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## Visibility & Invisibility of Communities in Urban Systems

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# **Visibility & Invisibility of Communities in Urban Systems**

Paula Mota Santos and João Borges de Sousa

NOTA DI LAVORO 70.2006

**APRIL 2006**

KTHC - Knowledge, Technology, Human Capital

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## Visibility & Invisibility of Communities in Urban Systems

### Summary

Information on the presence of Chinese and Ukrainian communities in Portugal, and namely in Greater Porto (northern Portugal) will be presented to then investigate how recent work on evolving networks might be a helpful tool in analysing the integration of migrant communities in urban systems, namely in helping to understand if the differential relationships between 'nodes' and 'vertices' might help to account for the higher and lesser visibility of these two communities within Greater Porto.

**Keywords:** Chinese, Ukrainian, Migrant Communities, Self Evolving Networks

**JEL Classification:** O15, O18, Z13

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# VISIBILITY & INVISIBILITY OF COMMUNITIES IN URBAN SYSTEMS

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## **INTRODUCTORY NOTE:**

*The present paper is a work in progress and in a way a portrait of a dialogue between two different areas of knowledge: anthropology and dynamic systems. Both authors share a common interest in the anthropomorphic. The first through the desire to understand human societies and the latter through the pursuit of networked systems (including robots, sensors and communication networks) that emulate, extend (and surpass?) the human capacities, both at the individual and at the societal levels. Thus the paper can be seen as constituted by two parts: one describing the Portuguese recent history concerning both emigration and immigration to then pay particular attention to the portrayal of both the Chinese and Ukrainian communities presence within Portuguese national space and particularly within the metropolitan region of greater Porto. The second part delineates possible approaches to the mapping and measuring of diversity taken from the perspective of dynamic systems, with especial emphasis on networks with evolving structure. The paper ends with a series of open questions for further research.*

## **INTRODUCTION**

At the end of the 1960s more than 100 thousand workers emigrated from Portugal per year. In 1997 the number of Portuguese emigrants throughout the world surpassed 4 million with the following distribution: Americas 54.3%, Europe 31.1%, Africa 12.4%, Oceania/Australia 1.3% and Asia 0.7%.

Within the European Union Portugal is one of the countries with most citizens living outside of their country of origin – approximately 1 million. In France, for instance, the Portuguese represent the first foreign nationality (Falcão 2002:3). In the last two decades, Portuguese emigration, although reduced, has not disappeared. The preferred destinations of the Portuguese emigrants in the year 1999 were: France (25.6%), Germany (24.3%), Switzerland (22.7%) and United Kingdom (8.8%). However, from a country of emigration, Portugal has become over the last decade a country of immigration (Falcão 2002:3).

Until 1980, immigration in Portugal never reached figures of more than 50 000 residents. But between 1986 and 1997, the number of foreigner citizens almost doubled from 87 000 to 157 000 individuals. Between the years of 1994 and 2003 there was an increase of 37.3% in the numbers of foreign citizens bearing the title of *legal residents*

in Portugal.<sup>1</sup> However, if for that same year of 2003 one adds the number of foreign citizens bearers of the *permit to stay* in Portugal,<sup>2</sup> the numbers of foreign citizens rises to nearly 435 000 individuals ([www.sef.pt/imagens\\_2/estatistica.gif](http://www.sef.pt/imagens_2/estatistica.gif)), representing a 73.3% growth over the number of registered foreign citizens within Portuguese national space.

The legal figure of the *Prorrogação de Permanência* (renewal of permit to stay in Portugal) legislated in 1998 (Dec-Lei N° 244/98) was the responsible for the 68.8% increase in the number of foreign citizens with Portuguese national space in the year 2001, time when the Portuguese government created a special period for illegal foreign citizens to legalize their presence in Portugal.<sup>3</sup> In 2001 the number of foreign citizens registered in Portugal (*Autorização de Permanência* status plus *Autorização de Residência* status) was of 300.503 by comparison to the 207.607 registered in 2000. This significant rise in immigrant numbers with legal status in Portugal clearly mirrors what is normally assumed to be the immigrant reality in foster countries, in which the real numbers of immigrant individuals is estimated to be the double of those with a legal status present within any national space.

In 2003 the number of inhabitants in Portuguese national space was of 10 474 685 people. For the same year, the number of legally registered foreign citizens was of 434 548, this is, 4% of the total population residing in Portugal is composed of immigrants. However, if we look at the data concerning Portuguese economy, according to the 2001 census, 6% of Portugal's active work force is constituted by immigrants (<http://www.acime.gov.pt/modules.php?name=News&file>).<sup>4</sup> To be noted that this percentage is obtained by using only those foreign citizens whose presence is recorded in the legal system. However, if the above referred to estimates concerning the illegal presence of immigrants is to be accepted, than the percentages here indicated could double. In fact SEF's Director has recently stated that the estimate is that there are c. 70 to 80 thousand illegal immigrants in Portugal (*O Público* 08/04/05). However, the Portugal-based immigrants' associations consider SEF's estimate to be quite conservative and speak of an estimate around the 100 thousand individuals with a status of illegal immigrants (*O Público* 08/04/05).

## 1. FOREIGN COMMUNITIES IN PORTUGAL

According to SEF's statistics for the years 2002 and 2003,<sup>5</sup> the African continent is the one that supplies the highest number of immigrants to Portugal, followed by the European continent, and then by the Americas. Asia features in fourth place (**Fig 1**).

