour and opinions of others. Social influence is when one's opinions are influenced by someone else. Social influence is also referenced in conformity, Socialization, peer pressure, obedience, leadership, persuasion.

Influence can be divided into three categories (Kelman, H, 1958)

Compliance: When people agree but actually keep their distinct opinions.

Identification: When people are influenced by someone who liked and replaced, such as famous celebrity.

Internalization: when people accept a belief or behaviour and agree both publicly and privately.

3.7. Behaviour MODEL

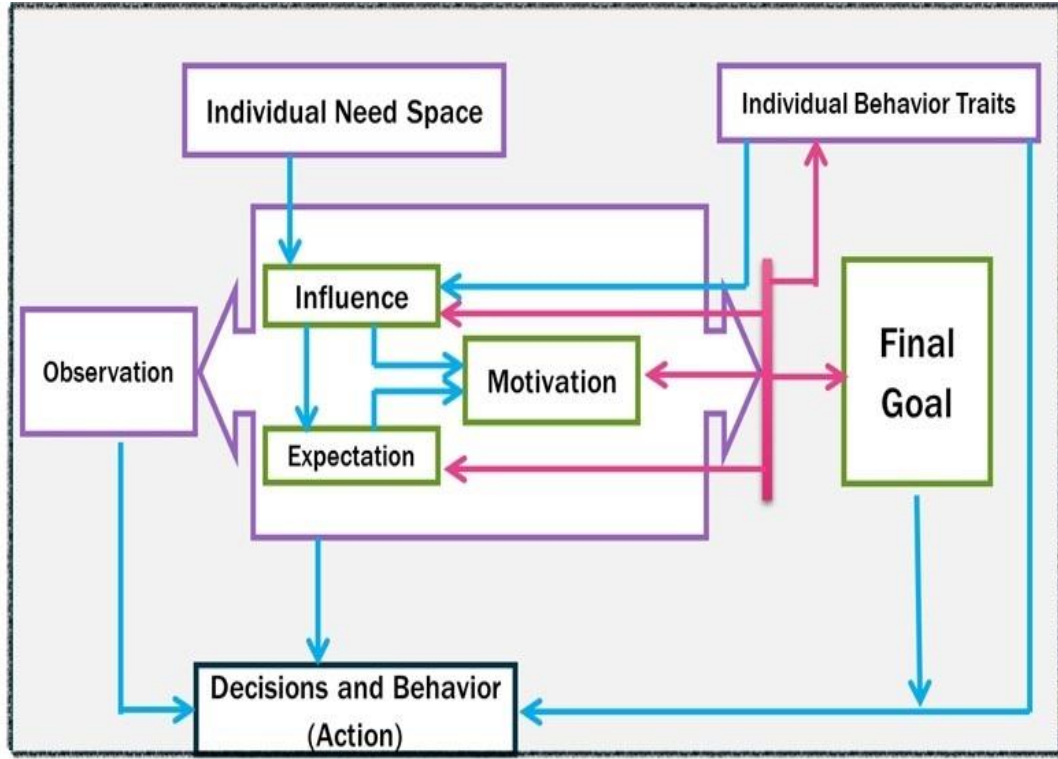


Figure 4 Proposed human behaviour model

State Transitions between Components

All the components in the module are connected to each other because of their inter-dependability, where according to our hypothesis all those factors that we discussed earlier are responsible for the dynamics of any other factor in the model. Above description of the aspects also signifies the relation between each of them. In the model, Individual needs are defined as never changing while behavioural traits change, but for current experiment behavioural traits are also assumed as independent. Other aspects such as influence, motivation and expectations are expected to change with every time step. The arrows in the model represent the state transition from one aspect to other.

CHAPTER 4. LEADERSHIP AS SOCIAL INFLUENCE

This Experiment is performed in order to understand one crucial aspect of the proposed model, that is, influence. In a social environment it is generally observed that a leader has a great influence on the entire society. This influence is evident mostly at the time of elections or any social epidemic. We are seeking for the understanding of how leader's personality traits are responsible for his win and how his personality traits attract followers (other members of the society). It is generally believed that every human wants his leader to have similar set of traits as his. This experiment partially implements the proposed human behaviour model, which is presented as follows. (Figure 5 presents a partial implementation of the proposed model)

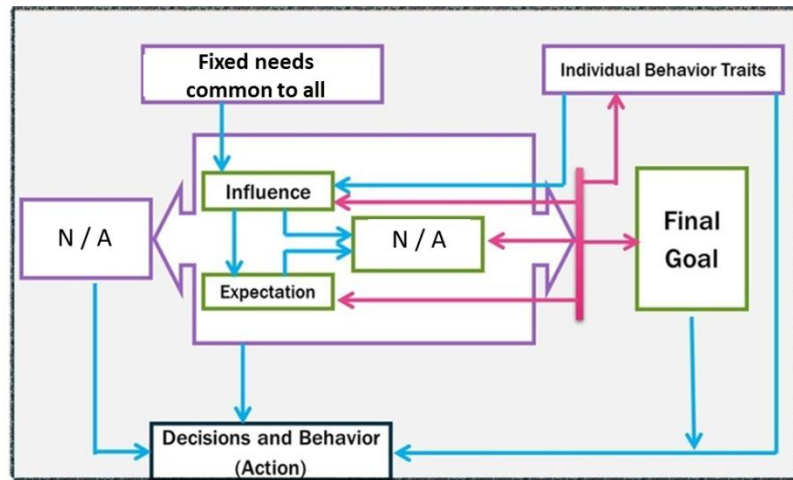


Figure 5 Model application on leader election study

4.1. Introduction to Leadership as influence

Assume in social networks the nodes as either leaders or followers and the links between them are their weighted mutual trait similarities. As in human society, a follower

picks a leader by examining each leader's behaviour towards him. This can be mapped to the process of various cluster formations in a social network. According to present studies in cluster formation, each node is kept in a cluster with maximum similarities. This same approach is used in determining links between two nodes in various link prediction methods. A cluster is thus formed where all nodes are bound to each other with a relative association of similar attributes. This research studies a social emergence problem of elections in democratic society where individual choose their leader, assuming that the leader and follower relation is based on some similarity between their behavioural traits. To inspect this assumption we consider a democratic social system where people are living in groups and to settle disputes and other issues they need to elect a leader with majority. The hypothesis behind studying a democratic society is that "when everyone has a right to choose leader then the reason behind different choices of leader could be observed by looking at their expectations from leader, this also gives a reason to the followers to be greedy about their expectations". Being greedy about expectations here means to select a leader having maximum similarities. Such individuals when given chance will choose themselves as the leader with highest probability of similarities count.

This experiment studies sub-group formation (clusters) in society practicing democratic election; the sub-groups here are expected to have a leader each. All these leaders in themselves are different than each other in some attributes (behavioural traits).

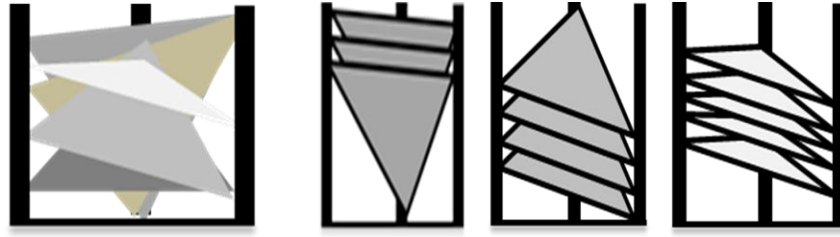


Figure 6 Different clusters of attribute relations

In figure 6 three pillars of attributes in black are showed with all the 2 d planes signifying each individual's behaviour based on these three attributes. These groups can be represented into 3 sub-groups as:

Considering the complexities of social networks this study presents a scenario of democratic election in society and the dynamics afterwards. Figure7 shows a social network with leaders as the centroid of the clusters in brown color, the dashed black links show interconnection between leaders. These same relations exist between all elements in the network.

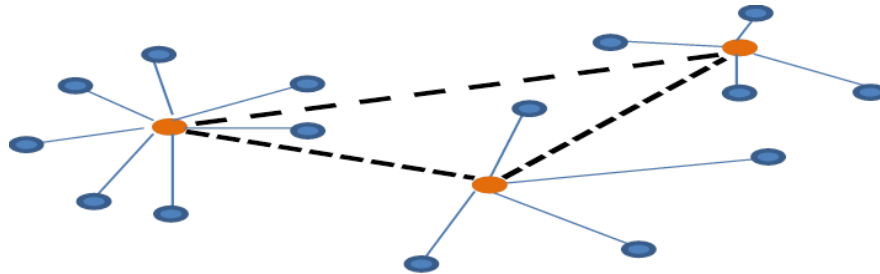


Figure 7 Social network with 3clusters

4.2. Background for Leadership experiment model

We briefly survey four areas of background work: Need of leadership, leader selection and its relation to behaviour qualities of a leader, group learning.

Need of leadership

In this section a survey on the work done by researchers is presented, which explains the study on “need of leadership and its origin”. Krause, (2002), state individuals come together under ecological and social pressures, thus leading to the emergence of a relation between a leader and their followers, also highlighting how people seeking protection and looking for resources stick with each other. Van Vugt, (2008) states that “the emergence of leadership is fine-tuned to specific coordination problems that humans have faced across evolutionary history”. He further explains that decision making in a group is facilitated by the emergence of some form of leadership and that some individuals persuade others to follow them in the direction of a preferred need.

Leader selection and its relation to behaviour qualities of a leader

In this section we are surveying those papers which describe the importance of behavioural quality of leadership, and its effect on followers. Seam A. Rands, (2003) describes that every leader possess a unique quality which can be behavioural which makes them specific to the decision-making role for example baboons, where a single dominant male tends to lead the group. Van Vught et. al., (2008) concluded for the relatively stable impressions that followers hold about leadership, such as intelligence, health, and generosity, while talking about clues as to why followers change their mind about a particular leader. Traits are stereotypically associated with leadership, such as dominance, assertiveness, intelligence, physical stature, social sensitivity, and many others. The typical research format for these early studies was to identify a group with leaders and followers and test for differences on the selected trait measures. (Krause,

2009; Lusseau, 2007; King and Cowlshaw, 2010) Dominance increases the probability of individuals to be followed and to act first. Seam A. Rands, (2003) further concludes that leadership can identify potential “mismatches” between how evolved mechanisms of leadership map onto our relatively novel social environment. For example, modern human leadership still correlates with age, sex, height, and weight even though there is little evidence suggesting these attributes still matter in present world.

Dyer, (2009), Van Vugt, (2008) describe the relation observed between leaders and followers in various activities, such as how a follower chooses to follow a specific leader depending on the mutual benefits and understanding of requirements. Suer and Deneubourg, (2011) highlights that individuals sharing same goal are likely to follow each other. And the same applies to the leader follower relationship. A follower will like to have a leader who shares traits and needs.

Group learning

This section presents a survey on those papers which highlight the learning procedure of followers in their approach and understanding.

Suer and Deneubourg, (2011), state that due to different needs and expectations, society accepts a distributed leadership where the followers to fall into a group decides their leader separately. In their work they also examined how biased leadership in favour of some individuals emerges through differences in the needs of group members. Simaan, (1973) states that agents improve themselves by following some strategy and even by changing strategies. King and Cowlshaw, (2009) describe that the behaviour of one or more individuals can result in a change of behaviour of many. This means that by looking

at other followers and observing a change in the achievements of a leader, the followers can change their perception to follow any leader. Conradt and Roper's (2007) models indicate that democratic decisions can evolve even when groups are heterogeneous in composition and when alternative decision outcomes differ in potential costs and these costs are large.

4.3. Implementation on leadership approach

Multi agent simulation is used to model the election scenario and the dynamics in leader-follower relation. Then an analysis of generated results is presented to understand a possible analogy with social networks. In the experimental setup we are populating 30 agents with each given initially a random IB set value (IB explained below) between the range 0.0 to 1 for other than Age and height [Population of only 30 agents is taken in order to reduce the complexity of calculation]. In the experiment, one election in a group is equal to one time step; values are calculated in each time step and are analyzed. Each agent is randomly selecting an expectation set, the expectation set is the random weight of traits (randomizing this is needed as people do have random qualities in real world, the only restriction is in selecting traits type which is done on the basis of psychological study). To study the effect of leaders success and failure on followers we are providing strategies to the leader, each leader will select a strategy and his success and failure in implementing that strategy is kept random (The reason behind assuming success as random is because, according to sociology, most dynamics are observed in such situations and analyzing followers state of mind will be clear, as in the experiment all agents are assumed greedy [greedy means that all are focused only on their expectation

and not for public good]). But this experiment considers behaviour, strategies and expectation are randomly assigned to individual agents in the real world. This study is done to establish an understanding of some possible patterns in such randomness. A graph in sub group formation can be drawn by observing the leader with maximum followers (In a social network, a cluster with maximum “closeness centrality” in the network) is expected as the outcome result.

The group overall expects a leader to be extraordinarily qualified. Each agent is assumed to have a defined set of individual behaviour (IB) that is $IB_{ag} = \{IB_1, IB_2, IB_3, IB_4, IB_5, \dots, IB_{17}\}$. In this paper 17 behavioural traits are compared for each agent and it is assumed that this trait is present in each agent but in different quantity (calculation of effectiveness on behaviour using meta-analysis in integer value). These individual differences are achievement (IB_1), ambition (IB_2), organizing skill (IB_3), need of power (IB_4), dominance (IB_5), honesty (IB_6), adjustment (IB_7), self-confidence (IB_8), creativity (IB_9), cognitive ability (IB_{10}), management skill (IB_{11}), experience (IB_{12}), age (IB_{13}), decision making (IB_{14}), energy (IB_{15}), initiative (IB_{16}) and height (IB_{17}). The relation of these individual differences to leadership is defined in the study by Brian J Hoffmann, (2010) (presented in table 1). We are considering the association between ambition Stogdill, (1948), initiative (Russell & Domm, 1995), energy (Howard & Bray, 1988) and need for power (McClelland & Boyatzis, 1982), dominance (Judge, 2002; Lord, 1986) achievement (Judge, 2002) conscientiousness (Judge, 2002), self-confidence (labelled self-esteem); Judge, (2002) and adjustment (labelled neuroticism); Judge, (2002); Lord (1986) with leader effectiveness.

There is a total number of thirty agents $Ag = \{ Ag1, Ag2, \dots, Ag30 \}$ in the group. To measure effectiveness of Individual behaviour we are taking the values for effectiveness of these traits as given by the study from Brijan J, (2011) using meta-analysis by Hunter, (1990) of surveyed data as $E_{ff} = \{0.28, 0.12, 0.05, 0.15, 0.31, 0.52, 0.35, 0.29, 0.29, 0.19, 0.40, 0.16, 0.48, 0.17, 0.10, 0.24, 0.48\}$. Initially a large number of subgroups are obtained after some steps when the expectations are static but the traits are changing with strategies. Agent's trust on others is transferred on each step and the experiment is continued until a specific number of leaders are obtained. The graphs obtained show dynamics on these specific selections.

