Human Dynamic Behavior: Reconstruction Trajectories Using CDRs

Suhad Faisal Behadili\textsuperscript{1} and Israa Abdulqasim Mohammed Ali \textsuperscript{2}
\textsuperscript{1}University of Baghdad, College of Science, Computer Science Dep., Baghdad, Iraq.\textsuperscript{2}Middle Technical University, Institute of Technology-Baghdad, Iraq.

\textsuperscript{1}suhad.f@sc.uobaghdad.edu.iq

Abstract. Investigating the human mobility patterns is a highly interesting field in the 21st century, and it takes vast attention from multi-disciplinary scientists in physics, economic, social, computer, engineering...etc. depending on the concept that relates between human mobility patterns and their communications. Hence, the necessity for a rich repository of data has emerged. Therefore, the most powerful solution is the usage of GSM network data, which gives millions of Call Details Records gained from urban regions. However, the available data still have shortcomings, because it gives only the indication of spatio-temporal data at only the moment of mobile communication activities. In this chapter, Gama platform development environment of constructing spatially multi agent simulation is used for modeling and simulating the individual reconstructed trajectories. As a result, the individual trajectories revealed the human daily life patterns.

Keywords: Human trajectory, CDRs, modeling, radius of gyration, GIS

1. Introduction

In the last decades, analyzing social networks drew high attention, in view of studying and analyzing the life patterns of human mobility. In addition, travel surveys gather long-term data on mobility. This may be done through an efficient automated dataset method such as the Global System of Positioning (GPS) technology for gathering spatial data in accurate time, speed, and direction. In addition to the vast records, which concern any mobile item (human/ car); the GPS technologies can verify the transportation modes, even if they have the same speed. Then, Automated smart card fare collection systems (RFID). These systems generate vast records of public transportation data concerning the cities, which were established in it \cite{16, 17, 18, 21}. These data in real-time mode, and they are time-referenced or space-referenced. They are commonly used to analyze the ridership that are benefitted from the public transportation network in the considered city. Moreover, the cellular networks (mobile networks) generates the most suitable data that are the Call Detailed Records (CDRs), hence their efficiency is approved in the urban planning/management, social studies, transportation analysis, geography, and communication studies, etc. therefore the mobile networks data are considered as an integral source of data for studying human mobility \cite{16, 17, 21}. Actually, the mobile data have unique characteristics, since they may represent human mobility in real-time (instantly), and at the same time offer spatial and time indications (spatio-temporal data) concurrently. Thus, CDRs have an extremely rich environment.
with complex nature that provide multi-perspective processes for human life [21]. The displacement (mobility) from a tower coverage to another, it’s a key point of transition from one position to the next, this can be considered for each consecutive activity between the two towers [18]. The capacity to identify and classify patterns of mobility through utilization of CDRs offers extensive information about spatio-temporal data that can be interpreted by aggregate city mobility patterns [12, 13, 14], and this opens the way to a wide variety of apps for crime or virus dissemination from urban infrastructure. However, as architecture requirements, the proposed spatio-temporal query schemes cannot convey adaptability to date. The processing of data, however, is computer-cost, and no temporal dimensional data, for example, between 2 days or between 2 hours or any spatial characteristics, for example in a certain neighborhood, near a certain location or an area intersection, are known to be processed [16, 17, 18]. Despite CDRs being well-known in the research community, they still have two limitations. First, while there are no contact activities (mobile phone idle), no details are available. Secondly, aggregated spatial data from each tower area, so as spatial data do not have an accurate mobile position for active mobile (coarse spatial granularity), but specify the estimated location within the area covered by this tower [21]. Furthermore, CDRs possess a privacy issue as mobile network subscribers’ information is vulnerable to be released for unlawful parties. Accordingly, to preserve the anonymity of the subscriber, it is hidden (anonymized). There are also other issues, including the mass size of data files (CDRs). Therefore, samples and correct manipulations are necessary in order to protect their integrity and to prevent misused or misunderstood. On the other hand, it is difficult to represent such data sets graphically or geographically, even because of the hardware/software constraints which may be encountered during processing. [16, 17, 18, 21]. About the fact that CDRs fix problems of acquisition financial or temporary, although have their projection/pathways that consume time, the investigators are trying by means of certain activities such as randomly selecting samples from CDRs to resolve this constraint. As well as, get the records of high frequency [20]. Indeed, CDRs submit several attributes such as the mobile network events that give the cell location spatially (In/Out calls, In/Out sms). And, the mobility events (Handover HO, LAU Location Area Update). Whereas, the HO is the generated records during the mobile changes its location (move from tower region to another). In other hands, the LAU is the generated records during the mobile changes the location area, where the location area is a group of cells for instance 150 cells, this type of data are very useful, because they are generated even if there are no communication events, hence they are more powerful to analyze the individual behavior. In general, there are two kinds of data, communication data and itinerancy (independent communication) data. Mobile phone data sets are therefore most potent media for individually or for rallies analyzing and discovering human mobility, because mobile phones are nowadays close to nearly everyone. As a result, the CDRs of phone data are the tremendously chosen tools for uncovering and understanding patterns of human life and the abnormal (anomalous) events over the whole examined data. Thus, many researches contributed through this type of activities, and some theories are used to help in this field like a percolation theory [20, 22, 23]. Finally, the next sections will present in the first section the individuals mobility modeling. The second section elaborates the individuals mobility modeling. The third section explains Gama agent-based modeling platform. Thereafter, the fourth section talks about trajectory reconstruction. Then, the fifth section represents the trajectories characteristics. As well as, the sixth section explores the trajectories in microscopic perspective. Moreover, the seventh section explores the simulation approach and the used algorithm. Finally, the conclusions of results are described.