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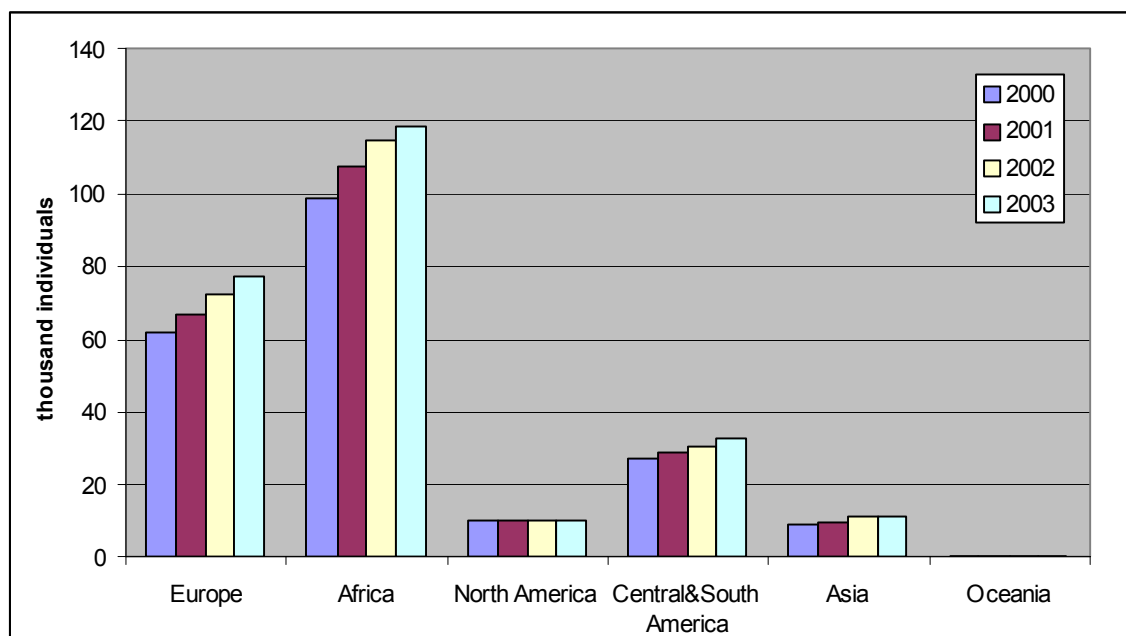
<sup>1</sup> These are the bearers of the *Autorização de Residência* (permit that bestows the legal resident status).

<sup>2</sup> *Autorização de Permanência* (permit that bestows the right to temporarily stay in Portugal).

<sup>3</sup> Besides this action in 2001, there were two other special campaigns for the legalising of foreign nationals in Portugal in the years 1992 and 1996. The creation of these two special periods of legalisation of foreign citizens clearly shows the importance of the recent waves of immigration in Portuguese society.

<sup>4</sup> Consultation made on June 2004.

<sup>5</sup> These statistics only work with the foreign nationals with *Autorização de Residência*



**Figure 1** – Number of immigrants according to geographic origin  
(Source: SEF, Relatório Estatísticos 2002 e 2003 – foreign nationals with *autorização de residência*)

The continent that has registered a strongest increase in percentual terms in its immigration flow between the years 2000 and 2003 was Asia (24,6%), followed by Europe (19%), Africa (16,8%) and South and Central America (15,6%). The flow from North America has registered a decrease (**Tab 1**).

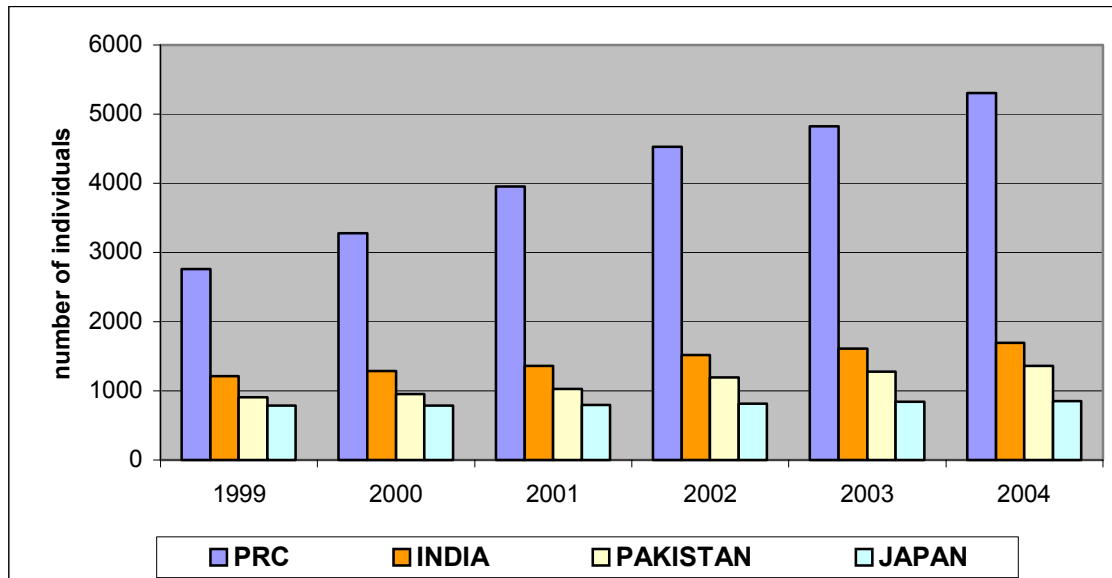
	EUROPE	AFRICA	NORTH AMERICA	CENTRAL & SOUTH AMERICA	ASIA
2000	61.709	98.754	10.201	27.419	8.721
2001	67.121	107.273	10.187	28.856	9.721
2002	72.229	114.386	10.143	30.424	10.935
2003	77.053	118.632	10.124	32.474	11.571
<b>growth rate %</b>	<b>19%</b>	<b>16,8%</b>	<b>-1%</b>	<b>15,6%</b>	<b>24,6%</b>

**Table 1** –Percentual growth of immigrant population in Portugal *per* geographical origin

Concerning the countries of origin of the foreign nationals with *Autorização de Residência*, SEF's statistics for the year 2003 indicate in first place Cape Verde (53,858 individuals), followed by Brazil (26,561 individuals), Angola (25,681 individuals) and Guiné-Bissau (20 209 individuals). Great Britain (16,784 individuals) and Spain (15,329 individuals) come up next. The latter two countries are thus the European countries with the higher number of nationals residing legally in Portugal. Still according to SEF's data for 2004, the Ukrainian nationals residing legally in Portugal (*Autorização de Residência*) are 1,497, an almost three fold increase over the 2003 numbers<sup>6</sup>, while those of Chinese nationality are 5,309 and thus displaying a less than

<sup>6</sup> SEF's statistics for 2003 referred 519 Ukrainian nationals holders of *Autorização de Residência*.