Table 1 Meta- analysis of the relationship between individual differences and leader effectiveness

(Brian J Hoffmann, 2010)¹

Variable	Total sample size	Number of data points	Corrected statistics			95% confidence interval		80% credibility interval		Q
			R_{xy}	RHO	SD_RHO	Lower bound	Upper bound	Lower bound	Upper bound	
Trait-like	115,327	498	.22	.27	0.22	.26	.27	-.01	.55	7,202.47**
Achievement motivation	11,167	35	.23	.28	0.17	.27	.30	.06	.50	459.57**
Initiative	1,580	17	.15	.19	0.20	.14	.24	-.07	.44	92.69**
Ambition	199	3	.15	.05	0.05	.07	.33	.14	.26	5.33
Energy	2,285	13	.23	.29	0.15	.25	.32	.10	.47	85.43**
Need for power	2,009	8	.12	.16	0	.12	.21	.16	.16	9.61
Dominance	10,335	44	.27	.35	0.23	.33	.37	.06	.64	787.28**
Extraversion	14,506	39	.12	.15	0.08	.13	.16	.05	.25	155.93**
Conscientiousness	4,234	17	.13	.16	0.07	.13	.19	.08	.24	46.53**
Honesty/integrity	3,123	11	.25	.29	0.21	.26	.32	.03	.55	171.91**
Self-confidence	11,888	55	.21	.24	0.19	.22	.25	.01	.48	566.88**
Adjustment	9,223	18	.10	.12	0.01	.10	.14	-.03	.28	166.27**
Creativity	5,869	22	.24	.31	0.18	.28	.33	.08	.54	267.02**
Flexibility	4,745	15	.14	.19	0.17	.16	.21	-.03	.40	181.90**
Self-monitoring	2,468	16	.16	.19	0.16	.16	.23	-.01	.39	94.96**
Charisma	15,711	86	.48	.57	0.33	.56	.58	.14	.99	3,967.55**
Cognitive ability	15,985	99	.15	.17	0.11	.16	.19	.04	.31	340.56**
State-like	31,524	165	.20	.26	0.20	.25	.27	.01	.51	1,672.02**
Technical knowledge	6,455	12	.15	.19	0.17	.17	.21	-.03	.41	215.06**
Past experience	4,368	43	.08	.10	0.15	.07	.13	-.09	.30	166.68**
Interpersonal skills	2,953	26	.25	.30	0.18	.27	.34	.07	.54	159.15**
Oral communication	4,002	25	.22	.25	0.13	.22	.28	.08	.42	120.10
Written communication	2,264	12	.18	.24	0.06	.21	.28	.16	.33	38.39**
Management skills	879	14	.33	.40	0.22	.34	.45	.12	.67	79.68**
Problem-solving skills	3,574	7	.28	.39	0.23	.37	.42	.10	.69	287.91**
Decision making	2,811	9	.38	.52	0.19	.49	.55	.27	.76	211.83**
Organizing and planning	4,218	17	.16	.17	0.13	.14	.20	-.01	.34	98.63**

Note. For the following tables, R_{xy} is the uncorrected mean sample weighted correlation, RHO is the fully corrected mean correlation, SD_RHO is the standard deviation of the fully corrected correlation coefficient, and Q is the test for homogeneity in the true correlations across studies, where ** = $p < .01$ and *denotes $p < .05$.

¹ This table as it is copied from the work (Brian J Hoffmann, 2010).

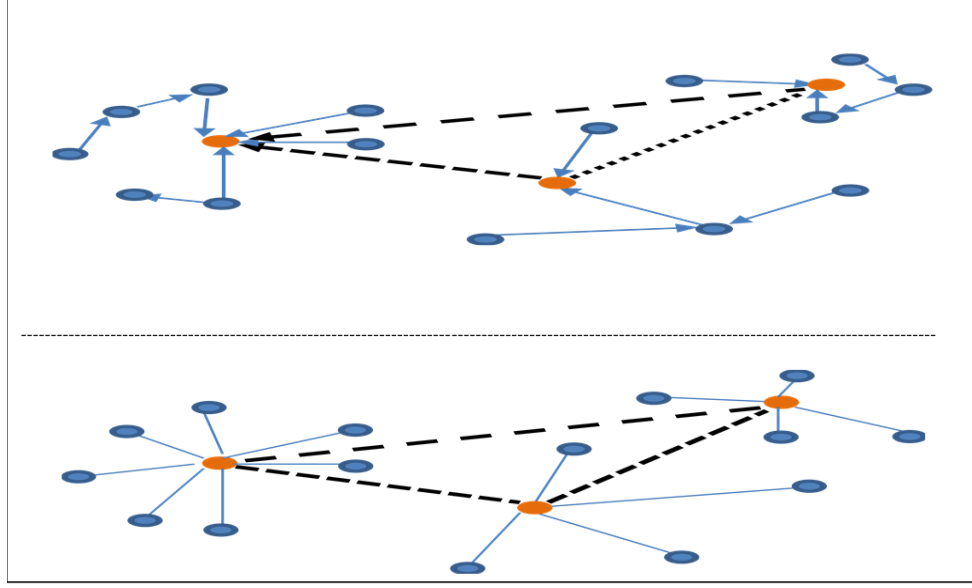


Figure 8 Formation of sub groups with leaders

Results for initial elections are calculated by comparing Obe of each agent to Obe of other agent and we will finally select three such potential agents (termed in this paper as expected leaders) to plot e_{11} , e_{12} , e_{13} . Figure 8 presents a network of agents with three final leaders in orange.

4.4. Results for leadership experiment

For analyzing the learning pattern of followers we consider three events in our approach i.e.

First the group identifies their three possible leaders who are selected on comparing their overall behavioural effectiveness. Figure 9 explains how the decision of the group according to their expectation these leaders changes with time step (each time step equals to one election). Here x-axis represents the id of agents (which are 30 in number). And y axis represents number of elections. We observed three scenarios and the discussion follows:

- Initial election: where all agents are compared then three agents (shown by rhombus symbol) are selected as expected.
- After 10 elections: We see a change in expected leader's selection. This shows new agents coming from group showing better behaviour than the previous one.
- After 40 elections: One more leader is changed
- After 70 elections: stability is observed in selections of expected three.
- After 100 elections: Same leaders are selected.

From these results, it is observed that the group is able to slowly categorize its possible choices of leaders. But who among them is to be elected as final leader is still a question, for that a record of how many followers do vote for these leaders is kept.

Figure 10 shows the number of followers following their best choice among the expected three leaders with every election (time step). In this figure x-axis represents agent Id. (Here all agents are shown because in previous graph we have seen a change in expected three).-We observe this behaviour through the number of election:

- Initial election: Out of total 27 number we can see 7

Followers are following agent id 15 (one among expected three by figure 55). So are 8 and 12 agents follow agent id 18 and 23 respectively.

- After 10 elections the expected leader are change by one.
- After 12 elections: This is a very important outcome where for the first time we are able to observe a majority (more than half) of followers following agent id 13. Besides the difference in expectations, the majority has chosen a single leader.

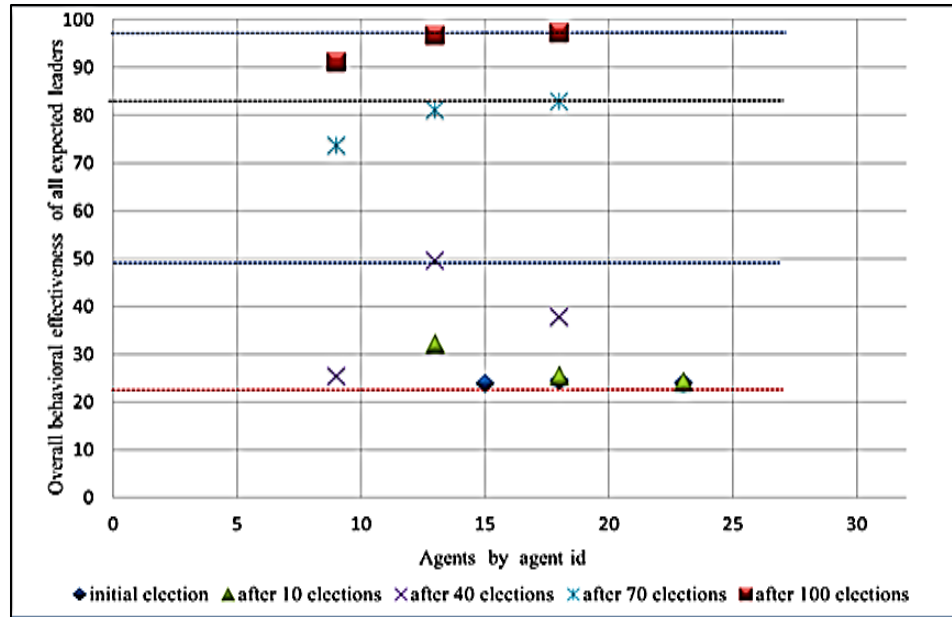


Figure 9 Expected leaders

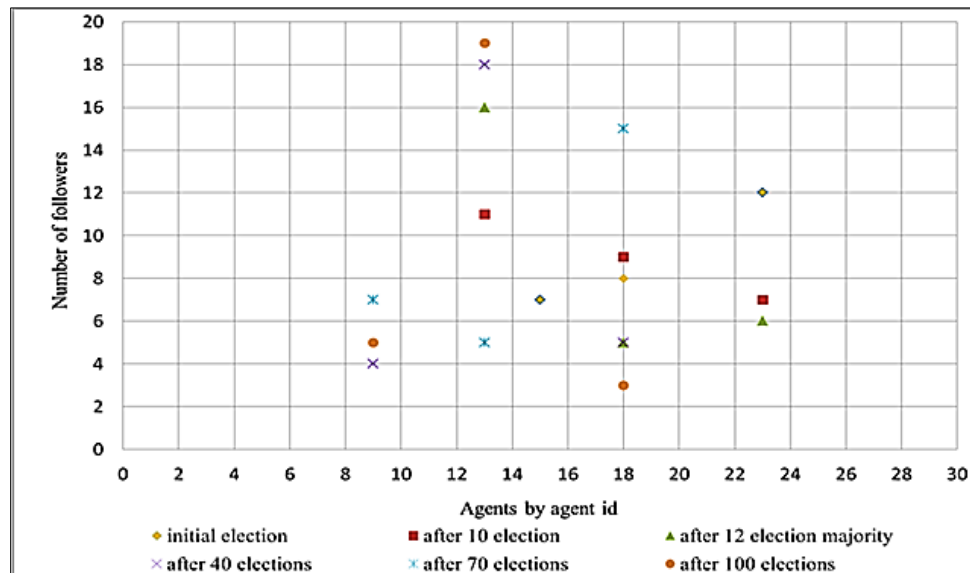


Figure 10 Followers following leaders

- After 40 elections: Again a change in the expected leaders
- But the majority is still following agent id 13.

- After 70 elections: an observation of a shift in followership towards the agent id 18. And also more than half is seen following him
- After 100 elections: there is a shift again.
- In the results from figure 10 the followers are observed coming under a mutual decisions on the selection of leader.

An Important observation between figure 9 and figure 10 is that after 100th election agent id 13 has less Obe then agent id 18. In figure 10 it is evident that the same majority chose agent 13 to follow. This highlights that followers are not only looking at Obe but are looking at specific expectations from leader. The same phenomenon is repeated at point A, B, C in figure 11.

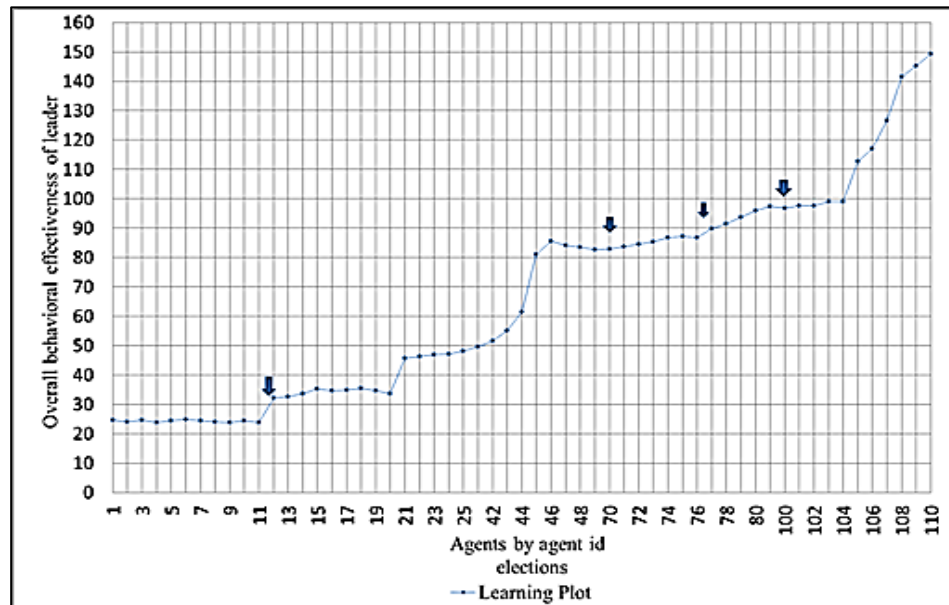


Figure 11 Followers Learning graph

Finally figure 11 plots the total Obe value of group in the event of selecting leaders. The x axis of graph represents number of elections and y axis represents Obe of that one leader (among the expected three) who wins with majority after every election. (Arrows in graph 3 shows change in leadership). One more important observation here is that before change in leadership in figure 57 we can see a decrease in graph, which is because of the decrease in Obe of the present leader. But it can be observed that followers are still following him. This event highlights the faith of followers in their leader even when he is failing, but after a certain failures when the followers find some one more capable they are switching there leader. The results presented in figure 57 shows a similarity between experience learning curve given by Bruce Henderson, (1968) and the follower's learning curve obtained.

Experience curve given by Henderson, (1965) defines the learning process of an individual whereas the obtained curve reflects learning of groups with member having different needs characteristic. Experience curve given by Henderson, (1965) defines the learning process of an individual whereas our curve reflects learning of groups with members having different needs characteristics.

CHAPTER 5. TEST AREA DESCRIPTION

The village project is designed to help archaeologists in studying the life style of small scale agrarian societies. This project implements an agent based simulation model of village eco-dynamics on the data, archaeologist acquired on this project. The prime goal is to investigate the interaction between landscape throughout different climatic conditions and social conditions prevailing in these agrarian societies and also the reason behind the mass evacuation of these regions during 1200 A.D.

The regions are:

VEP I is focused on an 1827 sq. km area near the Southern Western Colorado. This region was well established in the beginning of 600 AD to 1250 AD. These people completely evacuated this region around 1250- 1280 AD.

VEP II focuses on south western Colorado including Mesa Verde National Park and adjacent areas east and south of the VEP I area. This project, according to research by Crow Canyon Research Center, Archaeologist, has evidence that people from both the villages had long distance contacts with other. There are also ceramic data that confirm these theses.