2. Individuals’ mobility modeling

It has been inferred from system theory that any system (physical, ecological, social, and informational) has a number of agents (cities, people, etc.), which interacts, influences each other and impacts the entire system. Consequently, it involves the system environment, so it would have an influence on the external environment or not, though the external world is definitely affecting the internal processes and interactions within the system (feedback). These factors therefore motivate the system evolution along
with the determined spatial in the world during its lifetime. The models, however, vary in their complexity, which is caused by their interactive processes (inside/outside) the system world. This ranging begins simply as aggregated and evolved until disaggregated level in more powerful description of the spatio-temporal properties [28]. The researchers define the agent in multi abstractions depend on the multi aspects that holding in its nature, so there are several features that could be characterized the agent in any system and environment [28]:

1. Autonomy: Agents are autonomous, independent units that perform their operations with all needed interactions with other agents, then making their decisions without any central control.
2. Heterogeneity: Agents have the ability to deal with several different agents of several different attributes, and then the result is a cooperated heterogeneous agent during the system evolution.
3. Active: Agents are affecting the system simulation. There are many properties to the term "active", which could be named in the following:
   3.1. Pro-active/ goal-directed: Agents have behaviors that guide them to their predetermined goals.
   3.2. Reactive/Perceptive: Agents are constructed with respect to their environment and its entities, obstacles, destinations.
   3.3. Bounded Rationality: This feature refers to the Rational Choice models, which in fact represent the agents bounded relations, they have heterogeneity properties with their ability to make inductive, discrete, and adaptive choices. In order to obtain the goal(s) using free information access, foresight, and infinite analytical ability.
   3.4. Interactive/Communicative: Agents interacted with each other, their adjacent environments.
   3.5. Mobility: Agents have the intelligent mobile ability inside their models.
   3.6. Adaptation/Learning: agents can mobile in their models interactively and intelligently according to predetermined structured rules, and then would have dynamical states, so it could be adaptive and configure the Complex Adaptive Systems during their life evolution.

Based on preset model rules which are made to mimic a particular system [28], the agents could be dynamic, static, or alternating among the two states. In addition to the probabilities of interacting with the external system world and the space that preserves the agents called "environment," Such interactions amongst agents will produce various either new states or new subsystems within the involved system. The environment in which the agents operate will, in a basic way, be a space containing the system agents. This space could be a connected social network, grid cells (discreet), or spatial space (continuous). As a consequence, since the environment has a spatial nature, the agents must coordinate with it. Therefore, these agents are either dynamic or static. Therefore, in this type of model simulation, the compatibility between GIS and agency-based models is of key importance, in spite of the environment being just a limited geometric space [28]. So, due to the geometrical metrics significance, then GIS is a major highpoint in many of these simulation models [28].