10% growth in relation to 2003.<sup>7</sup> To note that of all the countries listed by SEF under the category of Asia, the People's Republic of China (PRC) is the one that registers the highest number of nationals within Portuguese national space, followed by India (1,614 individuals) and Pakistan (1,280 individuals) (Fig 2).<sup>8</sup>



**Figure 2** – Asian immigration into Portugal – distribution *per* four top nationalities  
(Source: SEF, Relatório Estatísticos 2000, 2001, 2002, 2003 and 2004 – foreign nationals with *autorização de residência*)

It must be noted that the statistics supplied by SEF in its annual reports only contemplate the foreign nationals with the permit of residency (*Autorização de Residência*), leaving out (apart, obviously from the illegal immigrants), the foreign nationals legally in Portugal but holders only of the permit to stay (*Autorização de Permanência*). Thus according to SEF's data that is not part of their annual reports, in 2003 there existed in Portugal 65,199 Ukrainian immigrants with a legal status (*Autorização de Permanência*) (Oliveira 2004).<sup>9</sup> In 2004 SEF's statistics These numbers show us the Ukrainian community to be the largest foreign community in Portugal, followed by the Brazilian community (64,417 individuals), Cape Verdean (62,766 individuals) and Angolan (34,267 individuals).

<sup>7</sup> SEF's statistics for 2003 referred 4,814 Chinese nationals holders of *Autorização de Residência*.

<sup>8</sup> To be noted that if the presence of individuals with Indian citizenship in Portugal might be related to the 20th century history and presence of Portugal in India, the same cannot be said concerning the PRC nationals. SEF statistics have an entry for Macao, whose number of individuals registered within Portuguese national space is very small (the statistics for 2004 register 3 citizens from Macao with a *Autorização de Residência*). The long presence of Portugal in Macao and its recent history (the devolution of the territory to the PRC took place in 1999) could lead to think that most of the Chinese presence was Macao related. However, the field work carried out so far indicates that it is not so: although Macao might have worked as an entrance into European space, most of the Chinese citizens residing in Portugal were mainland Chinese. In Porto, the majority comes from Zhenjiang province, a flow that started in the 1930s and, according to the narrative of the descendents of the original migrants, as a ripple of the Japan-China conflict.

<sup>9</sup> Article available in [www.acime.gov.pt/modules.php?name=News&file=print&sid=357](http://www.acime.gov.pt/modules.php?name=News&file=print&sid=357);

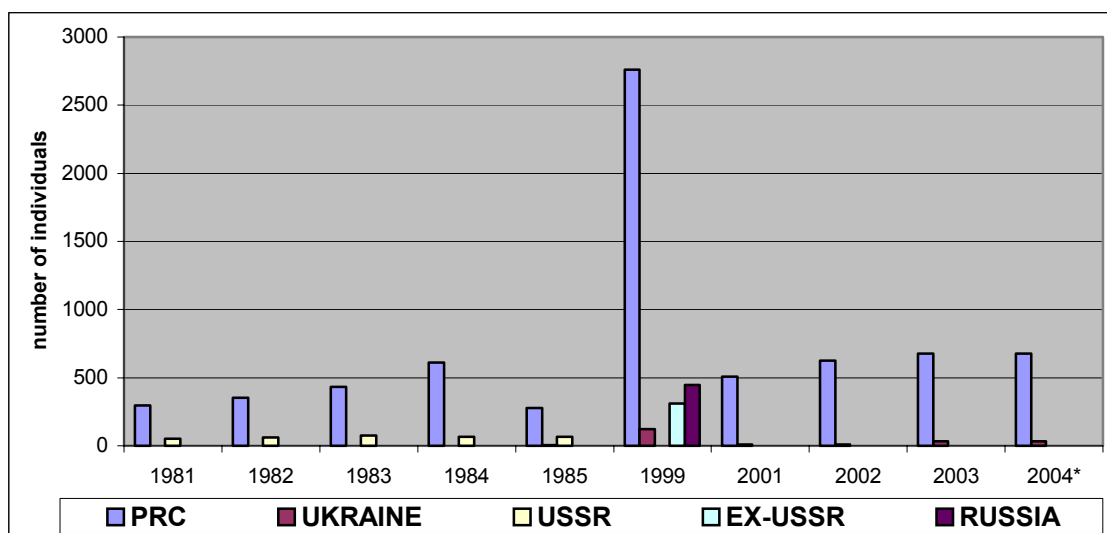
Consultation made in 8/07/04.

However, the data made available by SEF for the 2003 report lists 529 Ukrainian nationals with *Autorização de Residência* and 2,546 with *Autorização de Permanência*. The c 65,000 individuals referred to must be an accumulation of previous years' permits.

## 2. THE UKRAINIAN AND CHINESE COMMUNITIES IN PORTUGAL AND IN PORTO

### 2.1. RESIDENCY PERMIT HOLDERS:

**Figure 3** displays the situation of PRC and Ukrainian citizens in Portugal. The data concerning USSR and former USSR citizens was also included because it might include Ukrainian citizens.