The Mesa Verde region provides an idea for examining migration as a social process. The archaeologists gathered evidence by collecting various artifacts like pottery tellies and also some site information's, Here at village eco-dynamics they have big data repositories relevant to the social life of these people. They are making a whole inventory of these data.

5.1. Migration in the area

Researchers believe that the artifact procurement patterns reflects the communication patterns between the central Mesa Verde and the northern Rio Grande regions, and that there are evidence confirming eventual migration from the post to the other region. This research studies the migration activity with starting point as the Mesa Verde region. Artificial agents are created and it is assumed that the best needs for these agents are defense, direction, dependability on path and duration of the journey. Migration activity is considered as a human mobility event on large scale and it is mostly independent of any destination. It can be explained as a continuous movement until a favourable region (for settlement) is reached. That means a destination is defined with movement but not prior to the movement.

CHAPTER 6. EXPERIMENT SETUP

Our approach includes utilization of sensory information that depends on various aspects to manage in situations like migration, where human has to consider some aspects, such as the direction where they could possibly go, the duration of journey, protection during journey, maintaining their calories by travelling through an easy and walkable route. In our approach we are trying to study human migration techniques using the above explained perspective, for which we need FETE and 4D method together. 4D stands for four aspects of categorizing observed topological information during migration, where each D has its own significance. They are Direction, Defense, Dependability, and Duration.

Direction: The objective is to find a migration route from a source to any destination, but to move in a restricted direction band.

“Ancients used to follow landmarks instead of navigation equipment for tracking their path.” Figure 12 presents an understanding of directional restriction given to the agent.

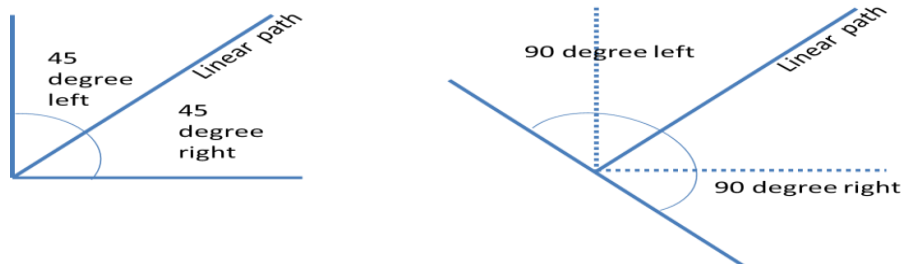


Figure 12 Direction Band a) 45 - 45, b) 90 - 90

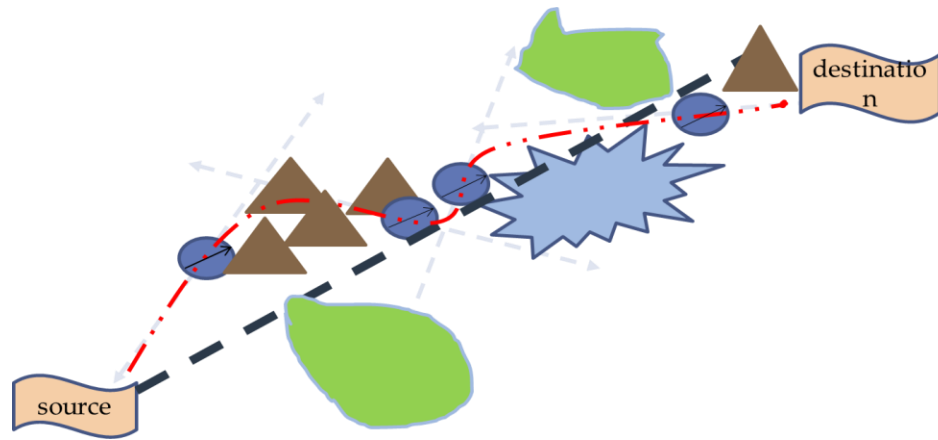


Figure 13 Direction relation between a cognitive path and linear path

Duration: Instead of considering it as time, Duration here is defined as the distance between the two regions. Figure 13 presents an understanding of differences between linear and cognitive path.

Distance: Distance is calculated by counting the number of steps in a path and in the research every step is considered a mile away, so the total distance is the number of total steps in mile unit. Figure 14 presents different cognitive path with different total distance.

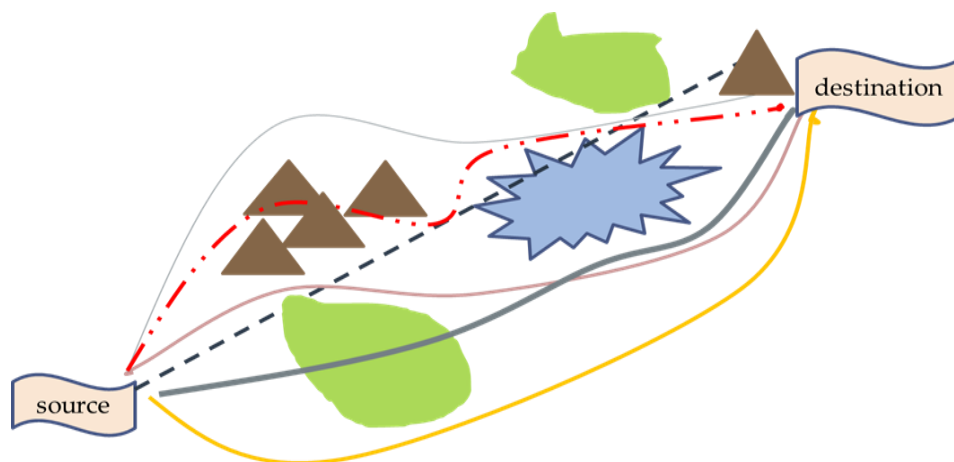


Figure 14 Distance relation among different paths

Defense: By Defense, we are not talking about their fighting skills or weapon technology. Our concern from defense here means how well they can keep watch on their enemies and other problems on their way. Figure 15 presents a understanding of visibility and security factor during movement.

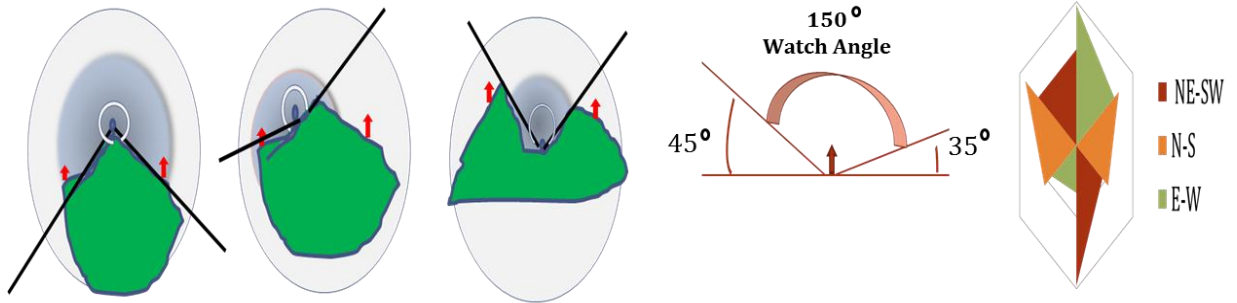


Figure 15 Visibility Relation

Dependability: We considered dependency as one factor where humans take into consideration the available resources, mainly water, along their path before starting their journey.

$$\text{Dependency} \left\{ \begin{array}{ll} \frac{r_{\text{route}} + w_{\text{route}}}{(r_{\text{req}} + w_{\text{req}}) * \text{number of people} * \text{duration}} & \text{if } r_{\text{route}} > 0, w_{\text{route}} > 0 \\ \frac{(r_{\text{route}} = \text{load}) + w_{\text{route}}}{(r_{\text{req}} + w_{\text{req}}) * \text{number of people} * \text{duration}} & \text{if } r_{\text{route}} > 0, w_{\text{route}} > 0 \\ & \text{and vice versa.} \\ \frac{(r_{\text{route}} + w_{\text{route}}) = \text{load}}{(r_{\text{req}} + w_{\text{req}}) * \text{number of people} * \text{duration}} & \text{if } r_{\text{route}} = 0, w_{\text{route}} = 0 \end{array} \right.$$

- Here r stands for resources and w for water.

Figure 16 Dependency Relation

6.1. Initial requirements

- Tropical details (weather) {using various DEM file downloaded from earthexplorer.usgs.gov.in}
- Land use (terrain types) {using various DEM file downloaded from earthexplorer.usgs.gov.in}

Land-cover values are given to specific land cover in the same manner as used by Devin and Barbe, (2012). He himself considered IGBP land cover classes for these values and their mapping into terrain coefficient system (Soule and Goldman, 1972) (Table 2)

Table 2 IGBP Land cover mappings

IGBP Class	Description	Terrain Coefficient
0	Water	1.8
1	Evergreen Needle leaf Forest	1.5
2	Evergreen Broad leaf Forest	1.5
3	Deciduous Needle leaf Forest	1.5
4	Deciduous Broad leaf Forest	1.5
5	Mixed Forest	1.5
6	Closed shrublands	1.2
7	Open shrublands	1.2
8	Woody savannas	1.2
9	Savannas	1.2

10	Grasslands	1.0
11	Permanent wetlands	1.8
12	Croplands	1.2
13	Urban and built-up	1.0
14	Cropland/ Natural vegetation mosaic	1.2
15	Snow and ice	1.5
16	Barren or Sparsely vegetated	1.0
254	Unclassified	0.0
255	Fill Value	0.0

FETE method takes some parameters like latitude, longitude, elevation and land cover information. We implemented an uphill and downhill metabolic rate calculation function; we are feeding the data by creating a matrix of elevation and land-cover data with longitude and latitude as the row and column parameter respectively. The topographical information should include three parameters; latitude, longitude and elevation of various features along the path.

6.2. Implementation of Model on the test area

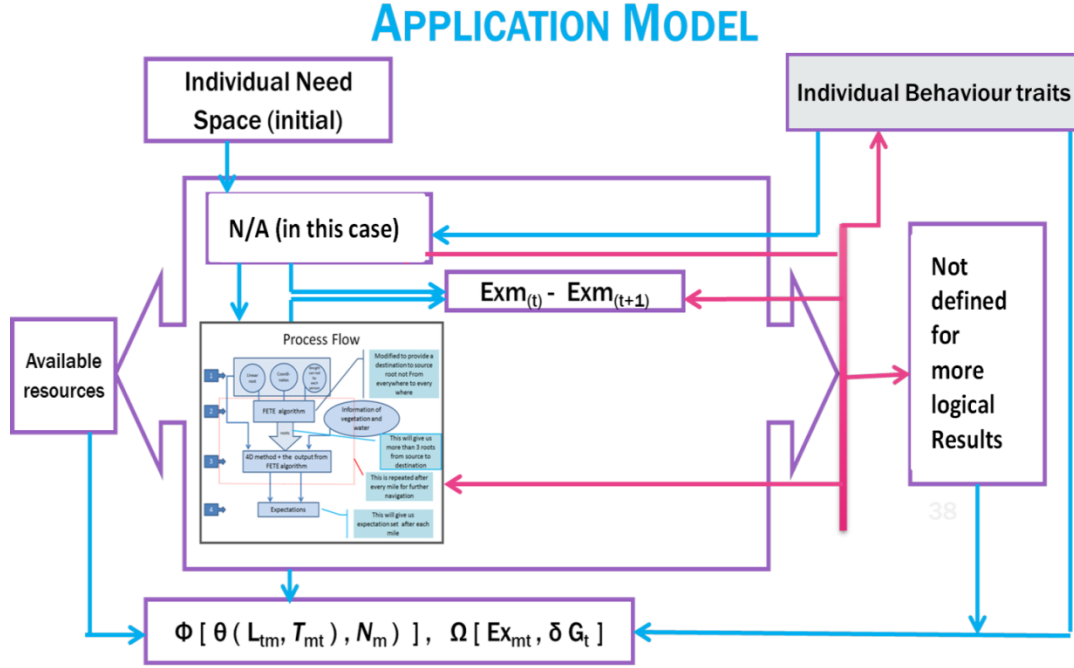


Figure 17 Implementation of Application Model

Figure 17 presents the implementation of the proposed model on the test case. Each aspect is presented in a relation to the test area.

6.3. Implementation in artificial simulation

To implement the model, the dem information of both regions is downloaded from earthexplorer.usgs.gov.in. This information mainly contains latitude, longitude, elevation of the region and land-use data. (All data was in meters) These data are then compressed to increase the scale from 1metre to 1mile (using GIS). A different matrix with rows representing longitude information and columns representing latitude information is created out of the Dem data. The data about elevation are kept in reference to the latitude and longitude information. The same procedure is used to create different matrices for

land cover information. This information is then passed to a function that calculates metabolic rate, given by Devin. The algorithm takes start point information and creates path, where destination Information are not given for this research.

Earlier, both source and destination information were provided, which was partially satisfied the objective of research, that is providing proper reasons for human mobility. Assuming, both destination and source are known then, such a movement is mere travel but cannot be considered as migration (especially in case of prehistoric settlements). The algorithms then call direction and angle calculation method to restrict the movement. This way another point in the provided direction band with less metabolic rate value is selected as the next move. For security calculation a function measures the total watch angle and returns the point with maximum value and hence a move again in the restricted direction band is made. Each step is of one mile in length traveled; therefore, the number of steps shows total distance and it is assumed that distance is proportional to duration. Results are plotted using GIS. Most of the results show three paths according to security criterion, but the length of the paths reflects which one is less time consuming. A look at our input data and how is it processed:

The format of input files which is downloaded from usgs.gov is presented below; all latitude and longitude are converted into UTM (Universal Transverse Mercator coordinate System for Colorado region using ARC GIS 10.1 software)

UTM system not only provided us an ease of calculation, but also with the flexibility in locating any point on a raster image of the area.

This approach made it easy to plot the results on the raster while and this file is mapped with land use shape file in order to produce a 2d map representation of the results. Table no., 3 represents the format of the input data.

Table 3 Input Data from Dem Files

POI NT ID	ELEVAT ION	X	Y	Grid ID	CLASS_NAME	Distance
2303	2188	164000.0000 00000	4134000.0000 00000	4177 2	Temperate or sub-polar needle leaf forest	646.3810 0141
2304	1964	168000.0000 00000	4134000.0000 00000	4177 6	Temperate or sub-polar needle leaf forest	646.3810 0141
2305	1838	172000.0000 00000	4134000.0000 00000	4178 0	Temperate or sub-polar shrubland	646.3810 0141
2306	1781	176000.0000 00000	4134000.0000 00000	4178 4	Cropland	646.3810 0141
2307	1872	180000.0000 00000	4134000.0000 00000	4178 8	Temperate or sub-polar shrubland	646.3810 0141
2308	1929	184000.0000 00000	4134000.0000 00000	4179 2	Temperate or sub-polar shrubland	646.3810 0141
2309	1970	188000.0000 00000	4134000.0000 00000	4179 6	Temperate or sub-polar shrubland	646.3810 0141

The above file downloaded from the source had 32 million such rows which have information on data at the scale of 30 to 30 meters. For the algorithm we assumed human observation for every one mile. We converted the file to a scale of 1 mile to 1 mile. This file is then passed to a function that creates separate matrices for elevation and land cover information. We below present an example of such matrices. Table no. 5 represents data for elevation information, all the data is in meters, where the first row and first column represents longitude and latitude information converted into UTM system.