3. Gama agent-based modeling platform

The Generic Agent-based Modeling Architecture (GAMA) is an agent-based modeling platform, developed by the MSI research team (part of UMI 209 UMMISCO research unit) since 2007. GAMA provides the expert, modeler and computer scientists with an efficient modeling and simulation development environment for constructing spatially multi agent simulation (integrates GIS). It is a modeling language based on GAML, XML [26, 33]. GAMA emerged empowered to build complex models integrated with GIS data, without additional library extensions or excessive programming efforts. The programming language that builds GAMA is the modeling language GAML, it is dedicated to agent-based modeling, it obtained its capabilities from managing environment data by localizing agents in a related continuous environment. It has the ability of linking between GAML and Java.
Consequently, it helps to develop hybrid models, which is achieved by using Java meta-information (annotations), and dedicated parsers and compilers [28]. The agent-based simulation platforms generally tend to integrate GIS (Graphic Information System) data with their capabilities of simulating any real model in order to represent the geographic environment. In spite of complexity degree, which characterizes them to be used and understood by the modelers. Meanwhile, the other models used to deal with a grid as models environments. The other representation was less precisely to give real models perception. For this reason, the emergence of this platform makes a difference in multi aspects like the simplification of usability, and the notion of agentification, integrating GIS data vector, data mining, and manipulating them as agents like any other object in the model. All the gained skills are easing the modeling and analysis efforts [32]. The objects in any model have properties, scales, dynamic events, & etc. Furthermore, GAMA makes the GIS data vector similar to these objects in their properties, as example the road in the model could be broken or shifted cause an earthquake. Ultimately, this platform gives GIS data a high flexibility in manipulation as other model objects [26]. There are several simulation systems focused on agents, but almost all of them cannot manage complex GIS data environments, such as Netlogo: The environment consists of a "patches" map, although the agents are described in continuous space with their coordinates. Then the GIS extension is applied, but a lot of sophisticated spatial processing is not available. Moreover, high programming capabilities are essential. CORMAS: The modeling of ecology and in particular the control of natural resources is mostly devoted to space representation and interaction, and high programming capabilities are essential. Furthermore, Repast J: the GIS merged with the library of OpenMap. It includes a few of GIS primitives, such as import/export shapefiles and raster files, data attributes access some geometric operations etc. In addition, programming skills of a high level are needed. CORM GIS: The integration of GIS by means of ArcGIS data connection. No primitive GIS exists such as union, intersection, etc. The updated version of the Repast Symphony (Repast S) toolkit is available. It uses geo-tools and has more primitive GIS. It helps to explicitly model a line network as a graph to determine the shortest routes. In addition, 3D data are viewed and managed. However, there are small numbers of GIS activities, and High programming skills are also required. Swarm: The initial implementation of the Swarm still does not allow GIS data to be integrated. This can be done, however, with the addition of a library known as Kenge that enables GIS data loading layers. There are neither spatial primitives nor saving the environment resulting from them, also its programming needs to be at a high quality [31, 32]. The simulation process means representing the reference system, which is a part of any real system by constructing a model (static/dynamic), then describing the whole system behaviors, parameters, events, activities, evolution, etc. The modeling needs to determine the language (concepts, syntax, and entities) to model a system, then to make a test (experiments) to this model for checking its imitating to the reference system as in real world, all this is done according to predetermined goals and concepts [29], as shown in figure 1.

**Figure 1. Summary of Simulation** [29]
1. **GAMAVI** This simulator is built in North Vietnam to help epidemiologists in studying the spread (daily behavior/depletion) of H5N1 virus. Its continuity in the semi-industrial and conventional sectors of poultry. So, the GAMA VI model used to study the relations between the virus and their environments like farms; poultry flocks, buildings, inner town ground; route, and flooded/dry of rice fields and ponds. All the environment items are agents and have their properties that give it the precise simulation to the real one [31].

2. **AROUND (Autonomous Robots for Observation of Urban Network after Disasters) /ISSUE**

   The ISSUE model deals with disasters scenarios by simulating the relief effort, that’s for learning human strategies. All the disaster items like devastated infrastructures, human casualties, and rescue teams, like ambulances, firemen or police officers, highways and houses, are modeled as agents, then input GIS data for the simulation of rescues. The agents move inside the disaster zone via the road network and communicate with each other. This agentification provides the buildings and roads with a dynamic behavior in the simulation process, for example an earthquake building will collapse and block a highway [33].

3. **Decision making and emergency communication system in rescue simulation for disabilities individuals.** In this model GAMA used to test the rescue simulation model. It is built for having a successful decision-making method to cross an emergency communication system. It is constructed to save individuals with disabilities in emergency conditions. This model focuses on the optimal way to choose which volunteer to help which handicapped person using the auction mechanism for decision making. This model uses GIS data, which represents a wide range disaster area including (buildings, roads, and individuals (handicapped/volunteer)) all of them as agents. This model represents the human behavior [27].

