Anticipating Systems in Demography

Petr Bulava
The University of Ostrava, Czech Republic
petr.bulava@osu.cz

Abstract
We will talk about models with an intelligent element inside. The intelligent element makes some predictions using the future stage of model which it is a part. The first model contains a process of driver or passenger decision making. Such process is not anticipatory necessarily but it is possible to presume that the driver or passenger tries to simulate his route. The second example refers demography. There is a complex model describing demographic processes using discrete simulation. We created an authority simulating the progress in this area and advising the citizens. Citizens may be convinced to leave the city. The nested model is much more alike to the main one in this case; this system can be called anticipatory with no doubt.
Keywords: demography, migration, nested simulation, reflective simulation, anticipatory systems

1 Introduction

In this paper we deal with a special category of simulation models. Simulation models we are talking about depend strongly on intelligent members inside of them. Such situations are rather common except those ones in which included intelligent members do some predictions of the whole model satisfying the definition of anticipating system. Intelligent members are models of humans here. Using other words, in this paper we talk about systems partly directed by humans. As we proceed in out considerations we will make some remarks about the definition of reflectivity. What is an intelligent member of model? From author's point of view such members must embody behaviour resulting from non-trivial rules which can be formally called if-then rules fuzzy or strict, multi-criterional decision process, some form of binary trees etc. When taking human thinking into account there is possible to use nested or reflective simulation because real people often make their decision by predicting their own future or their surrounding's future.

2 Time Schedule Check

The simplest way of anticipating using simulation is described first. The solved problem can be formulated as follows. Let a schedule of mass transport system is given. Even in a not too large city this schedule consists of hundreds departures and it is impossible to visually check all sequences. Next, large cities usually check critical lines and departures to avoid overfilled transport vehicles. So the primary goal of the project we talk here about is to check time schedules and to find critical points in it.

International Journal of Computing Anticipatory Systems, Volume 20, 2008
Edited by D. M. Dubois, CHAOS, Liège, Belgium, ISSN 1373-5411 ISBN 2-930396-07-5

More concretely here we solved time schedules for a city nearby Ostrava in Czech Republic with about 85 thousands citizens. The situation is the same for other mass transport system is provided by busses. The complete time schedule consists of 21 buss lines. The problem is solved by the discrete simulation which is organized into two levels. First one deals with the macro-world. It maps one day from 4 am to 23 pm. The complete schedule is saved into the model as well as the whole city map. The first step when constructing this model is done when all busses – still empty – circle on the city map. Busses in the real world have their finite capacity. The information about bus line capacity is never fixed and known so we give this capacity to every departure according to departure time and line number.

Next, we take travelers into account. Travelers are given by their origin and destination by a mechanism which depends on point of interest in the city. It is easy to formulate such point for a citizen who lives in that city. So in our model we consider schools, city hospital and shops to be attractive for citizens. These points of interest are transformed to nearest bus stops. It is clear that the intensity of new travelers must be the function of time to pass the validity check. Like before it is easy to write down this function. It is in the form of two trapezoids because we expect two critical time periods during the day. First take place about 7 am when children go to school and workers to their employments. Second one can be awaited between 1 pm and 4 pm when travelers move in the opposite direction. There is the constant intensity between these two periods because retired citizen use this time for shopping and medical visits. Generators of travelers work according to this rule and they give destination and origin stops both as result of random function. Used probability density accepts that some stops are more attractive then other (points of interest).

At the end of macro-world discussion part let us notify that this level of simulation is defined on real time scale. Moments in this model can be easily mapped to the real time.

How to find the route which will be probably chosen by the traveler? This question became more and more complicated as the model gets larger. For small city it is sufficient just to find the fastest route. This can be done using nested simulation – let me call it nested not reflective at this point please. The nested simulation represents the thinking of traveler and it is incredible fast in comparison to other processes in the main simulation. We may assume that a traveler finds his optimal route in one moment. He imagines all busses moving from actual time to time increased by 120 minutes. By assuming that traveler won't wait longer we obtain fastest algorithm. The searching algorithm works on multi-agent ideas and can be presented as a modification to known Dijkstra method using simulation.