Table 4 Elevation Matrix

The column here represents data according to longitude while rows represents latitude [All data values are converted into UTM coordinates]	Null	41936 14	41906 14	41876 14	41846 14	4181614
	160489. 2	2313	2269	2175	2140	2027
	163489. 2	2393	1892	2278	2182	2128
	166489. 2	2392	2285	2361	2264	2185
	169489. 2	2520	2499	2155	2367	2235
	172489. 2	2528	2466	2486	2410	2331
	175489. 2	2520	2587	2510	2465	2401
	178489. 2	2423	2539	2557	2554	2498
	181489. 2	2277	2450	2646	2535	2575
	184489. 2	2136	2319	2624	2651	2493
	187489. 2	0	2180	2311	2475	2549

The following table represents a matrix of land cover information; each land cover is given a value by using IGBP land cover classes as explained. [Table no. 2]

Table 5 Land cover Matrix

The column here represents data according to longitude while rows represents latitude [All data values are converted into UTM coordinates]	Null	4193614	4190614	4187614	4184614	4181614
	160489.2	1.2	1.2	1.2	1.2	1.2
	163489.2	1.2	1.2	1.2	1.2	1.2
	166489.2	1.2	1.2	1.5	1.2	1.2
	169489.2	1.2	1.5	1.2	1.2	1.2
	172489.2	1.5	1.5	1.5	1.5	1.5
	175489.2	1.5	1.5	1.5	1.5	1.5
	178489.2	1.5	1.5	1.2	1.5	1.5

	181489.2	1.5	1.5	1.5	1.2	1.5
	184489.2	1.2	1.2	1.5	1.5	1.5
	187489.2	0	1.2	1.2	1.2	1.5

All these tables are linked to each other using coordinates as keys in the relation. The information gathered from tables separately is fed into a function to check for positive and negative elevation difference and then it is passed to another function that calculates slope, angles and visibility using Devin and Barber(2012).

public double[] calculate_ve(double x,double y,double elevation,double x1,double y1,double elevation1)

This function returns slope information and velocity information that is then passed to another function to calculate metabolic rate, which is different for uphill and downhill climb.

public double calculate_avg_group_MRT_bwttwocoordinates(double Velocity,double avg_group_load,double avg_group_weight,double landcover,double percentages_slope, double elevation,double elevation1)

This information is then passed on to a function that puts some direction and security related restrictions on the data and returns coordinates of next move out of 8 possible moves. Below described is the format of the output files that have coordinates of the path from starting point and all are in UTM coordinate system for a direction band of 45-45 and for least secure paths.

Table 6 Result format

The column here represents data according to longitude while rows represents latitude [All data values are converted into UTM coordinates]	x	y	Elevation	Elevation Difference	Visibility
	169489.2	4133614	1964	108	349.7547586
	172489.2	4130614	1856	26	349.9438983
	175489.2	4127614	1830	262	349.2214964
	175489.2	4124614	2092	19	349.4851182
	175489.2	4121614	2073	105	349.6414338
	178489.2	4118614	1968	24	349.88676
	181489.2	4115614	1944	157	349.8863317
	181489.2	4112614	1787	201	349.7278259
	184489.2	4112614	1988	48	349.8505027
	187489.2	4112614	1940	108	349.7547586

Below we present a Process Flow Model in our implementation

Process Flow Model:

This Model reflects the steps in our implementations for calculation of the ultimate paths.

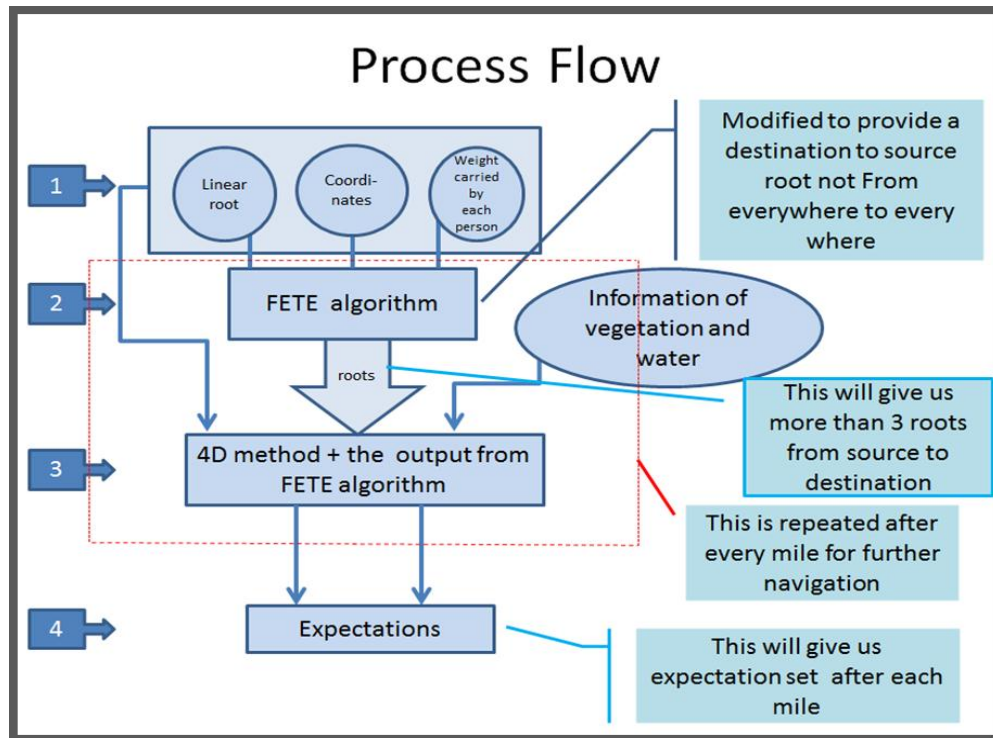


Figure 18 Process Flow Model

(Figure 18) This process flow model explains the connectivity between our algorithms, the first level shows the input level, which describes the various attributes of input used. This input is passed on to a fete algorithm that gives us some results. The outcome from fete algorithm goes to 4D method that calculates the desired path and returns coordinates of the point in the path. This coordinates are then plotted on a raster file of that are using GIS software to develop results. This results also contains some graphs on excel data to explain the various observed topological factor

CHAPTER 7. RESULTS

FETE Results:

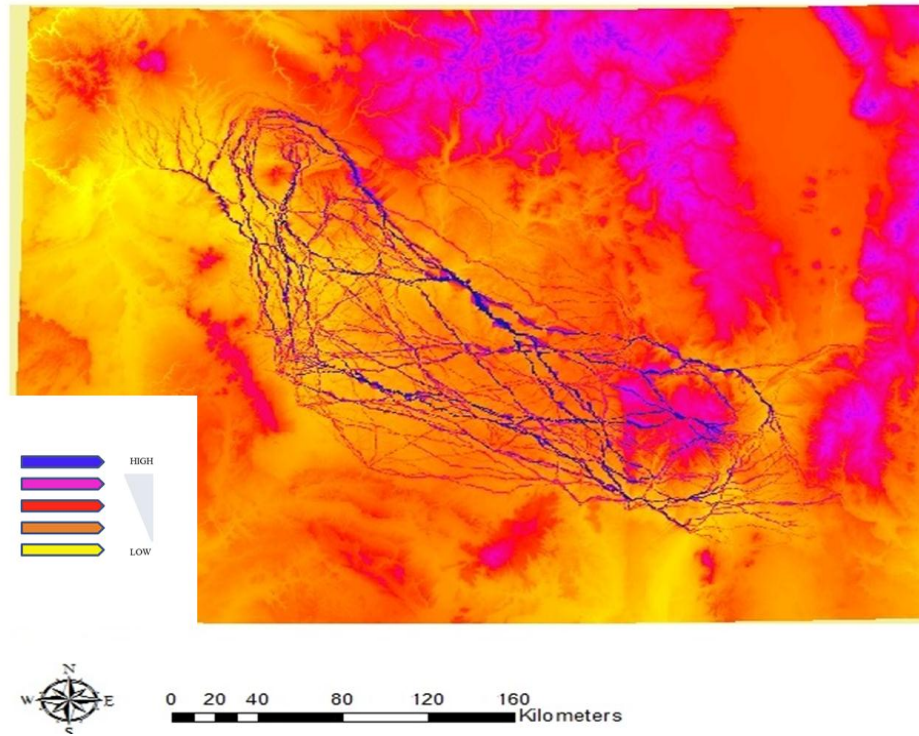


Figure12 Denton's Result (fete results)

This early results depict the migration paths constructed only by using FETE algorithms. The algorithms mainly follow the low differences in elevation area. The root created by Devin and Barber(2012) is a type of network between the points of movement. This point of movement is connected with the first point more adjacent to the starting point.

The following results we present are categorized according to 4 different observations. They are Elevation difference travelled, elevation of the point travelled, visibility provided by those points and the distance of the routes.

In the elevation difference travelled section, we can see the differences in variation in elevation value with every step. This result will help us in determining the characteristic of the routes and analyzing which one is better.

In the elevation data, the true elevation of the routes are plotted, as the nature of algorithm defines it is the step wise difference in elevation that makes a path easier than actual elevation differences from sea level. This sketches the hypothesis of human moving from one point to other; he compares elevation of other point from his current position, not the elevation from sea level.

Visibility provided by the path is a chart presenting total angle of visibility from all travelled points in the path. The result shows that a high elevation path provides better visibility to the agent while walking.

The distance of the routes section compares the routes on the basis of their length.

Result 45 -45:

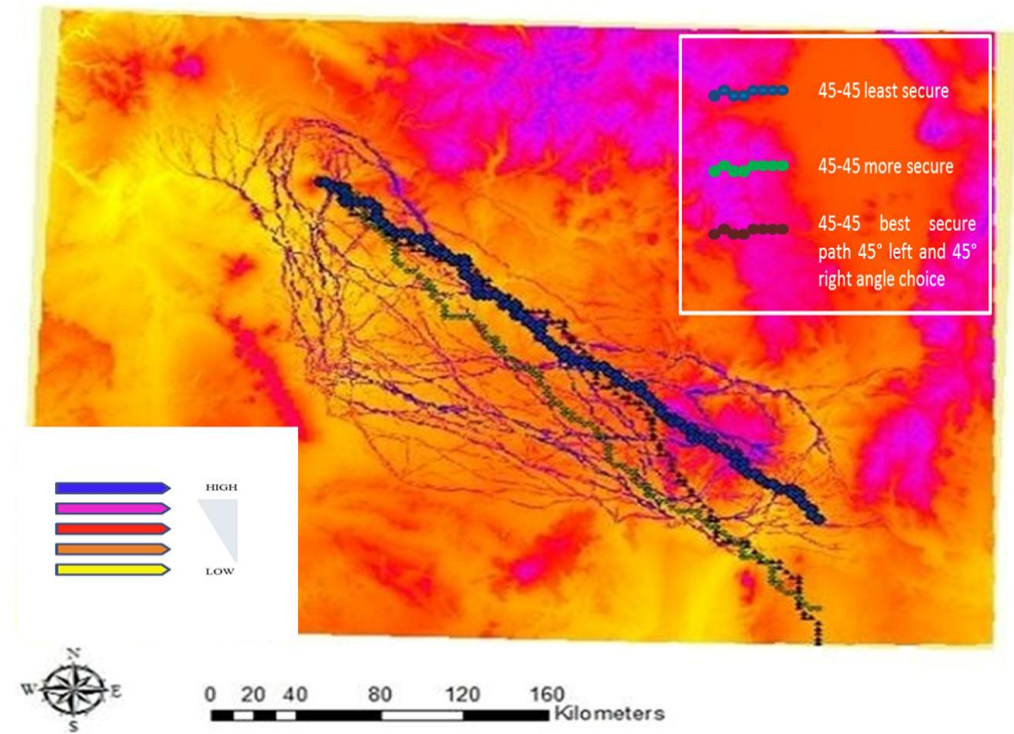


Figure 19 Three paths on direction band 45 - 45 over test region

Results description:

(Figure 19) These results represent three different paths according to level of security provided by the paths; the above graph shows results for directional band of 45 degree right to 45 degree left movement. In the charts below an analysis on the value of elevation, elevation difference, and visibility is presented. Most of the results show that a path with best security travels through high elevation region and provide maximum visibility angle, but could be lengthy in distance.

Elevation differences 45-45:

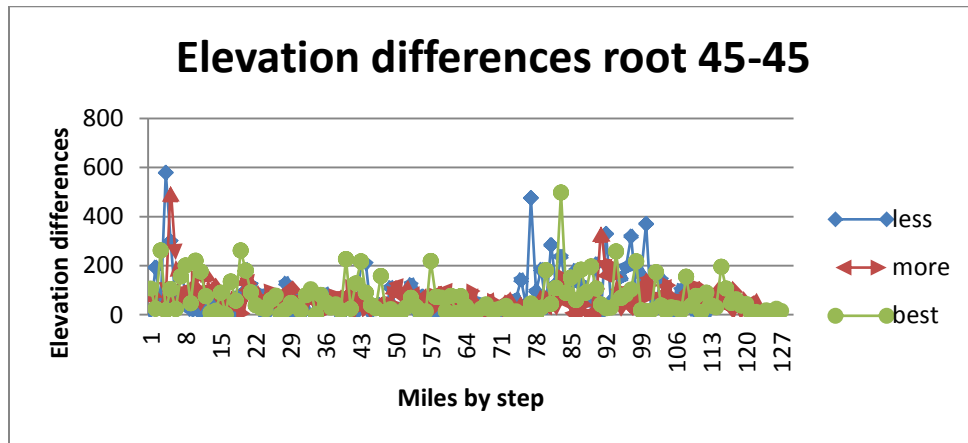


Figure 20 Elevation differences results for three paths on direction band 45 – 45

(Figure 20) Among the paths plotted on the graph above, the green one is the one which goes through the high region, where the other two red and blue go through lesser elevation areas. In the results (figure 21) below we can see these paths thus follow the elevation area respectively from less to best with increasing elevation. Both figure 20 and figure 21 are calculated by assigning the agent directional band of 45 degree left to 45 degree right.