4. **Trajectories reconstruction**

   This research observed 615,712 customers over 12 days, the study data were based on a database of 51,958,652 entry records (CDRs). It includes individuals who appear irrelevant (discreetly). This implies all mobile activities are registered from start-to-end time, but there is a loss of information because there is no indication of individuals’ occurrence when mobile through inactive cases [14] [12]. [13]. There is no information when the phone is idle, i.e. disconnected or has neither telephone calls nor text messages. Moreover, only towers (X, Y) coordinates have available spatial data, and therefore an assessment of individual transitions from position to other (tower to other) is considered. To approximate it, it is assumed that the locations on the basis of the tower coverage, and the signal intensity. So, the principal problem used to calculate the individual speed would also not be precise, but would be approximated, because the distance between the two consecutive transition points registered in CDRs is used. Once it’s known how far the transition can take us, it must be figured out how long each should take by time. With respect to the discreet and non-deterministic nature of these data. The efficient approach to analysis and simulation will therefore constitute the collective behavior. Since each individual could vanish for a while, making an individual working without a suitable standard of success on the behavior of individuals in the observed area. Generally, the date format of Armada DB is (D/M/Y: H/Min/Sec), this format needs to be extracted as follows:

   1. The data of each day activities would be derived into a separate table.
   2. Extract time format into hours and minutes, ignoring the seconds part, due to their slightly effects as speed indications for individuals mobility.
   3. Convert the time format into another form to acquire time series as in equation (1):
Timing (in minutes) = hours * 60 + minute  \hspace{1cm} (I)

The extracted 12 tables each for a specified day in the registered period (4-15) July 2008. The acquired tables of day activities processed in ArcMap 10.2.2 to obtain the transformed spatial data via NTF Lambert II, and to transform the entire file into shape file format. Hence, it would be suitable to get processing in Gama-Platform.

5. Trajectories characteristics

The considerable relevance of uncovering human trajectories that imposes the tendency to construct statistical models. Indeed, human trajectories possess random statistical patterns; the most difficult problem therefore is to trace human day-to-day activities is a challenging topic [2, 17]. However, mobile data with a focus on the areas with the largest mobile telephone network penetration is being used to support mobility studies. Those areas are distinguished by their maturity, stability and growth. Their models thus investigate the mobility of humans and social relationships in the rich, industrialized and well-developed areas. Therefore, they see the two thirds of people living without good conditions as examples for just one-third of the world population and ignore the other two-thirds. The telecom operator provides a large number of CDRs containing highly useful spatio-temporal data at various granularities as citywide, statewide, or nationwide. These data are not only applicable to the telecommunications provider, but could form the basis for a wider range of socially connoted applications, such as commute patterns, travel routes, individuals concentrations, etc. The main problems in the creation of intelligent cities are the powerful quest for spatio-temporal patterns of the CDR databases, and the use of computational techniques. However, the telecommunications operators available commercial networks cannot currently deal with these types of spatio-temporal computations. One approach for examining such patterns is to scan the entire database sequentially, or to call records and check them using a subsequence matching algorithm[15]. The individual trajectory of the mobility is regarded as the microscopic degree of complexity (mobility abstraction level) consisting of sequenced coordinates positions along the time, which is seen in figure 2 [5, 6, 7] at the period that the separate agent displacement is shown. While data sources vary, such as billing systems, GPS, or GSM, the aggregated jump size $\Delta r$ and wait time $t$ distributions are common [3]. Whereas $r$ indicates the distance traveled by an individual during time between two consecutive activities, $t$ denotes the amount of time a person spends between two consecutive activities. [3]. The parameters will show the pattern of life patterns for the formed dynamic population. This will nearly reflect dynamic perspectives of the population. Furthermore, the activities distributions are uncovered the frequent patterns and behaviors similarities throughout evolution of $r_g$ in time.

![Figure 2. Agent displacement in spatio-temporal](image)
6. Trajectories in microscopic perspective

Indeed, cell phone data is too heterogeneous, as mobile users can be extremely active with a high volume of calls/SMSs or extremely inactive with a low volume of calls/SMSs. Thus, the sample may be based on their number of behaviors [9, 12]. Thus, dynamic individuals possess general physical properties that can be used to compensate for the absence of data in the absence of reported mobile activity [8, 13]. Whereas, the sparsity of human activities causing insufficient spatial details. These characteristics can be used to create a statistical model of mobility patterns with the use of the most common mobility characteristics to verify the life patterns and dynamic behavior [8]. The common physical characteristics could be formed as follows [2, 6]:

1. Center of mass $cm$: Most visited locations by individual, as in equations (2) and (3).

$$x_{cm} = x_{cm} = \sum_{i=1}^{n} x_i / n$$  \hfill (2)

$$y_{cm} = \sum_{i=1}^{n} y_i / n$$  \hfill (3)

Where $x_i$ and $y_i$ are the coordinates of spatial positions, $n$ is the number of spatial positions, which are registered in CDRs.