After completing both parts into one project we got busses circling on city map and transferring travelers inside. After some correction the project gave correct results.

So it was possible to check time schedules using graphical interface. The second output is simpler. It is a function with two parameters – two bus stops. It makes chart with time on the x axe and time necessary to get from first to the second given stop. Using this it is possible to look for lack of connection easily.

3 Reflective and Nested Simulation

We will make a short remark about terms anticipating system in the weak form, nested simulation and reflective simulation. The reflective simulation is commonly understood as a special case of more general term nested simulation today. They both work on two independent time axes but may differ in the modeled system. When both main and nested level of simulation refers to the same system we speak about reflective simulation. Anticipatory system in the weak form uses some nested system making predictions about the upper-level system. It is obvious that when such anticipating system is implemented using simulation the nested system will be reflective. Nested simulation can be understood as generalized form of reflective simulation. This is still in the unity with the principe above but differs in the derivation ordering.

Difficult question concerns about distinction between this both terms. At first sight is clear that even in surly reflective simulation the likeness between nested and main system is not complete. At least the member containing reflective simulation must be omitted or modified otherwise there is a recusion. Some authors suppose this feature to be automatic but from my point of view this is only a beginning of a larger problem. In fact only minor part of reflective simulation contains complete – with respect to the note above – system derived from the main one. The likeness between them is rather unclear in much more cases. Let us show this is true using the previous project. The main simulation contains travelers and busses but the nested simulation omits travelers. But it still shows busses circling on the same map and respecting the same time schedule. We can see that nested model is smaller in the sense of mapping between sets. Second objection says that some thinks in the nested system works in other way so no member of main simulation it can be mapped to this member. Agents looking for the shortest path are such extraordinary members. All these ideas can be transferred back to the definition of anticipating system as reflective simulation we suppose to be the implementation of anticipating system. The reason for this chapter is to point out that relation of reflectivity is fuzzy. There are other considerations in next chapters about this.

4 What Next?

We thought about many possible applications of reflective simulation with humans after finishing previous project. Similar idea can be applied to automobile traffic in a city. There are cars instead of busses and car drivers are travelers in this approach.

Other aspects are much more interesting – driving car gives more possibilities to spare time then using a mass transport device. In original project only bus stops we taken into account and we didn't care about crossings, semaphores and jams. Beside this we have to work with crossings instead of bus stops – there is much more crossings then bus stops so the algorithm lasts longer. Other interesting problem lies in driver profile because various drivers enter the city. This causes that

- We must define special strategy for each type of driver. Consider that driver unfamiliar with the region will try to follow main streets even if it takes a longer time. More experienced driver may use smaller streets to avoid jams and semaphores.
- Unexperienced driver will use less detailed map than the experienced one. Such driver needn't know semaphores and less important crossings.

We may ask if wider GPS navigation usage can cause any changes. I don't think so. GPS usually finds fastest route and doesn't think about jams and semaphores so unfamiliar driver will stay the same and will follow the same pattern. To build strategies we define regions as areas in the city where all streets are of the same type which means that number or bars, width ad traffic density are roughly the same there. Strategy of inexperienced drivers will be to hold wider regions. Experienced drives can use all regions but prefer less busy ones. Next, first project is closed – there is no bus entering or leaving city. Here we assume cars moving inside the city as well as cars driving through however.