Elevation Data 45-45:

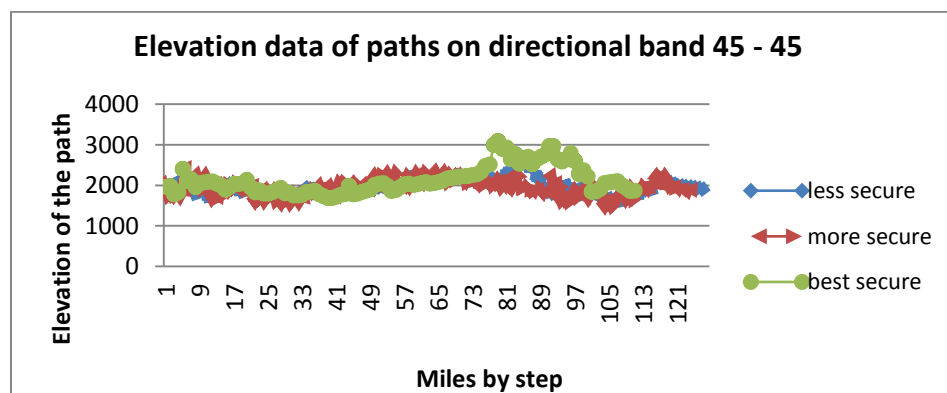


Figure 21 Elevation results for three paths on direction band 45 – 45

Visibility data 45-45:

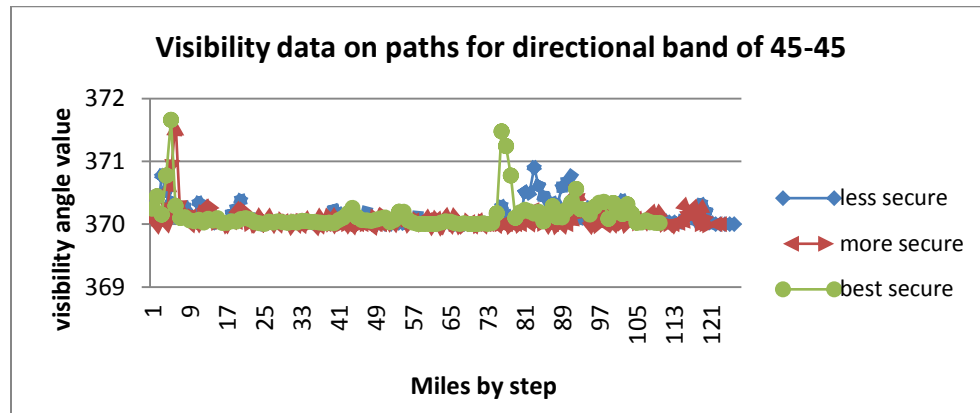


Figure 22 Visibility angle variations on three paths for directional band 45-45

(Figure 22) Visibility data for each path shows the independence of observation provided by the route to the agent calculated on directional band of 45degree left - 45 degree right. We made a hypothesis earlier in our research that there should be a reason why would people like to travel from high elevation area. And we assumed that high visibility means high security. Such can be seen in above results.

Distance data 45-45:

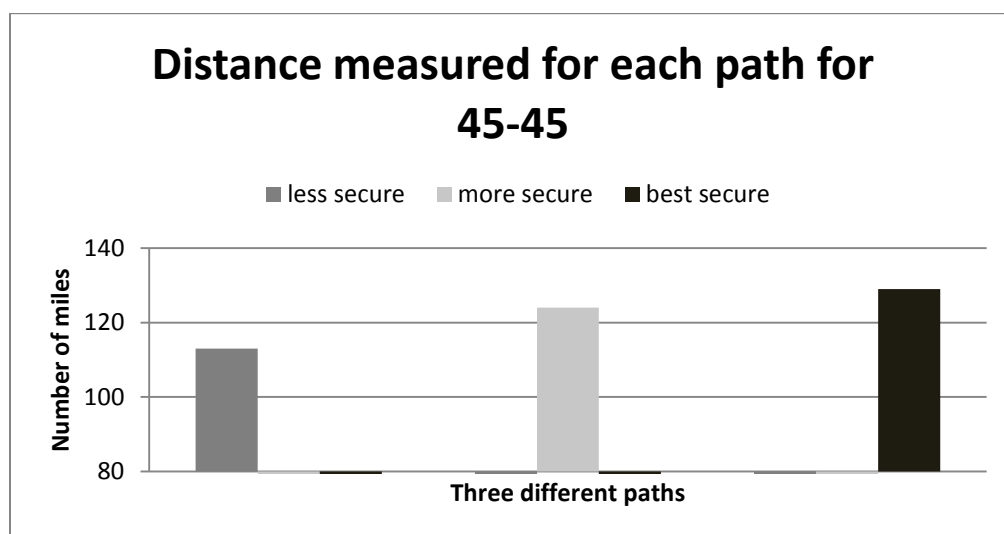


Figure 23 Distance calculation for three paths in directional band 45 -45

Results 90-45:

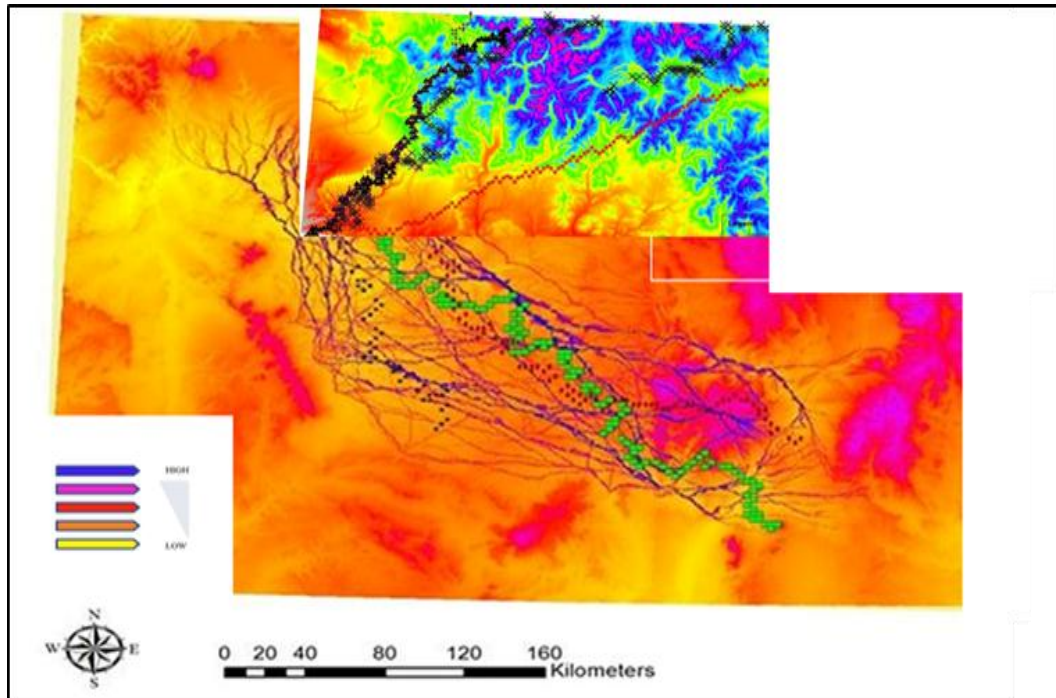


Figure 24 Three paths on direction band 90 - 45 over test region

Results Descriptions:

(Figure 24) These results represent three different paths according to level of security provided by the paths. The above graph shows results for directional band of 90 degree right to 45 degree left movement. In the charts below, an analysis on the value of elevation, elevation difference, and visibility is presented. Most of the results show that a path with best security travels through a high elevation region and provides maximum visibility angle, but could be lengthy in distance.

Results 90-45:

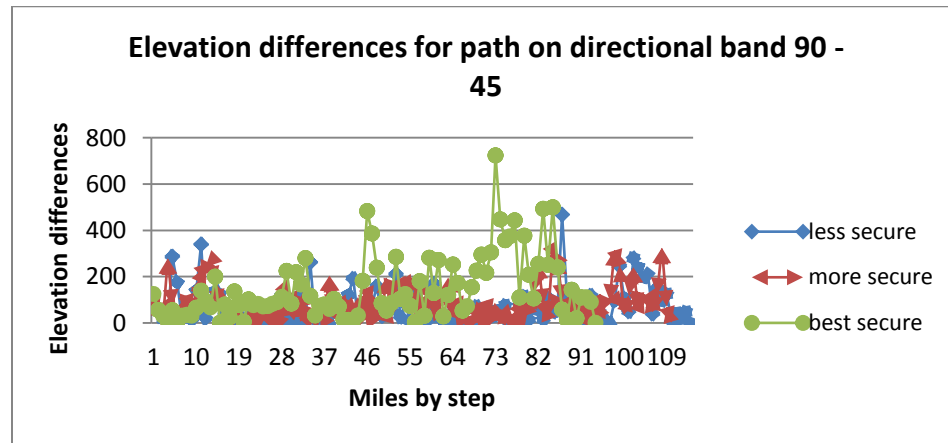


Figure 25 Elevation differences results for three paths on direction band 90 – 45

(Figure 25) Among the paths plotted on the graph above the green one is the one which goes through the high region, where other two red and blue goes through lesser elevation area. In the results (Figure 26) below we can see these paths thus follow the elevation area respectively from least to best with increasing elevation. Both figure 25 and figure 26 are calculated by assigning the agent a directional band of 90 degree left to 45 degree right.

Elevation 90-45:

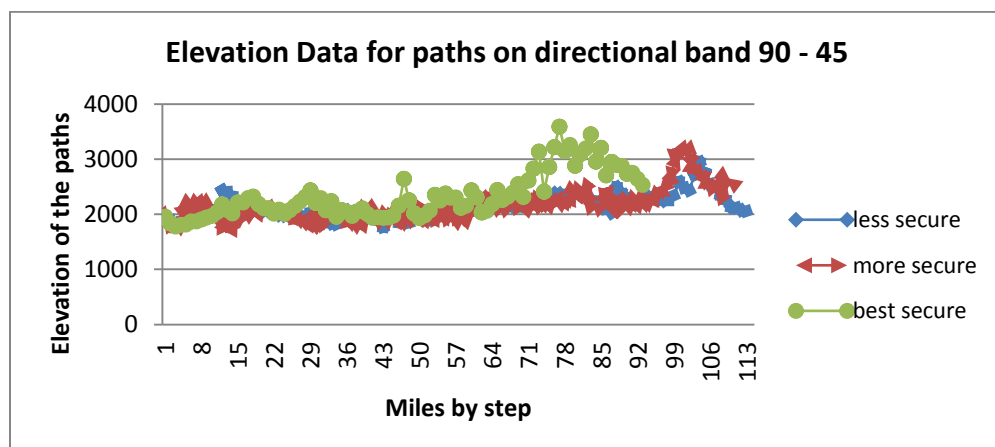


Figure 26 Elevation results for three paths on direction band 45 – 45

Visibility Data 90-45:

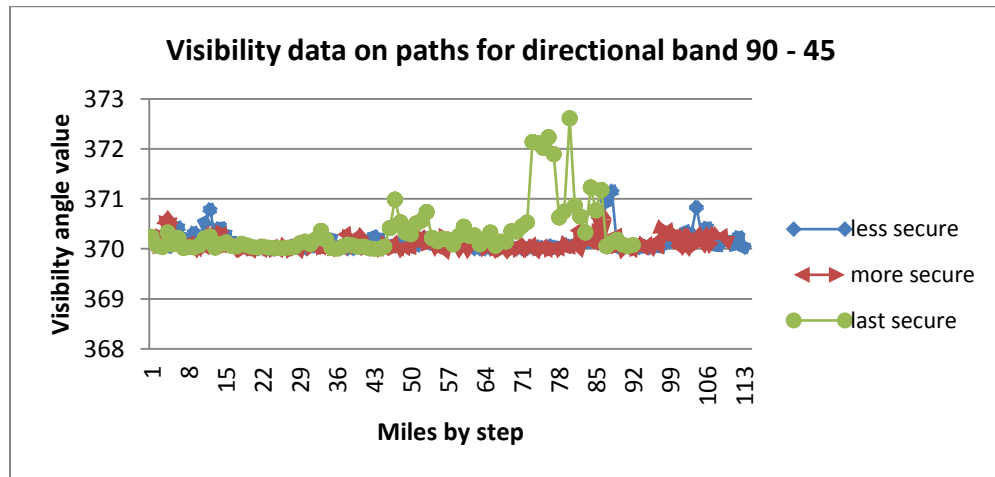


Figure 27 Visibility angle variations on three paths for directional band 90-45

(Figure 27) Visibility data for each path shows the independence of observation provided by the route to the agent calculated on directional band of 90 degree left - 45 degree right. We made a hypothesis earlier in our research that there should be a reason why would people like to travel from high elevation area. And we assumed that high visibility means high security. Such can be seen in above results.

Distance Data 90-45:

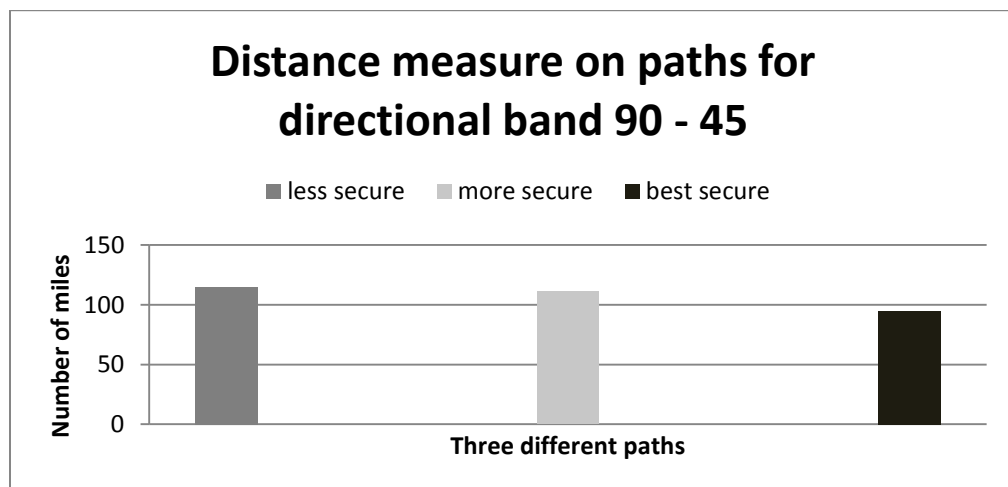


Figure 28 Distance calculation for three paths in directional band 90 -45

Results 45-90:

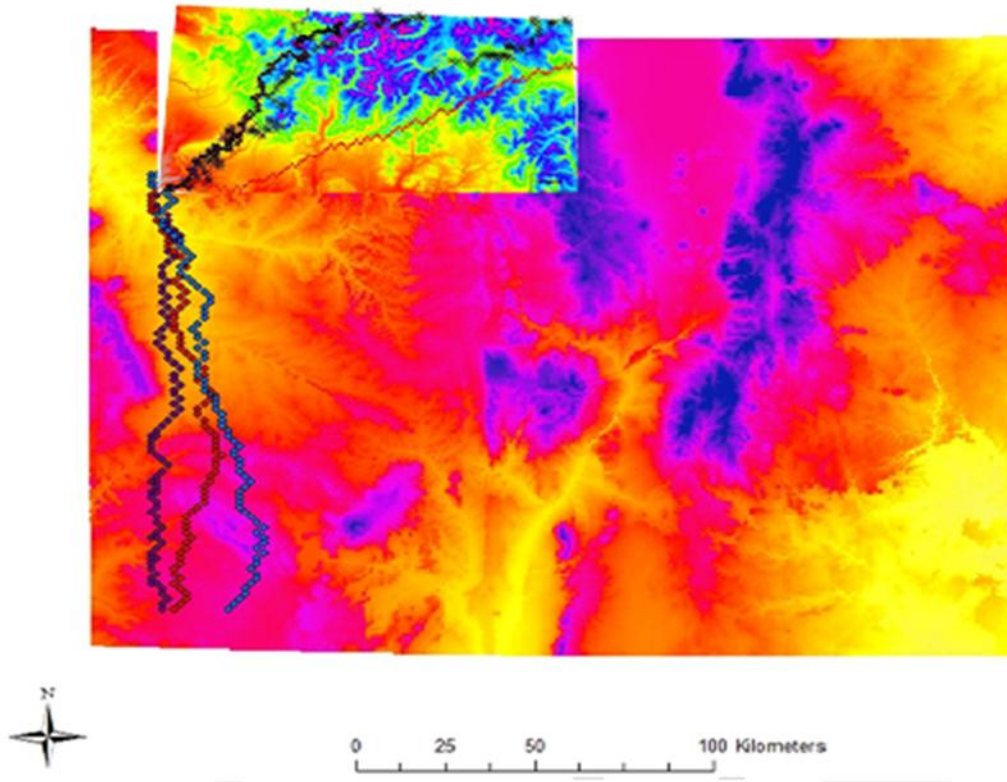


Figure 29 Three paths on direction band 45 - 90 over test region

Results Descriptions:

(Figure 29) These results represent three different paths according to level of security provided by the paths. The above graph shows results for directional band of 45 degree right to 90 degree left movement. In the charts below an analysis on the value of elevation, elevation difference, and visibility is presented. Most of the results show that a path with best security travels through high elevation region and provide maximum visibility angle, but could be lengthy in distance.