**Figure 3** – PRC and Ukrainian national citizens holders of *Autorização de Residência* in Portugal

(Source: SEF)

\* provisional data

The reality concerning the holders of *Autorização de Residência* is not very different in proportional terms when considering the Porto District alone. What can be noted is a steady increase in the flow of PRC nationals into the Porto District, while the national level figures display a peak in 1999 followed by a steady flow with levels much lower to those of 1999 (**Tab 2** and **Fig 4**).

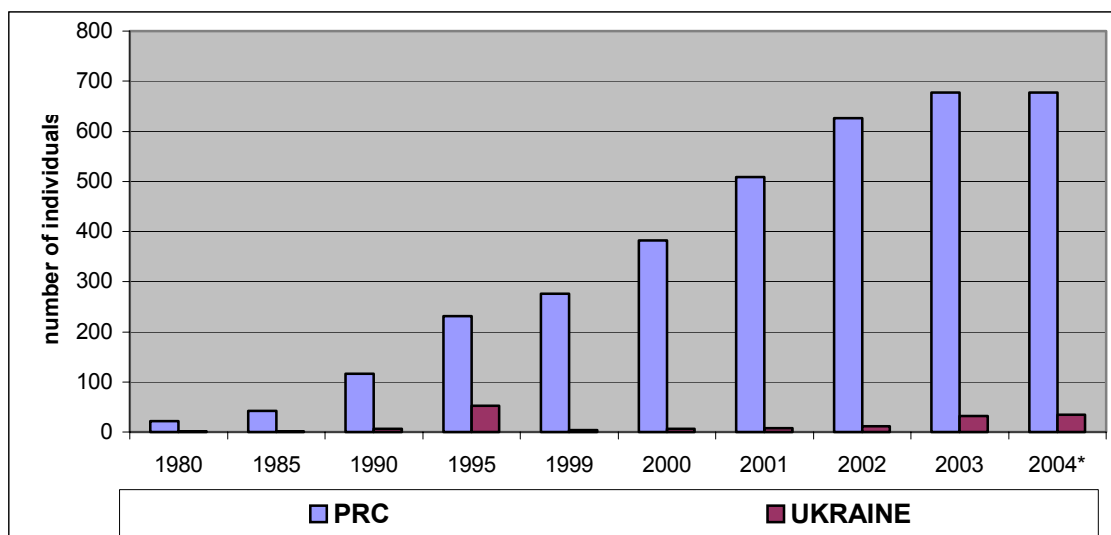
	1980	1985	1990	1995	1999	2000	2001	2002	2003	2004*
<b>PRC</b>	22	42	116	231	276	382	509	626	677	677
<b>UKRAINE</b>				1	4	7	8	11	32	35
<b>USSR</b>	1	1	7							
<b>EX-USSR</b>				38						
<b>RUSSIA</b>				14						

**Table 2** – PRC, Ukrainian, USSR, ex-USSR and Russian national citizens holders of *Autorização de Residência* in the Porto district

(Source: SEF statistics)

\* provisional data





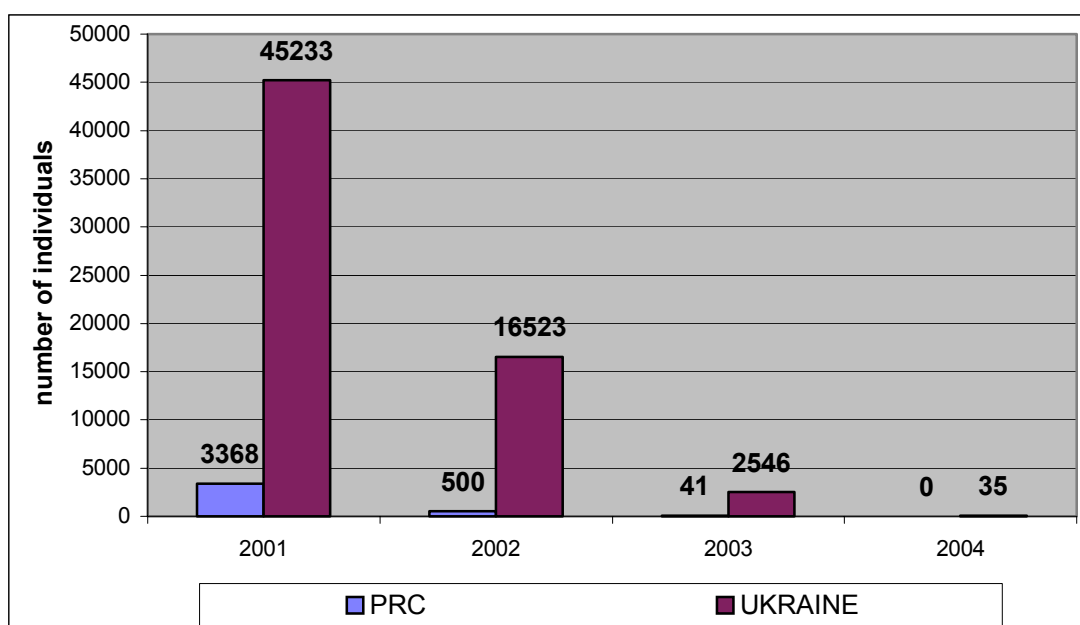
**Figure 4** – PRC and Ukraine nationals holders of *Autorização de Residência* in the Porto District  
(Source: SEF statistics)

\* provisional data

NOTE: the number of individuals listed on Table 2 under USSR, EX-USSR and Russia were added to the Ukrainian category for the sake of simplifying the chart.