2. Radius of gyration $r_g$: Using the average of all individual locations, it calculates the area visited by an individual, which is the distance traveled over a period of time. The distribution of $r_g$ demonstrates population heterogeneity, with individuals traveling regularly in $P(r_g)$ either long or short distances within $r_g(t)$ as defined in equation (4) [13].

$$r_g^a = \sqrt{\frac{1}{n_c^a(t)} \sum_{i=1}^{n_c^a(t)} (r_i^a - \overrightarrow{r_{cm}^a})^2}$$  \hfill (4)

Where $r_i^a \rightarrow$ indicates the $i = 1 ... n_c^a(t)$ positions recorded for individual $a$, and $\overrightarrow{r_{cm}^a} = \frac{1}{n_c^a(t)} \sum_{i=1}^{n_c^a(t)} r_i^a$, indicate the individual trajectory’s center of mass [10, 11].

3. The most frequently visited positions show an individual’s preference for visited positions.

4. Principal axes $\theta$ is the moment of inertia: Is a technique that enables the analysis of individual trajectories within a standard reference frame by diagonalizing and comparing each trajectory inertia tensor. The moment of inertia of any object is determined by the average distance between the object mass and a given axis. This could be expressed through a 2D matrix named tensor of inertia. Thereafter, utilizing standard physical formula for obtaining the inertia tensor of individual trajectories, as in equations (5 - 8) respectively:

$$I = (I_{xx} \ I_{xy} \ I_{yx} \ I_{yy})$$  \hfill (5)

$$I_{xx} = \sum_{i=1}^{n} \overline{y_i}^2$$  \hfill (6)
\[ I_{yy} = \sum_{i=1}^{n} x_i^2 \]  
\[ I_{yx} = -\sum_{i=1}^{n} x_i y_i \]  

(7)  
(8)

Where, tensor \( I \) is symmetric, it provides a collection of coordinates that transforms \( I \) into a diagonal object. These coordinates, known as the tensor theory axes (\( \hat{e}_1, \hat{e}_2 \)), form \( I \) as in equation (13):

\[ I_D = (I_1 \ 0 \ 0 \ I_2) \]  

(9)

Where, \( I_1 \) and \( I_2 \) are the fundamental moments of inertia, and also correspond to the eigenvalues of \( I \). They can, however, be determined from the initial points using the equations below (10-12):

\[ I_1 = \frac{1}{2}(I_{xx} + I_{yy}) - \frac{1}{2}\mu \]  

(10)

\[ I_2 = \frac{1}{2}(I_{xx} + I_{yy}) - \frac{1}{2}\mu \]  

(11)

\[ \mu = \sqrt{4I_{xy}I_{yx} + I_{xx}^2 - 2I_{xx}I_{yy} + I_{yy}^2} \]  

(12)

Where, individual trajectory as \((x_1, y_1), (x_2, y_2), \ldots \ldots, (x_{nc}, y_{nc})\), where \( n_c \) denotes the individual's number of positions passed. The eigenvectors define the theory axes (\( \hat{e}_1, \hat{e}_2 \)). Individual trajectory rotation can be accomplished by converting the individual's theory axes (\( \hat{e}_1, \hat{e}_2 \)) to a standard intrinsic reference frame (\( \hat{e}_x, \hat{e}_y \)). Thus, estimating the angle between \( \hat{e}_x \) and \( \hat{e}_1 \) as follows:

\[ \cos(\theta) = \frac{\vec{v}_1 \cdot \hat{e}_x}{|\vec{v}_1|} \]  

(13)

Where, \( \vec{v}_1 \) represents the eigenvector associated with the eigenvalue \( I_1 \) as in the following equation (14):

\[ \vec{v}_1 = \left[ \frac{I_{xy}}{\frac{1}{2}I_{xx} - \frac{1}{2}I_{yy} + \frac{1}{2}\mu} \ I \right] \]  

(14)

Hence, obtaining the following equation (15):

\[ \cos \theta = -I_{xy} \left( \frac{I}{2I_{xx} - \frac{1}{2}I_{yy} + \frac{1}{2}\mu} \right)^{-l} \left( \frac{I}{\left(\frac{I_{xx} - \frac{1}{2}I_{yy} + \frac{1}{2}\mu}{I_{yy} + \frac{1}{2}\mu}\right)^2} \right) \]  

(15)

Rotation by \( \theta \) produced a 180° conditional rotation, as the most frequently occurring position in \( x>0 \).

5. Standard deviation, \( \sigma \) is used to determine whether they move horizontally and vertically. A however, trajectories are calculated on individuals's unique position, as in equation (16-17).
\[ \sigma_x^a = \sqrt{\frac{1}{n_c} \sum_{i=1}^{n_c} (x_i^a - x_{cm})^2} \]  
(16) 
\[ \sigma_y^a = \sqrt{\frac{1}{n_c} \sum_{i=1}^{n_c} (y_i^a - y_{cm})^2} \]  
(17)

Then, universal density using equation (18):

\[ \tilde{\Phi} = \left( \frac{x}{\sigma_x}, \frac{y}{\sigma_y} \right) \]  
(18)

Treating every person according to his/her position in the hierarchy according to the \( r_s \) spatial density function. Following this approach, groupings would be formed by setting radius of gyration variables to different values depending on mobility characteristics, so the individuals’ movement trajectories would be rescaled to their radius of gyration.