Results data 45-90:

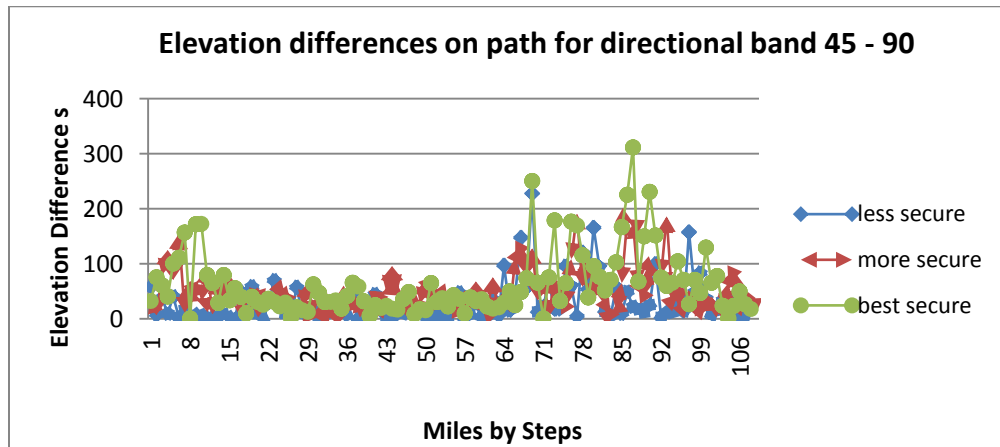


Figure 30 Elevation differences results for three paths on direction band 45 – 90

(Figure 30) Among the paths plotted on the graph above the green one is the one which goes through the high region, where other two red and blue goes through lesser elevation area. In the results (Figure 31) below we can see these paths thus follow the elevation area respectively from less to best with increasing elevation. Both figure 30 and figure 31 are calculated by assigning the agent directional band of 45 degree left to 90 degree right.

Elevation data 45-90:

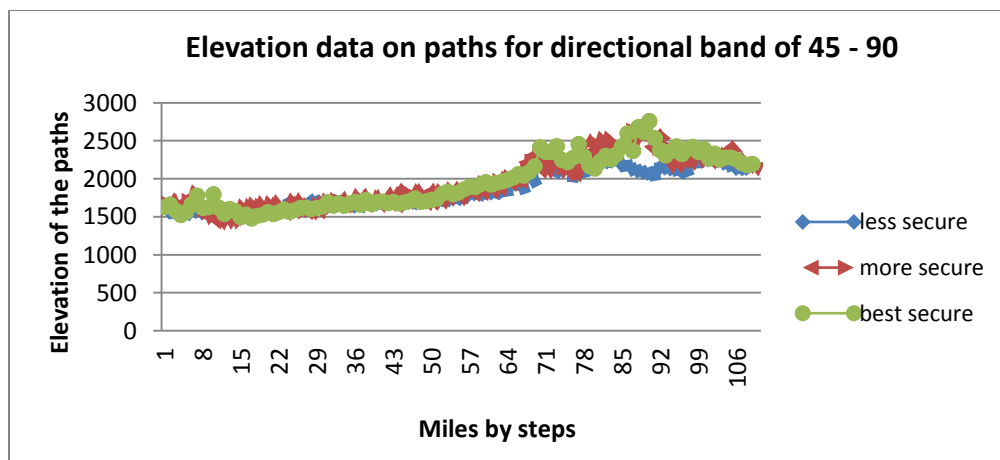


Figure 31 Elevation results for three paths on direction band 45 -90

Visibility Data 45-90:

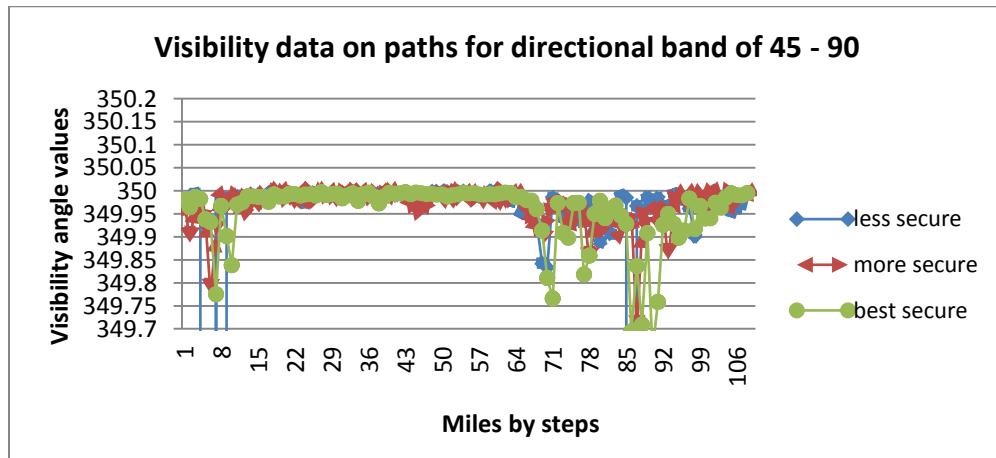


Figure 32 Visibility angle variations on three paths for directional band 45-90

(Figure 32) Visibility data for each path shows the independence of observation provided by the route to the agent calculated on directional band of 45 degree left – 90 degree right. We made a hypothesis earlier in our research that there should be a reason why would people like to travel from high elevation area. And we assumed that high visibility means high security. Such can be seen in above results.

Distance data 45-90:

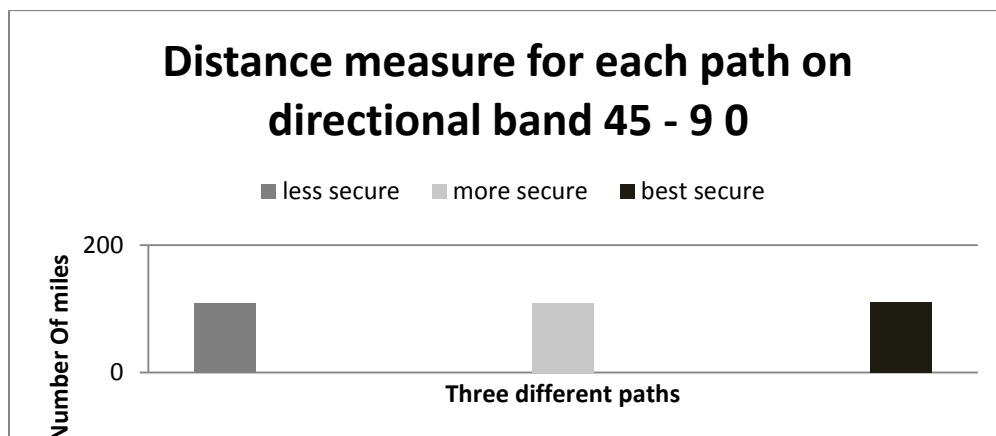


Figure 33 Distance calculation for three paths in directional band 45 -90

Results 0-90:

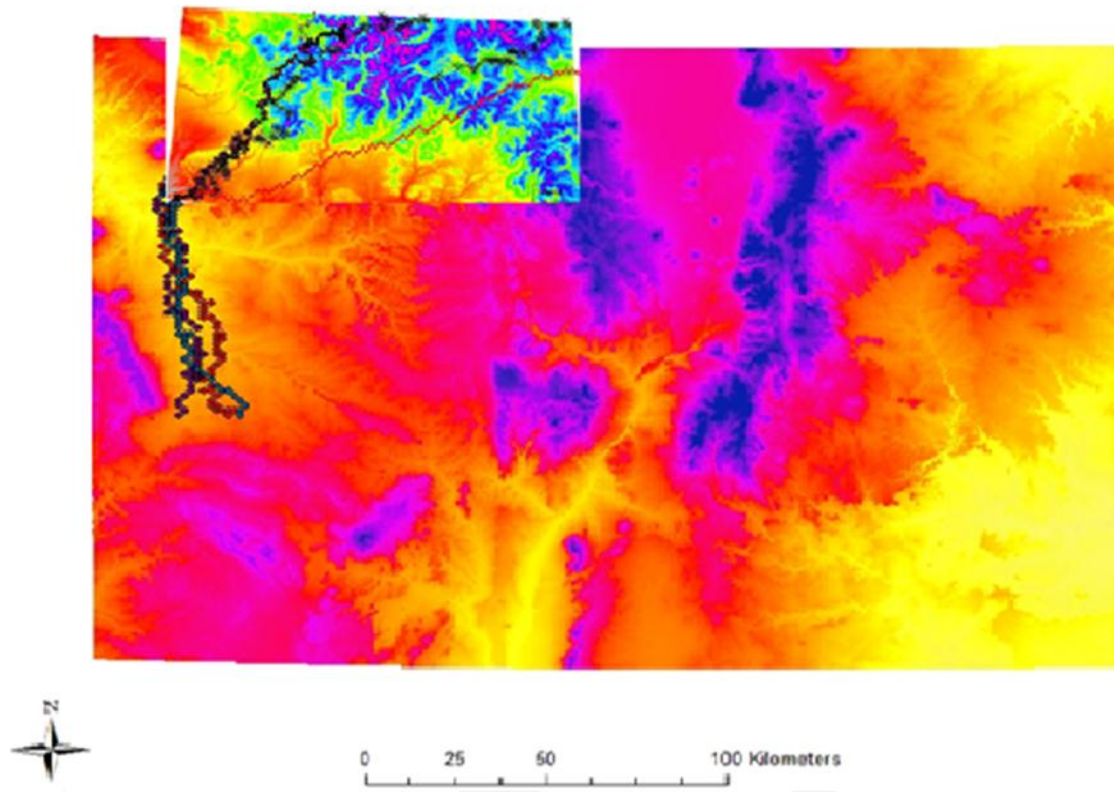


Figure 34 Three paths on direction band 00 - 90 over test region

Results Descriptions:

(Figure 34) These results represent three different paths according to level of security provided by the paths. The above graph shows results for directional band of 00 degree right to 90 degree left movement. In the charts below an analysis on the value of elevation, elevation difference, and visibility is presented. Most of the results show that a path with best security travels through high elevation region and provide maximum visibility angle, but could be lengthy in distance.

Result 0-90:

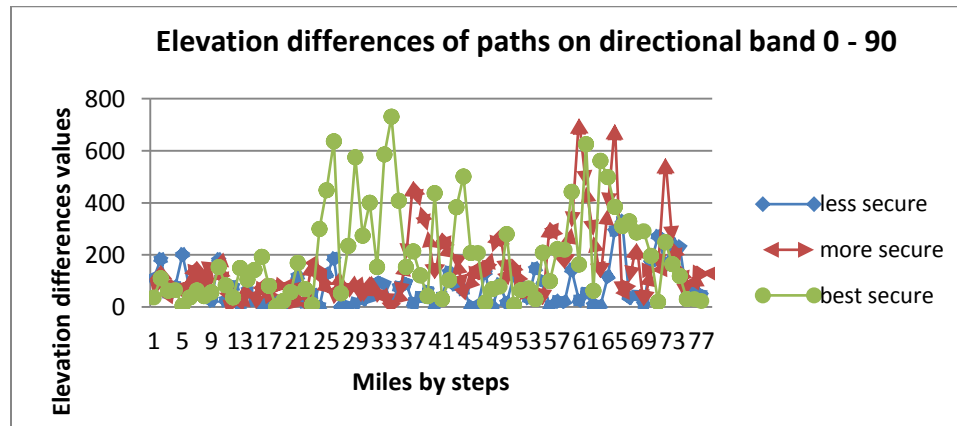


Figure 35 Elevation differences results for three paths on direction band 0 – 90

(Figure 35) Among the paths plotted on the graph above the green one is the one which goes through the high region, where the other two red and blue goes through lesser elevation area. In the results (figure 36) below we can see these paths thus follow the elevation area respectively from less to best with increasing elevation. Both figure 35 and figure 36 are calculated by assigning the agent directional band of 0 degree right to 90 degree left.