We can see that in both cases anticipating object doesn't try to predict whole system but his closest neighborhood only. When planning his route driver imagines him passing crossings but doesn't care other cars. He works with an attribute of every street that says average time needed to pass from the beginning to the end of it. In first project we used agents to spread bus stops, each bus stop could be occupied by not more then one agent. When other agent arriving later by another bus tries to occupy the same stop he is annihilated. Considering cars we make this control at the moment when the agent – car leaves the crossing because the fact that agent A approached the crossing before agent B is no victory for him if it is blocked in a jam and agent B can go through. Model with cars can have large applications when ready. For example it can predict situation by planned diversion. It is often difficult to find optimal precautions because in case of partially blocked heavily used street reserve routes would be blocked fast. Potential solution to check by project is to warn drivers before they enter blocked street, but not to tell about reserve routes early. Reserve route will be longer. Experienced drivers will follow they own navigation and inexperienced ones will use the longer reserve route they find at the place of the blockade. In this way we can distribute the traffic to more flows.

5 Anticipation in Demography

The last project described in this paper concerns a different area. In the 16. Century mathematics started to study demographical processes by using statistical methods and it caused the origin of new science as we know it today. During four centuries quantitative methods have dominated in the branch which deals with all aspects of human life. Classical quantitative approach can be called "from the top" which means that all units are aggregated and after that these global numbers are analyzed. In this paper we show an alternative way of demographic predictions. Our approach can be characterized as "from the bottom" – we try to model a unit in all aspect of its modeled life. Then we observe emergency behavior; we simulate life of all units inside the model. Construction of this model is non-trivial; there are serious problems to face up. Some of them we will show later. From the other hand one must accent that this approach has great advantages. We will talk about four of them:

1. rules according which a unit lives its modeled life are parallel to real process of human life and because of this they can be easily formulated and controlled.
2. flexibility of discrete simulation which gives large possibilities in model building
3. there are no prerequisites unlike statistical methods. Let us say that common tools for time series analyze needs some conditions to be met. For example time series should have 36 or 50 members; there should be no heteroscedasticity etc. Many methods suppose that regressors affecting analyzed time period are fixed. From the other side some methods suppose that affecting conditions change during time period but question is how much can they be changed to keep these methods valid. This point looks like author disrespects quantitative methods. It is not true; main goal is only to offer new method which can be in some occasion better than classical ones. Moreover some we need some coefficients which were earlier computed by statistical methods.
4. the possibility of some anticipating in this system. Approach "from the top" doesn't have any nested model. Anticipating in the society can be understood as strong from some point of view – it is hidden in time series but elements creating these numbers contained anticipating part.

Let us make second remark. We will show ways to build population in the model later so we need to tell how demographic processes work and how demography models them today. There are two main processes – called primary: mortality and natality. All other aspects which one can meet in the demography are called secondary. It is clear that first step when constructing our model is to have these two primary processes working. Mortality is one of very stabile processes. Almost all countries in the world have already passed so called demography revolution so expected lifetime is about to be fixed. There are some corrections to face up the increasing trend of human lifetime in the model but this is not important here. Function of time in years where be save the probability that a human is still alive in given age is – except hard periods like wars or epidemic – still the same; the scale changes only. This process is well described by experience tables in very simple form so it is easy to implement it to our model.

Next we have to define a mechanism of creating new people – we talk about the process of natality of course. This process is one of giving reason for this project. It is very various in the real world. Natality in Czech Republic has changed dramatically since 1990. Other interesting problems are connected with this. According to the structure of model we must determine for every woman how many children she will born as well as her age at each birth. It is not easy; we need help of statistical office. From the other hand it is simple to model multi-births because a suitable empiric rule is well known: there is one pair of twins for every 81 single births. This rate is preserved for higher orders. Office that ordered this study needed to decide between to build new flats or not. Roughly said a flat corresponds with the term of the family. So we needed to work with families – every human in the model is a member of some family (may be the only member).