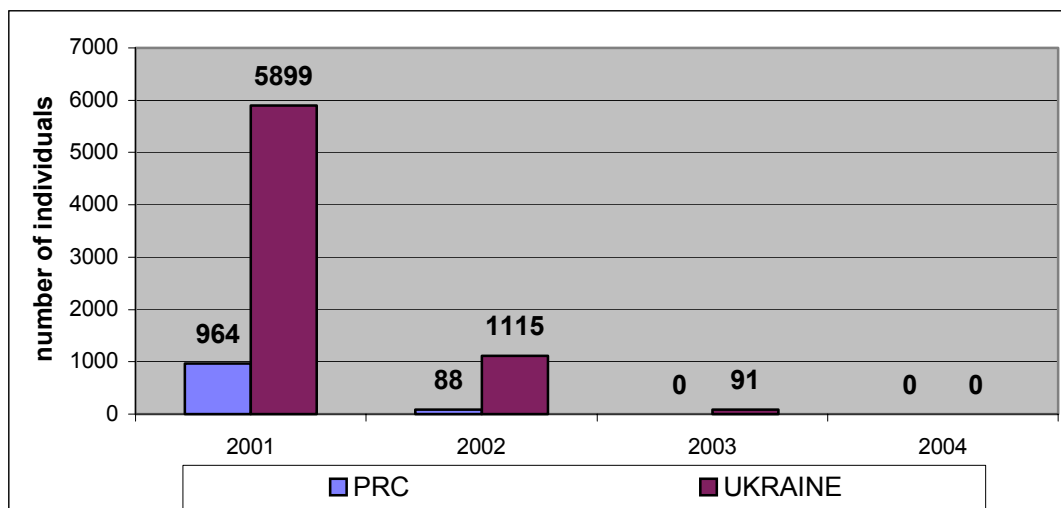
## 2.2. PERMIT TO STAY HOLDERS:

At the level of the Portuguese national space we find that the Ukrainian nationals who have legalized their presence in Portugal through the Permit to Stay (*Autorização de Permanência*) is much higher than the one for Chinese citizens (**Fig 5**).



**Figure 5** – PRC and Ukraine nationals holders of *Autorização de Permanência* in Portugal

The situation concerning the Porto district mirrors the one at national level, with a much higher number of Ukrainian nationals legalizing their presence within Portugal through the Permit to Stay (*Autorização de Permanência*) (**Fig 6**).



**Figure 6** – PRC and Ukraine nationals holders of *Autorização de Permanência* in the Porto District

If we add up the number of both *Autorização de Permanência* and of *Autorização de Residência* bestowed to PRC and Ukrainian nationals, we get a clearer picture of their presence in Portugal (**Tab 3**)

(Note: out of this picture are those citizens who have not entered the legal system).

	PRC	PRC	<b>TOTAL</b>	Ukraine	Ukraine	<b>TOTAL</b>
	<i>Aut/Perm</i>	<i>Aut/Res</i>		<i>Aut/Perm</i>	<i>Aut/Res</i>	
<b>2001</b>	3 368	3 831	<b>7 199</b>	45 233	201	<b>45 434</b>
<b>2002</b>	500	4 529	<b>5 029</b>	16 523	299	<b>16 822</b>
<b>2003</b>	41	4 816	<b>4 857</b>	2 546	527	<b>3 073</b>
<b>2004</b>	0	5 197	<b>5107</b>	35	1 353	<b>1 388</b>

**Table 3-** Number of PRC and Ukrainian nationals in Portugal who obtained either a Permit to Stay or of Residency (2001/2004)

What can be seen from this data is that both communities present their higher number of citizens entering the legal system in 2001, year in which the Portuguese government created the *Autorização de Permanência* as a middle status, one that while allowing foreign citizens to legalize their presence, would not accord them a long term permit to live in Portugal.

From the data can also be inferred:

- 1) the presence in Portugal of a high number of Ukrainian citizens immediately prior to 2001
- 2) the great disparity between the proportion of citizens that within each nationality applies for one permit or the other, with the Chinese community being able to fulfil the more demanding conditions (namely the one of holding a job) of the bestowal of an *Autorização de Residência*

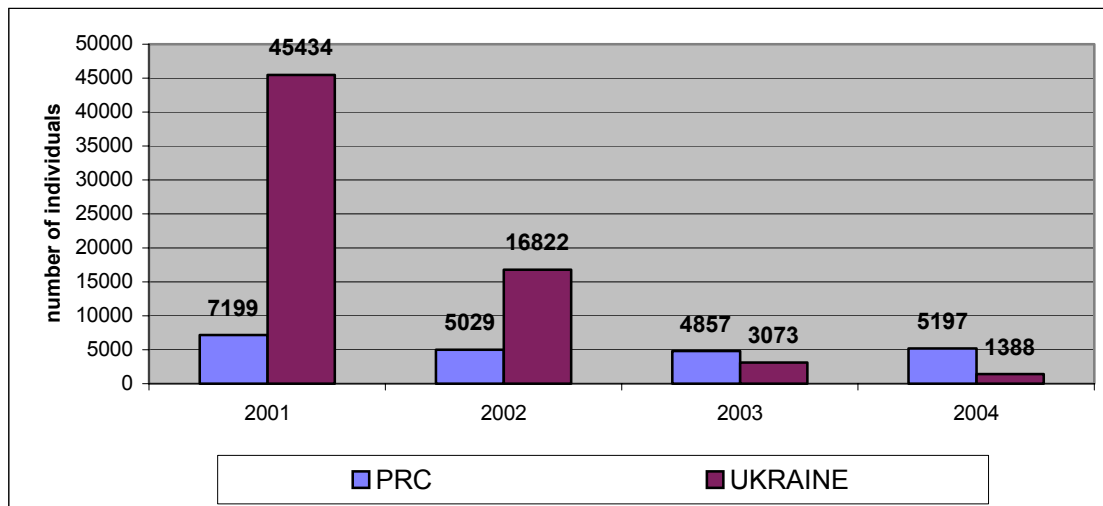
- 3) the rapid decrease in numbers of the Ukrainian nationals applying for a legal status of immigrant *per year*, while the numbers of Chinese nationals seem to maintain a fairly steady incoming flow