7. Simulation approach

All CDRs contain a large amount of lack of data: these CDRs have unique identifiers, rather than smooth records: since the recorded data are only concerned with events and are not constant, they are identified by distinct locations (just when makes mobile phone activity). Since this is the case, data is needed to compensate for the mobility time invariance, these trends cannot be utilized without first computing the same type of estimations mentioned earlier [12, 13]. Algorithm 1 calculates an individual O-complexity trajectory, which is carried out via Gama-Platform. Figures 1 and 2 can be used for 12 days to simulate one single trajectory. Therefore, individual dynamic actions may be explored separately from the variance of his or her daily trajectories; note that day 9 is missing data, so that its path was incomplete and very narrow. In contrast, his other days' trajectory pattern was roughly identical and limited to specific areas.

Moreover, because the distance between both successive transition locations is taken from CDRs, the fundamental problem which is used for calculating individual speed will not be precise, but is estimated. In order to obtain the speed of movement, as in the equation (19), this distance will then be divided by the time difference of each transition.

\[ \text{Estimated Speed} = \frac{\text{Traveled Distance}}{\text{Elapsed Time}} \]  
(19)

The Traveled Distance is the distance between two consecutive locations in the Elapsed Period, which is the amount of time required to travel between them. Non-deterministic and discrete data imply caution; since individuals can theoretically vanish for an extended period of time, no useful monitoring can be performed. As a result, the group is the only technique available for data analysis and simulation[1].

Appropriately, the modeling of individual trajectories in Gama-Platform emphasized on the provided spatial locations, each of them is the center of Voronoi polygon, whereas it is the basic division technique of total observed region. In addition, the accumulated locations are arranged according to their occurrence in the spatio-temporal unit (Timing, location \( (X, Y) \)). However, the mobility is estimated as traveled distance along aggregated locations. The anomalous events could be noted from unusual mobility behavior in comparison with usual recorded activities [18, 21].
Furthermore, each day will have Timing in Minutes is 24 hours \( \times 60 + \) minutes = 1440 Minutes, hence the individual could mobile across 190 towers coordinates, and so the resulted data would be 1440 \( \times 190 \) spatio-temporal units in minutes. Then, constructing the agent-based model to build the simulator using Armada DB files that covers the external environment as a background view, which is actually the shape file of the observed region polygons. Thereafter, representing the towers, and individuals on the region map, each item of them is manipulated as an agent (region map, towers, individual...etc.). Gama-Platform submits the agentification property to all model elements. In order to construct the model in several steps as follows:

1. Convert all related data files using ArcGIS utilities into the following formats:
   1.1. *.shp shape format, which is the feature geometry itself.
   1.2. *.shx shape index format as a positional index of feature geometry, allows seeking forwards and backwards quickly.
   1.3. *.dbf attribute format as columnar attributes for each shape, in dBase IV format.
   1.4. *.prj projection format, the coordinate system and projection information, a plain text file describing the projection using well-known text format.
2. Build each element as an independent species (region map, towers, and individual).
3. Give each species its own attributes (representation symbols and colors, dynamic or static features equations for the agent (individual)).
4. Calculate agent speed and directions.

The most powerful feature in Gama-Platform is the capability in coordinating all agents with full attributes either spatial, or temporal in a spatio-temporal integration. However, the simulator would activate its properties smoothly and integrally [18, 19].

**Figure 3.** Alias519 potential trajectory for period falls on Friday day 4 - Wednesday day 9 July 2008.

**Algorithm_1:** Estimation of Potential Individual Trajectories.

```plaintext
Data: Shape File of Individuals Sorted by Time
Result: Real and Estimated Individual Trajectory
ReadData ← Shapefile;
AgentAttrib ← (time, position (x, y), personID);
Create ← AgentSpecies (personID);
AgentAttrib ← Sort(AgentAttribTime);
While not eof (File) do
    PointsList ← position(x, y);
    TimeList ← time;
    For j=1 to eof (PointsList) do
        if PointsList(i + 1) ≠ PointsList(i) then
            Distance ← PointsList(i + 1)−PointsList(i);
            TimeDiff ← TimeList(i + 1)−TimeList(i);
        end
        Speed ← Distance/TimeDiff;
        Trajectory ← Trajectory + PointsList(i);
    end
    Draw (Trajectory);
End
```