It is time to tell how to build the starting population. It must have the same structure as real today population which mean that it must preserve:

- age structure
- rate between numbers of man and women in every age group
- number of families

Because we need to build a large number of men in the model we have prepared a probability density that corresponds with real age structure independent of gender. After that we generate an accurate number of humans and according to its age – which we already know here – decide about its gender. Let us remark that gender rate differs alongside age. But all necessary data are accessible. If generated human is a children up to 18 years it is canceled because of reason that is showed later. After a human is created it must be added to any family. This process demanded some experiments to make it accurate. The basic idea is to search a family in which this new human can be added. If no such family exists then a new family is generated and our new human is the only member of it – probably for now only. We generate families with "normal" structure. There are some rules to understand what is allowable. A short example of not allowable configuration follows:

- family with three and more adults at the age between 18 and 60 years where members can't be considered as parents and children
- family with three and more adults over 60
- family with two members of the same gender between 18 and 60 where they can't be considered as parent and its son or daughter

It is clear that there may be some families with the forbidden configuration in the real world but we suppose that their number is very low. Next it is crucial to keep the structure of family members. Because families are generated without regard to real structure it is necessary to check that the result is correct. Especially, it is difficult to comply with too many children in the family. We will shortly outline what's going on. There is a conflict between two demands.

At first the age structure must be preserved. At second we try to determine number of births in every woman life. And now, it is possible to obtain an unsolvable situation when a woman would be added to a family with too many children. So we don't generate children in the first step but we generate children when rest of family is completed. It is not sufficient to create families at the beginning; we must define all processes which change membership to family. There can be many such processes, let's enumerate some of them:

- marriage
- birth
- death
- migration
- leaving parent's house

Almost all of these events are easy to represent in our model. Migration is the only process which can't be modeled using classical technique because this process is very variable and a bit mysterious as well. Theoretically, even the genesis of migration is not clear; there are at least two concepts. At first step it is necessary to tell what can influent migration to get some correct method. Everyone can give many important reasons; a partial answer is hidden in forms which people moving to other city have to fill. Some part of migrating people leaves the city from reason which can't be predicted but the larger part is directly or indirectly influenced by situation in the city. In author's opinion lots of people move out because of housing. Let us explain it: why young pair shortly after marriage leaves the city? Because they have no place to go. Te same answer is for other situations.

How to model the decision making process here? People are not used to make such decisions shortly before they carry out it – it is a long time process. We suppose that people contemplating leaving the city study the housing situation there and make predictions themselves. Our approach tries to close in. We consider an authority like city office or something else making short time predictions. It simulates to know how many flats will be occupied and how many will be free. The result is used to advice people later. There is a form of anticipating here; the authority starts with actual state and supports only some of processes included in the main simulation. If we return to previous remarks about nested and reflective simulation we would see that here the nested simulation is subset of the main one without any additive elements. We can talk about reflective simulation thus.

6 Conclusion

Real human often anticipate so models containing people can often include some form of anticipating. Such models can be considered as special case of larger group – models with intelligent elements. Manners of anticipation can be various; starting from simple nested simulation used in the project with busses through more complicated variants like projects with cars to truly reflective simulation used in the last model.

References

[1] Pavlík, Z. a kol.:Základy demografie, Academia Praha, 1986
[2] Roubíček, V.:Úvod do demografie, Codex Bohemia, 1997
[3] Rosen, R.:Anticipatory Systems, Pergamon Press, 1985
[4] Dubois, D.M.: (Editor) International Journal of Computing Anticipatory Systems
[5] Kindler, E.,Křivý, I.,Tanguy, A.: Automatic Conversion to Reflective Simulation Models. In: Proceedings of 28th ASU Conference, 2003, pp. 15-26.
[6] Kindler, E.,Křivý, I.,Tanguy, A.: Taxonomy of nesting simulation models according to three criteria: number of nested models, level of nesting, reflectivity. In: Proceedings of ASIS 2003, MARQ 2003, Ostrava, pp. 353-364.
[7] Bulava, P.: Transport system in Havirov. In: Proceedings of 28th ASU Conference, 2003, pp. 57-62.
[8] Cipra, T.: Analýza časových řad s aplikacemi v ekonomii. Státní nakladatelství technické literatury 1986, Praha