Elevation 0-90:

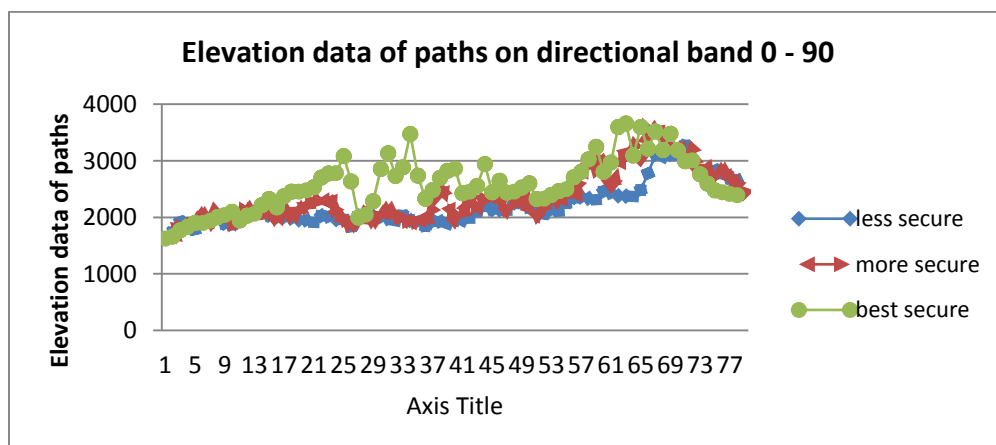


Figure 36 Elevation results for three paths on direction band 0 – 90

Visibility 0- 90:

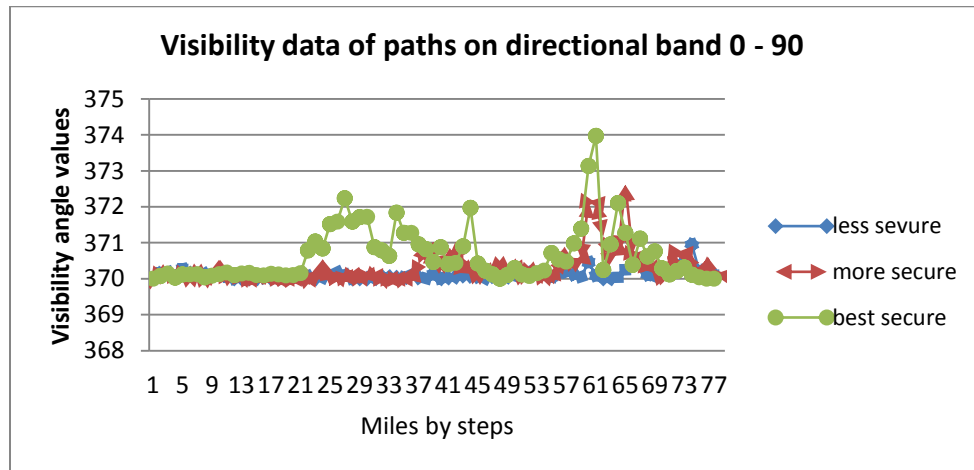


Figure 37 Visibility variations on three paths for directional band 0-90

(Figure 37) Visibility data for each path shows the independence of observation provided by the route to the agent calculated on directional band of 0 degree left - 90 degree right. We made a hypothesis earlier in our research that there should be a reason why would people like to travel from high elevation area. And we assumed that high visibility means high security. Such can be seen in above results.

Distance 0-90:

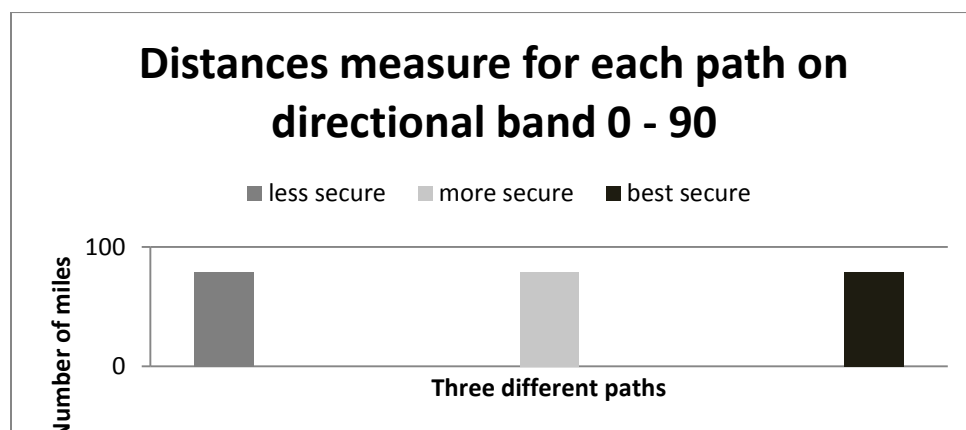


Figure 38 Distance calculation for three paths in directional band 0 -90

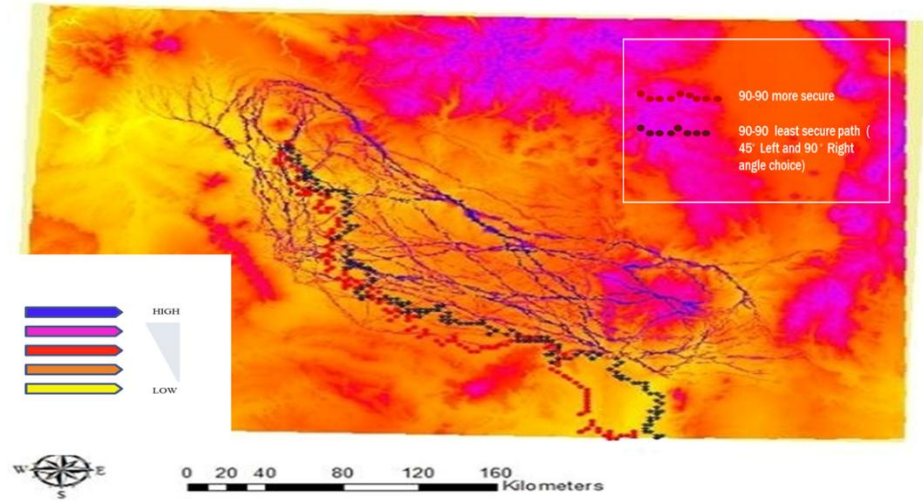


Figure 39 Paths calculated on direction band 90 - 90 over test region and upper region

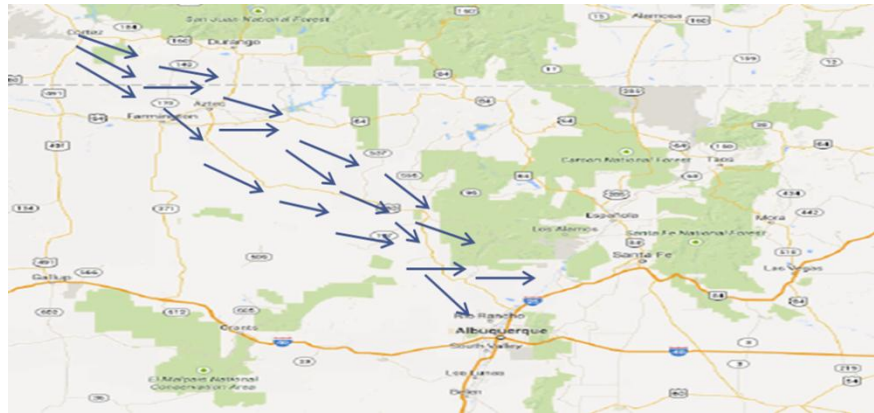


Figure 40 Paths plotted on earth maps (Google Maps, 2012)

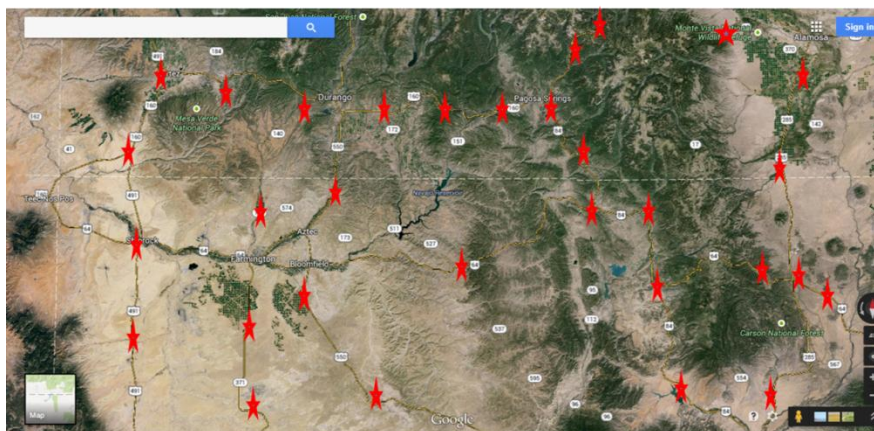


Figure 41 US development roads plotted on earth maps (Google Maps, 2012)

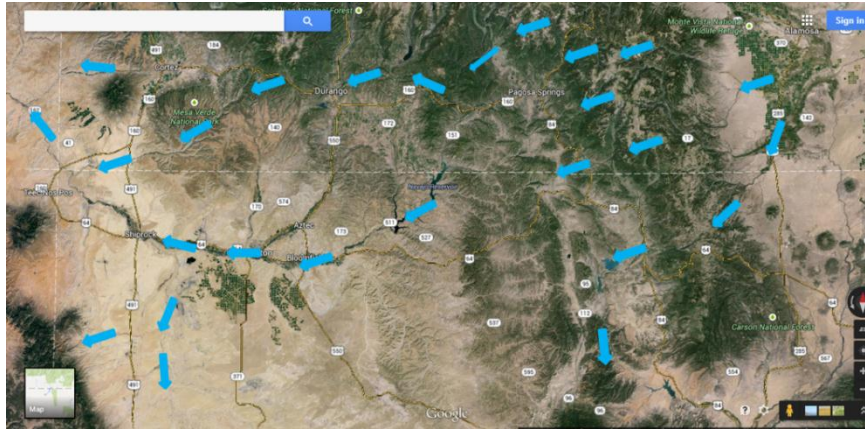


Figure 42 River routes plotted on earth maps (Google Maps. 2012)

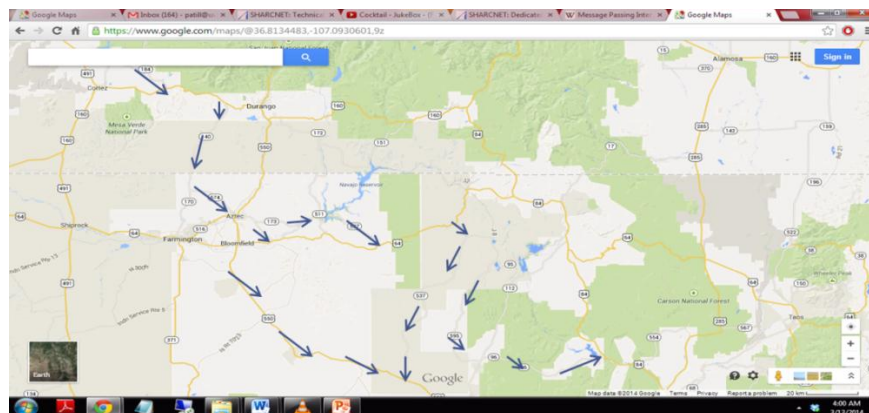


Figure 43 Minor road development sites on earth maps (Google Maps. 2012)

Results Description:

Results from figure 41 contain some of our plotted results on the area using GIS software. These results are presented in order to catch similarities between some major and minor road development sites of U S authorities in that region (refer to figure40 – figure43). We also present similarities with the migration patterns depicted by archaeologists from Crow Canyon Research Center.

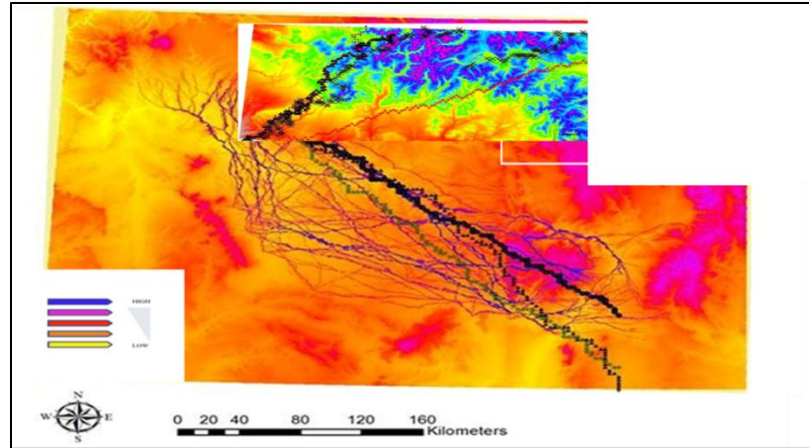


Figure 44 Paths calculated on direction band 45 - 45 over test region and upper region

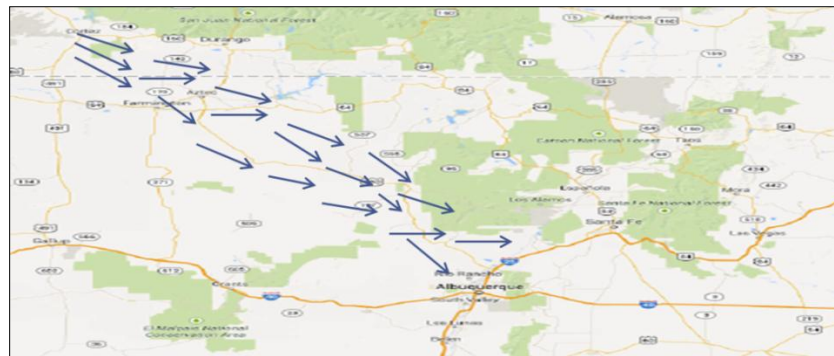


Figure 45 Paths plotted on earth maps (Google Maps, 2012)

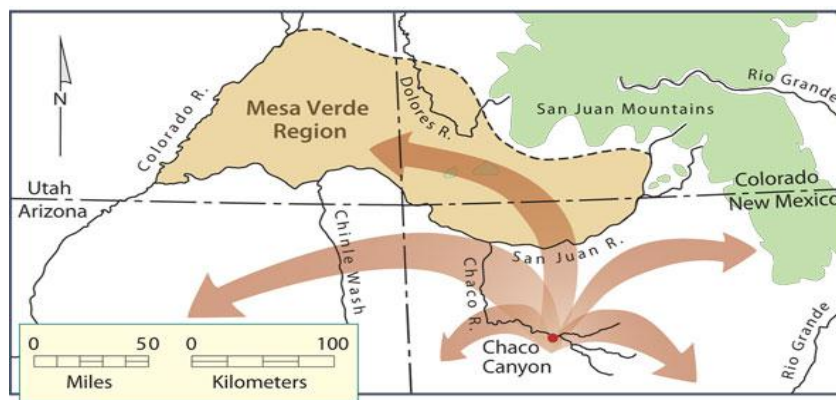


Figure 46 Archaeological maps [New Mexico region only], (Crow Canyon Archaeology Center, 2011)

Figure 44 presents results plotted using calculations done using the proposed approach on the test area. Figure 45 presents the same routes on US map. Figure 46 presents the

archaeological sites that present evidence of migration from Chaco Canyon area to other areas.