10
8. Conclusions
The resulting trajectories as shown in the figures 3 and 4 are variants according to the daily life of the elected individual (Alias519). Where, the investigated data fall within Friday 4 - Mardi 15 of July 2008. The potential trajectories are classified, and elaborated into sub figures of figure 3 and 4 as (3.a, 3.d, 3.e, 3.f, 4.a, 4.b, 4.e, and 4.f), these days fall on workdays. Nevertheless, the sub figures (3.b, 3.c, 4.c, 4.d) fall on off days according to the France year calendar. These figures show the regular patterns for the individual during the investigated period. As well as, it is obvious that off days trajectories are almost identical. On the other hand, the workdays trajectories are almost identical too, but the workdays and
off days have different trajectories. It is concluded that the daily life pattern of this individual is varying according to the work rhythm. GAMA platform as a multi-agent simulation platform, integrates GIS data, benefits from OpenGL to simulate in 3D, so when working with GIS data, then, GAMA overcomes the difficulty of having high-level programming skills by allowing for the automated modeling of GIS data as agents, as well as optimized agents dynamic representation.

References

[1] V. Soto, V. Frias-Martinez, J. Virseda, E. Frias-Martinez. (July 2011). Prediction of Socioeconomic Levels using Cell Phone Records. In 19th International Conference, UMAP, Girona, Spain.
[2] Marta C. González, Cesar A. Hidalgo, Albert-Laszlo Barabasi. (2009). Understanding individual Human Mobility Patterns. Nature.
[3] Fosca Giannotti, Luca Pappalardo, Dino Pedreschi, & Dashun Wang. (2013) .Mobility Data Modeling, Management, and Understanding. Cambridge University Press.
[4] Chaoming Song, TalKoren, PuWang, Albert-László Barabási. (2010). Modeling the Scaling Properties of Human Mobility, Nature Physics volume 6, pages 818–823.
[5] Corina Iovan, Ana-Maria Olteanu-Raimond, Thomas Couronn, & Zbigniew Smedra. (2013). Geographic Information Science at the Heart of Europe, Part of the series Lecture Notes in Geoinformation and Cartography pp 247-265. Springer International Publishing Switzerland.
[6] Christian M. Schneider, Vitaly Belik, Thomas Couronnê, Zbigniew Smedra, & Marta C. González. (2013). Unravelling Daily Human Mobility Motifs. Journal of the Royal Society Interface.
[7] Xiao-Yong Yan, Xiao-Pu Han, Tao Zhou, Bing-Hong Wang. (2010). Exact Solution of Gyration Radius of Individual’s trajectory for a Simplified Human Mobility Model. Chinese Physical Society and IOP Publishing Ltd.
[8] Marta C. González, Cesar A. Hidalgo, Albert-Laszlo Barabasi. (2008). Understanding Individual Human Mobility Patterns Supplementary Material. Nature.
[9] Pu Wang, Marta C. González, Cesar A. Hidalgo, Albert-Laszlo Barabasi. (2009). Understanding the Spreading Patterns of Mobile Phone Viruses, Supporting on line Material. Science Express. http://mobilephenvirus.barabasilab.com/paper/som.pdf.
[10] Sahar Hoteit, Stefano Secci, Stanislav Sobolevsky, Carlo Ratti, Guy Pujolle. (2014). Estimating Human Trajectories and Hotspots through Mobile Phone Data. Computer Networks.
[11] Sahar Hoteit, Stefano Secci, Stanislav Sobolevsky, Guy Pujolle, Carlo Ratti. (2013). Estimating Real Human Trajectories through Mobile Phone Data. Mobile Data Management (MDM), IEEE 14th International Conference, Volume 2, Pages 148-153, IEEE.
[12] Suhad Faisal Behadili, Cyrille Bertelle, Loay E. George. (May 2018,). Modeling City Pulsation Via Mobile Data, Technologies and Management Research ijtemr, 5(4), 115-122. DOI: 10.5281/zenodo.1250532.
[13] Suhad Faisal Behadili, Cyrille Bertelle, Loay E. George. (January 2016). Modelling Dynamic Patterns using Mobile Data, Conference: Sixth International Conference on Computer Science, Engineering and Applications )CCSEA 2016) At :Dubai ,UAE, Volume: Computer Science & Information Technology (CS & IT), AIRCC Publishing Corporation, Vol 6, Number2 ,Pp .25-30 ,Doi :10.5121/Csit.2016.60203.
[14] Suhad Faisal Behadili, Cyrille Bertelle, & Loay E. George. (January 2016). Human Mobility Patterns Modelling using CDRs, International Journal of UbiComp (IJU), Vol. 7, No. 1.
[15] Suhad Faisal Behadili, Cyrille Bertelle, & Loay E. George. (Jan. 2-3 2016), Human Trajectories Characteristics, ISBN 978-93-84422-51-6, Proceedings of 2016, International Conference on Urban Planning, Transport and Construction Engineering (ICUPTCE’16), Pattaya, pp. 30-36.
[16] Suhad Faisal Behadili, Cyrille Bertelle, & Loay E. George. (June 2016). Adaptive Modeling Of Urban Dynamics During Ephemeral Event Via Mobile Phone Traces, Informatics Engineering, an International Journal (IEIJ), Vol.4, No.2, DOI : 10.5121/iej.2016.4204.