The situation concerning the Porto District is the following (**Tab 4**):

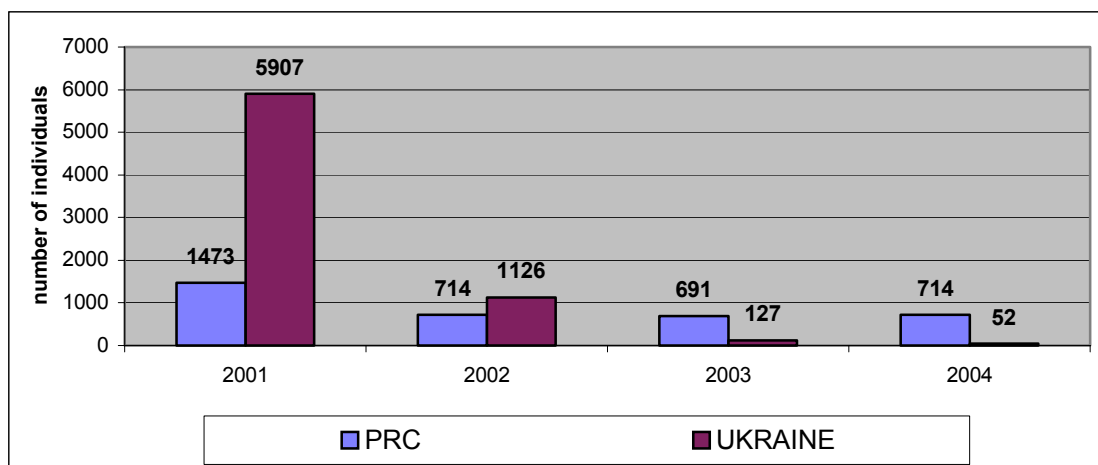
	PRC	PRC	<b>TOTAL</b>	Ukraine	Ukraine	<b>TOTAL</b>
	<i>Aut/Perm</i>	<i>Aut/Res</i>		<i>Aut/Perm</i>	<i>Aut/Res</i>	
<b>2001</b>	964	509	<b>1 473</b>	5 899	8	<b>5 907</b>
<b>2002</b>	88	626	<b>714</b>	1 115	11	<b>1 126</b>
<b>2003</b>	0	691	<b>691</b>	91	36	<b>127</b>
<b>2004</b>	0	714	<b>714</b>	0	52	<b>52</b>

**Table 4** - Number of PRC and Ukrainian nationals in the Porto district who obtained either a Permit to Stay or of Residency (2001/2004)

**Figures 7 and 8** allow for the comparison between the national and the Porto District level. It is possible to see how the Porto district reality mirrors the national level reality.



**Figure 7** - Number of PRC and Ukrainian nationals in Portugal who obtained either a Permit to Stay or of Residency



**Figure 8** - Number of PRC and Ukrainian nationals in the Porto District who obtained either a Permit to Stay or of Residency

Figures 9 and 10 show the distribution per gender and respective evolution of both immigrant communities in Portugal.

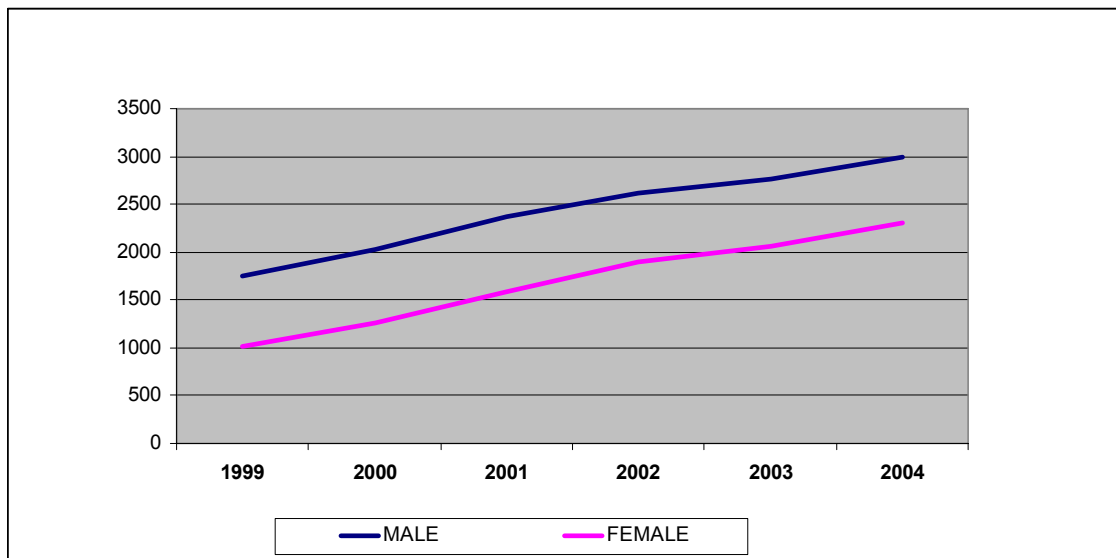


Figure 9 PRChina immigrant population in Portugal – distribution per gender and respective evolution