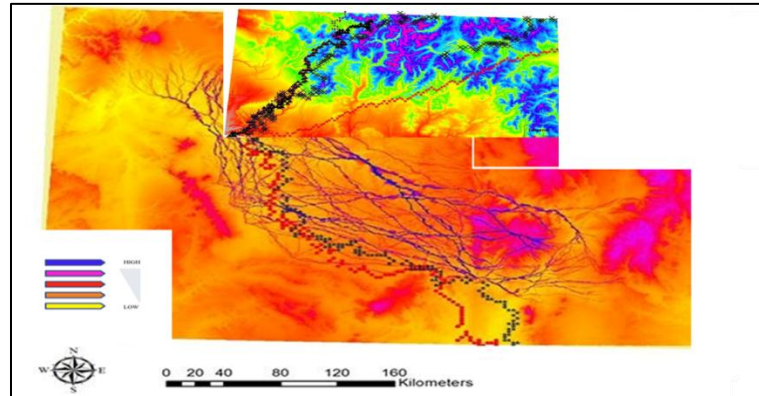


Figure 47 Paths calculated on direction band 90 - 90 over test region and upper region

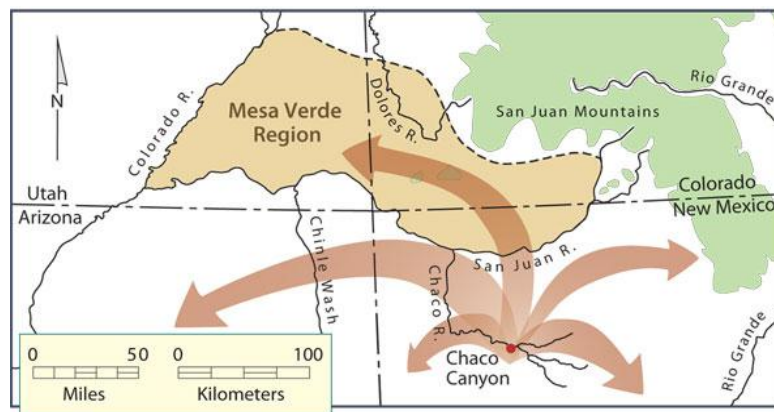


Figure 48 Archaeological maps [New Mexico region only], (Crow Canyon Archaeology Center, 2011)

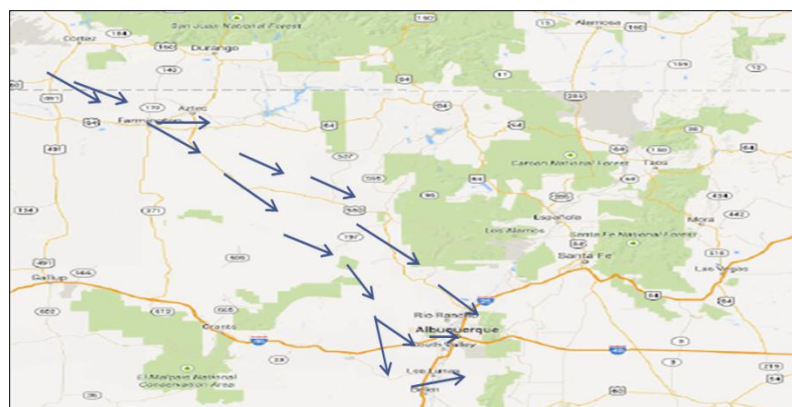


Figure 49 Paths plotted on earth map (Google Maps, 2012)

Figure 47 presents results plotted using calculations done using the proposed approach on the test area. Figure 48 presents the same routes on US map. Figure 49 presents the archaeological sites that presents evidence of migration from chaco canyon area to other areas.

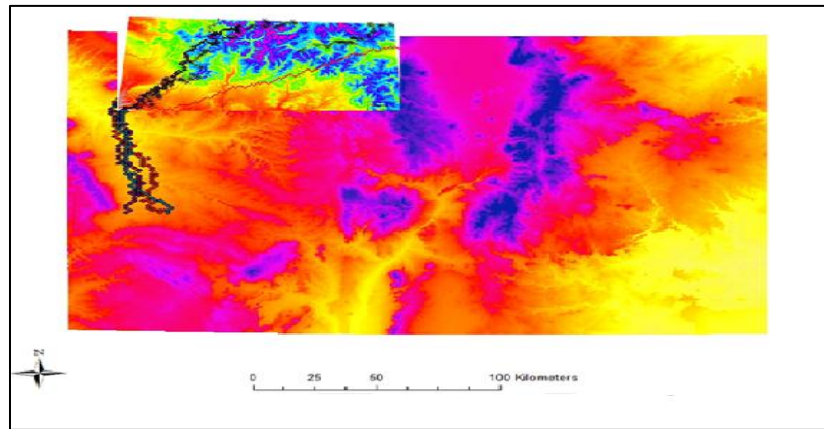


Figure 50 Paths calculated on direction band 90- 0 over test region and upper region

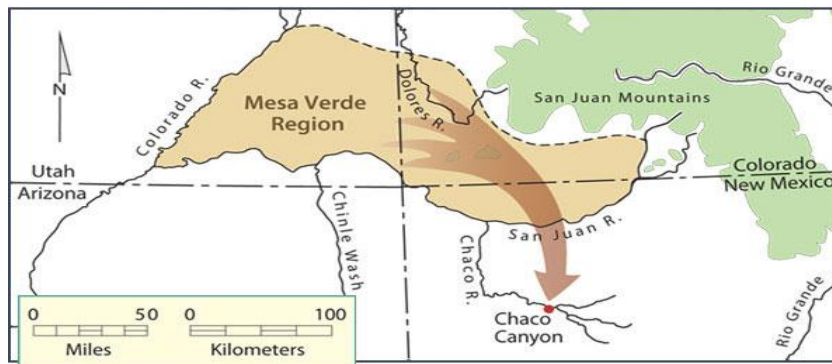


Figure 51 Archaeological maps [New Mexico region only], (Crow Canyon Archaeology Center, 2011)



Figure 52 Paths plotted on earth maps (Google Maps. 2012)

Figure 50 presents results plotted using calculations done using the proposed approach on the test area. Figure 51 presents the same routes on US map. Figure 52 presents the archaeological sites that presents evidence of migration from chaco canyon area to other areas.

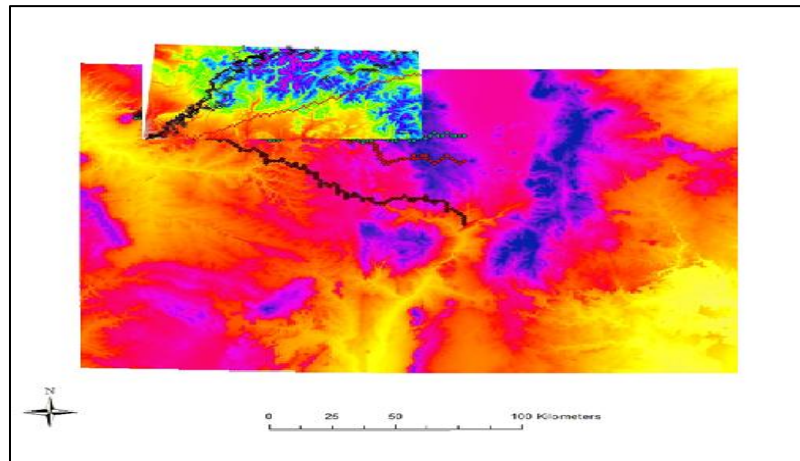


Figure 53 Paths calculated on direction band 0-90 over test region and upper region

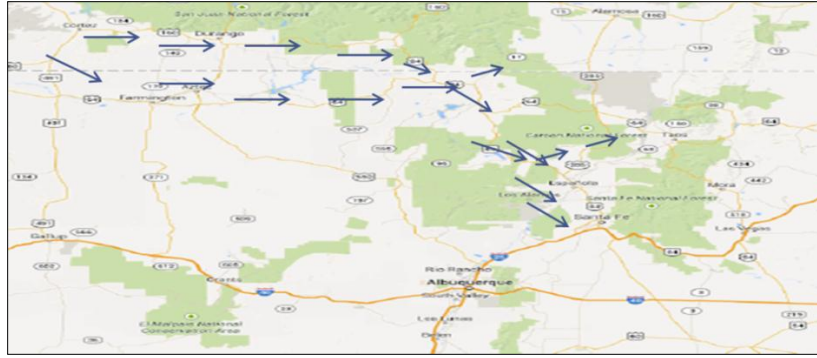


Figure 54 Paths plotted on earth maps (Google Maps. 2012)

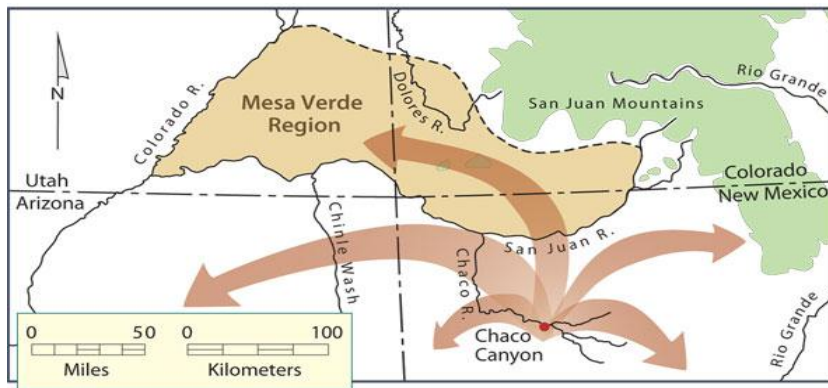


Figure 55 Archaeological maps [New Mexico region only], (Crow Canyon Archaeology Center, 2011)

Figure 53 presents results plotted using calculations done using the proposed approach on the test area. Figure 54 presents the same routes on US map. Figure 55 presents the archaeological sites that presents evidence of migration from chaco canyon area to other areas.

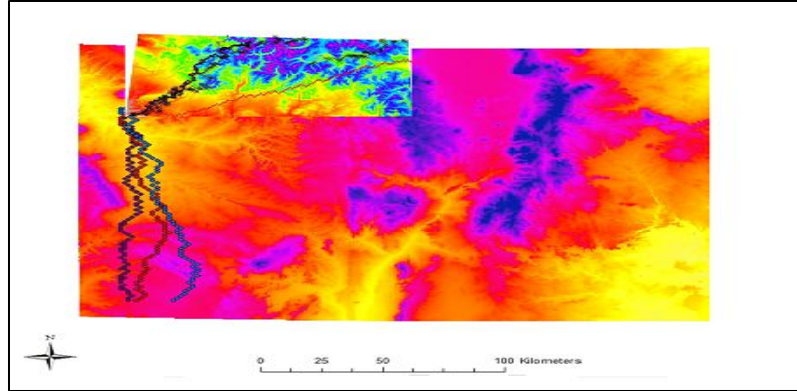


Figure 56 Paths calculated on direction band 90-45 over test region and upper region

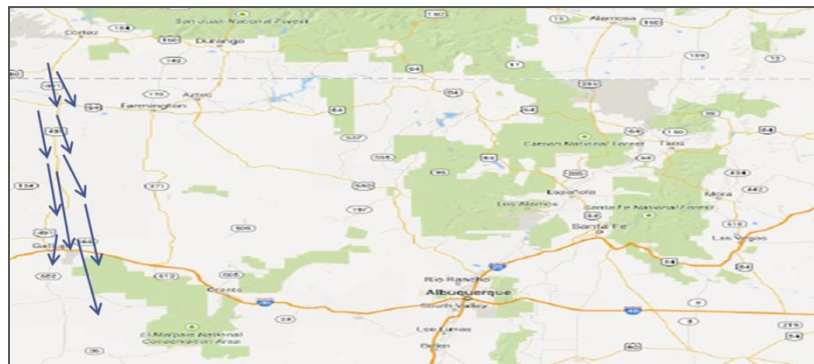


Figure 57 Paths plotted on earth maps (Google Maps, 2012)

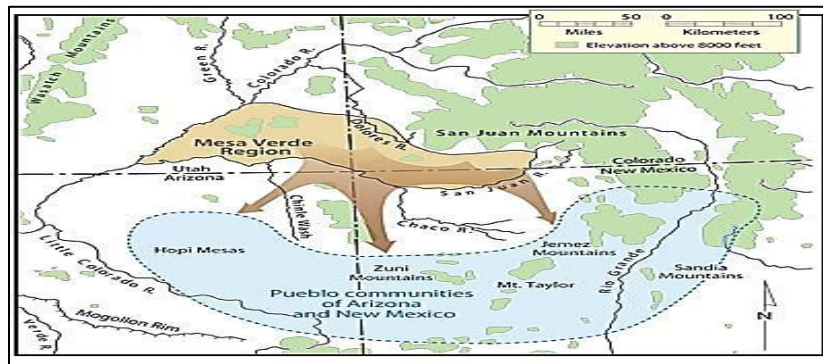


Figure 58 Archaeological maps [New Mexico region only], (Crow Canyon Archaeology Center, 2011)

Figure 56 presents results plotted using calculations done using the proposed approach on the test area. Figure 57 presents the same routes on US map. Figure 58 presents the archaeological sites that presents evidence of migration from chaco canyon area to other areas.

CHAPTER 8. CONCLUSION

In the beginning of this research a hypothesis is presented on the role of human behaviour in path prediction. In order to prove the hypothesis an approach is developed. This approach includes development of a sophisticated computational model to describe some important phases of human behaviour. The approach investigates the very fundamental reasons on how human acts in any situation and to prove that his actions are mere reflection of various aspects of his behaviour. With the test area and results, this study concludes that this hypothesis is right to some extent despite all assumptions. In a philosophical way, it is said that *“It is not human who makes a mistake in choices all the time, sometimes the situations (social and environmental conditions as for this research) are the one responsible.”*

In the thesis, various numerical calculations are performed to ensure the religious working of one model. In this research most of the attention is focused on analyzing human behaviour in solving path prediction problem. With the study it is shown that human decisions are actually based on their observations also the different aspects explained in the research of their behaviour affects his utilization of those observations.

Therefore, with the above obtained results from the proposed approach, this study would like to draw everyone’s attention towards the conclusion that if we have to create agents with human intelligence then we need to investigate a human’s way of interacting with his social environment.

Although, the proposed model is not sufficient and does not consider all aspects of human behaviour, we believe that with some improvements this approach can be utilized in some manner and in many areas. For improvements, this research requires focus on some of the limitations in the model such as, this model doesn't consider emotions.

All the components are assumed to be present in very restricted limit. This study considered influence as singular entity representing all classes of influences altogether and same is considered for motivation and expectation, whereas the research done in all this individual fields suggest various classifications for all the above aspects. Hence at this elementary level the study includes test case specified participation of these aspects.

As explained in chapter 5, that migration is a continuous movement in which destination is defined during action. Such decisions are made under some influence. Primarily, this influence could be explained as the reasons behind leaving the other region or the act of leadership. This relation is hard to understand with the limited resources used in the above study. However, an attempt is made to explain this dynamics using leadership example but the research lack in providing sufficient information to integrate the leader-follower relation in migration study. This leaves the study with a reason and a direction for future advances in this approach.

This study surveyed many behavioural models and included most of the elements of these models into one computational model from a perspective of a pedestrian. This research shows, a subjective integration of few behavioural models, that can be employed to solve a human behaviour related problems. The model we had provides a general guideline on integrating human behaviour with path prediction method. Till now,

researchers studied connections between them but this work provides an approach on computationally implementing it. We may conclude with this study that the model can support social hypothesis in many other mobility prediction problems.

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