[17] Suhad Faisal Behadili, Cyrille Bertelle, & Loay E. George. (January 2017). Adaptive Modeling of Urban Dynamics During Armada Event Using CDRs, I.J. Information Technology and Computer Science, 2017, 1, 1-8 Published Online, In Mecs (Http://Www.Mecs-Presse.Org), Doi: 10.5815/ijitcs.2017.

[18] Suhad Faisal Behadili, Cyrille Bertelle, & Loay E. George. (Dec 2016). Adaptive Modeling of Urban Dynamics with Mobile Phone Database, Book, Publisher: ÉDITIONS UNIVERSITAIRES EUROPÉENNES est gestionnée par OmniScriptum Management GmbH Editor: aromanelli, ISBN: 978-3-639-54645-3, https://www.amazon.com/Adaptive-Modeling-Dynamics-Mobile-Database/dp/3639546458

[19] Suhad Faisal Behadili. (Nov. 2016). Adaptive Modeling of Urban Dynamics With Mobile Phone Database, PhD. thesis, France, Normandie University, Le Havre.

[20] Thomas Couronné, Zbigniew Smoreda, & Ana-Maria Olteanu. (Oct. 10-11, 2011). individual mobility and communication patterns, Analysis of Mobile Phone Datasets and Networks, in: NETMOB conference, MIT, Cambridge, MA.

[21] Zbigniew Smoreda, Ana-Maria Olteanu-Raimond, & Thomas Couronné. (2013). Spatiotemporal data from mobile phones for personal mobility assessment, Transport Survey Methods: Best Practice for Decision Making, Emerald, pp 745-767.

[22] Julit’an Candia, Marta C. González, PuWang, Timothy Schoenharl, Greg Madey, & Albert-Laszlo Barabasi. (21 May 2008). Uncovering individual and collective human dynamics from mobile phone records. Journal of Physics A: Mathematical and Theoretical, Vol. 41, No. 22., doi:10.1088/1751-8113/41/22/224015  Key: citeulike:10064440

[23] Patrick Taillandier, & Alexis Drogoul. (2010). From GIS Data to GIS Agents, Modeling with the GAMA simulation platform. Conference: TF-SIM.

[24] Patrick Taillandier, & Alexis Drogoul. (2010). From GIS Data to GIS Agents, Modeling with the GAMA simulation platform. Conference: TF-SIM.

[25] Kohei Arai , & Tran Xuan Sang. (2013). Decision Making and Emergency Communication System in Rescue Simulation for People with Disabilities, (IJARAI) International Journal of Advanced Research in Artificial Intelligence, Vol. 2, No.3.

[26] Alexis Drogoul. (2009). An Introduction to GAMA, IRD. UMI UMMISCO 209, Bondy, France.

[27] Alexis Drogoul. (2009). An introduction to Agent-Based Modeling, IRD. UMI UMMISCO 209, MSI Team, 26, 27 & 28 oct. 2009, Hanoi, Vietnam.

[28] Patrick Taillandier. Duc An Vo, Edouard Amouroux, & Alexis Drogoul. (2012). GAMA: A Simulation Platform That Integrates Geographical Information Data, Agent- Based Modeling and Multi-scale Control. International Conference on Principles and Practice of Multi-Agent Systems PRIMA 2010: Principles and Practice of Multi-Agent Systems pp 242-258.

[29] Patrick Taillandier. Vo Duc An, Edouard Amouroux, & Alexis Drogoul. (2010). GAMA: bringing GIS and multi-level capabilities to multi agent simulation. European Workshop on Multi-Agent Systems, 2010, Paris, France.

[30] Patrick Taillandier, & Alexis Drogoul. (2011). From Grid Environment to Geographic Vector Agents, Modeling with the GAMA simulation Platform. Conference of the International Cartographic Association, 2011, Paris, France.

[31] Edouard Amouroux, Chu Thanh-Quang, Alain Boucher, & Alexis Drogoul. (2007). GAMA: An environment for implementing and running spatially explicit multi-agent simulations. Pacific Rim International Conference on Multi-Agents PRIMA 2007: Agent Computing and Multi-Agent Systems pp 359-371.