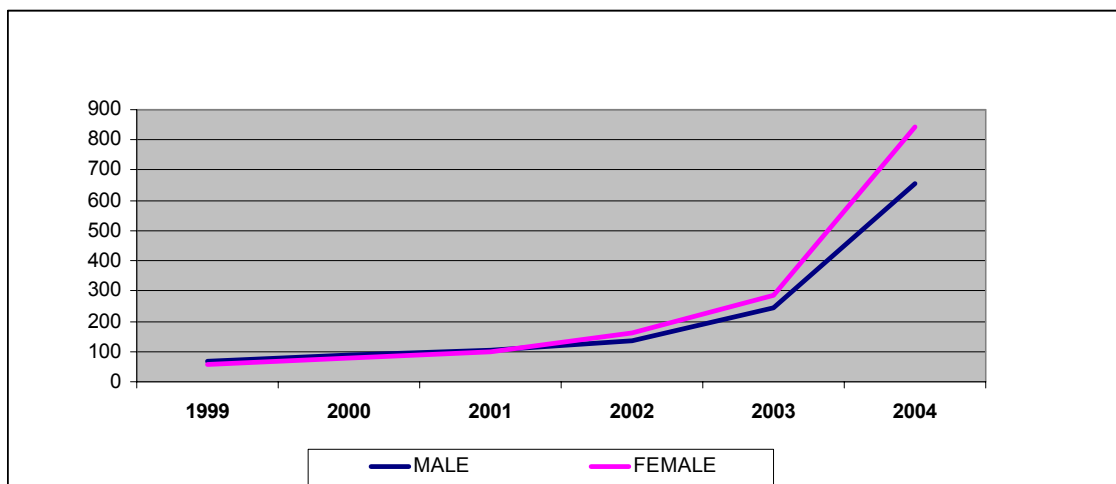
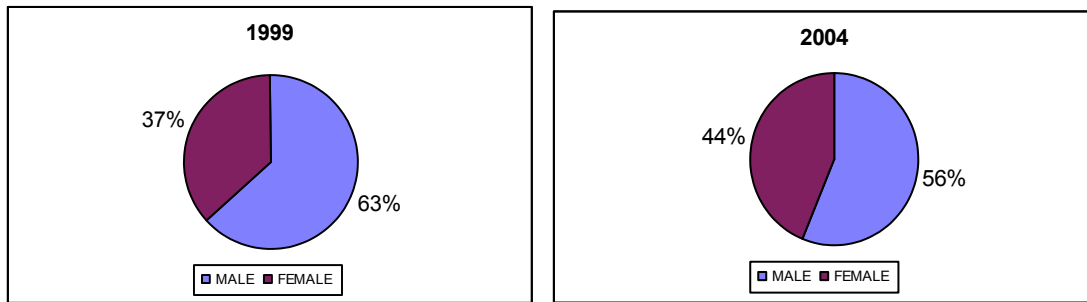


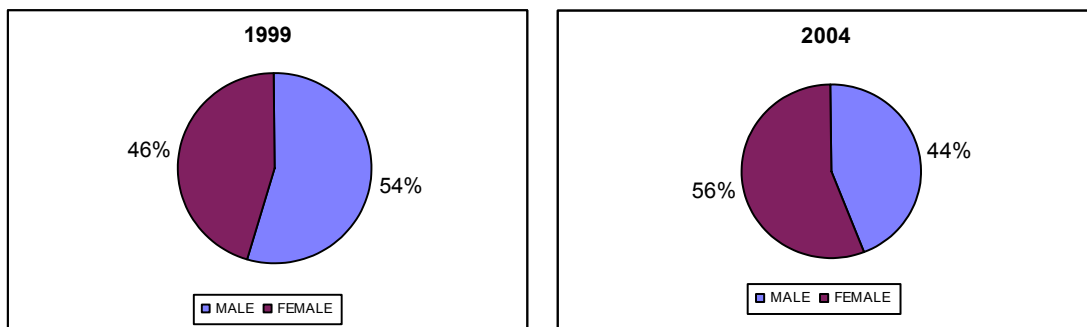
Figure 10 Ukrainian immigrant population in Portugal – distribution per gender and respective evolution

What can be perceived is that in the case of the Chinese community the ratio among male and female individuals is rather constant through out the five years on display, although the female contingent has been gaining a stronger presence. This community displays a higher degree of *masculinization* of its immigrant community while the Ukrainian immigrant community although it started with a fairly even presence of male and female individuals has been displaying a slight *feminization* of its contingent in Portuguese national space.

Figures 11 and 12 show the percentage of male and female individuals in both communities, both in 1999 and in 2004.



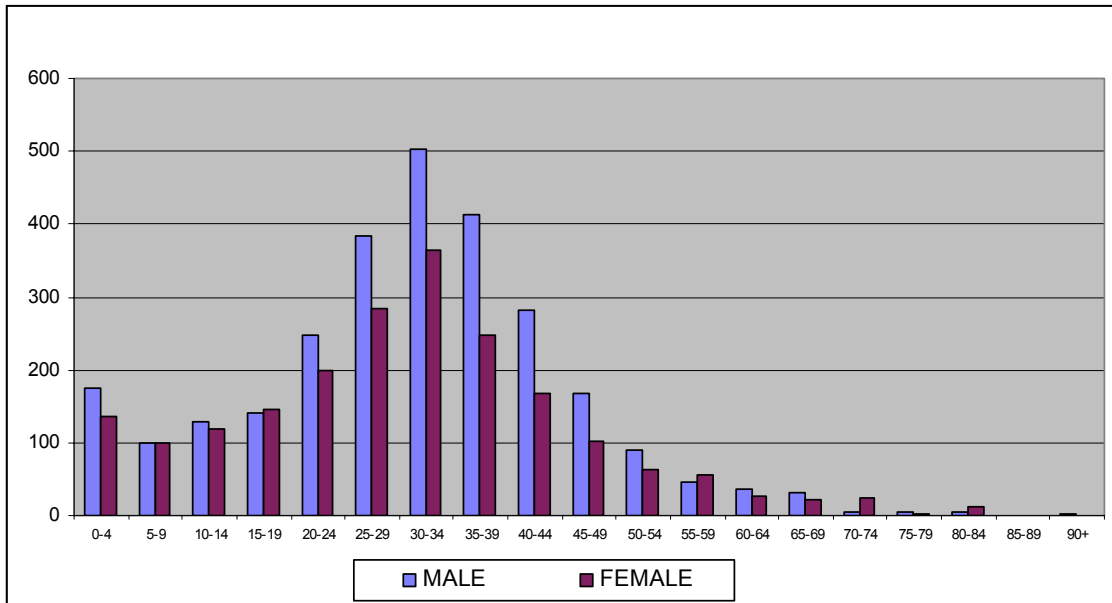
**Figure 11** PRChina immigrant population in Portugal – distribution per gender - years 1999 and 2004



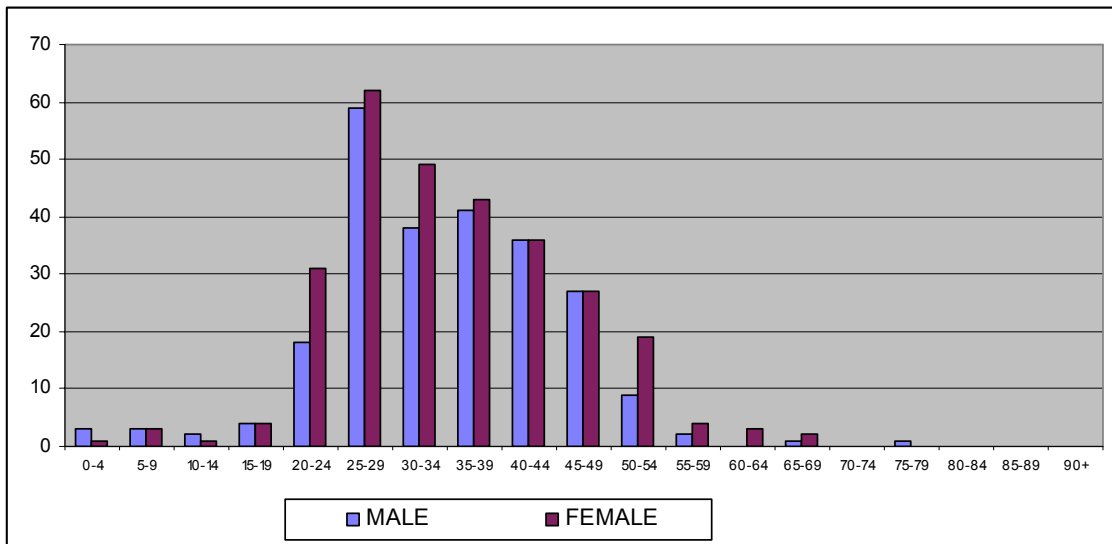
**Figure 12** Ukrainian immigrant population in Portugal – distribution per gender - years 1999 and 2004

The pie charts for the years 1999 and 2004 show in a very clear manner the increased weight of the female contingent in the Chinese community and what is practically an inversion of the proportion between male and female contingent in the Ukrainian community.

The two communities are also different concerning the age sets registered within each community (**Fig 13** and **14**). Although both communities display the higher number of individuals within the young adults sets (mid twenties to thirties), the Chinese community registers a much higher presence of infants and teenagers than the Ukrainian community does. This results from the particular way Chinese immigration takes place, one where the family is seen as a seminal resource and capital within the setting up of an economically successful life in foreign countries. The importance of the family within the Chinese model of immigration (one that stems from the importance of the family unit within Chinese society) can also be seen through the presence of elderly individuals, a reality totally absent from the Ukrainian community. It must be added that the Chinese presence in Portugal is older than the Ukrainian: in Porto there are three families whose forebears initiated their presence in the late 1920s, going already in their fourth generation.



**Figure 13** PRChina immigrant population in Portugal – distribution per age sets – year 2003.



**Figure 14** Ukrainian immigrant population in Portugal – distribution per age sets - year 2003

### 3. THE UKRAINIAN AND CHINESE COMMUNITIES IN PORTUGAL AND IN PORTO- field work notes

Most Chinese in Porto come from Zhenjiang province (north of Fujian province). There are two different worlds in the community: a core of ‘traditional’ families (four generations) (**Fig 15**) and an increased number of transnational Chinese (responsible for the increase seen in the statistics) fitting more within what has been called Chinese Diaspora and also analyzed by the work of Ong (1997; 1999).

## Past and present



**Figure 15** The Machado Tsou family- past and present

he community explores a specific niche within Portuguese economy: the traditional ‘Chinese restaurants’, the small corner-shops selling all kinds of goods at an extremely good value price (‘loja dos chineses’) (**Fig 16**) and outlets in the outskirts of greater Porto from where most small shop owners (both Chinese and non Chinese) buy their goods from. Within the city of Porto the higher concentration of ‘Chinese shops’ takes place in the old part of the city in an area that was already reputed to have extremely good values merchandise, namely electronics). This area and the one in Mindelo (outskirts of Vila do Conde, a city part of greater Porto) are referred by Portuguese media as Chinatowns (**Fig 17**)

## Past and present



**Figure 16-** Chinese commercial ventures

## Past and present



Figure 17- The Mindelo outlet

The Chinese community is represented by the *Liga dos Chinese em Portugal*, a exclusively male domain. The place within the hierarchy is directly related to the amount of money you are able to contribute to the *Liga* finances. The *Liga* official address is of an office of its more senu«ior members. However, most of the *liga* business is conducted through meetings in one of the communities restaurant, in a private space away from the Portuguese costumers' glance and where according to the *Liga*'s members, 'proper' Chinese food is served. The *Liga* deals with all the immigration paperwork for the community's members.

The Ukrainian community is also represented by an association named *Drusba* (Friendship). *Drusba* was founded by one of the women (a former biology teacher) and the field work carried out reveal it to be mostly a female run domain. The association occupies a space supplied by the local Junta de Freguesia (Riot Tinto's civil parish) (**fig 18**). Unlike the *Liga*, that has a legal counselor and representation (a Portuguese lawyer), *Drusba* cannot and does not deal with the immigration paper work for its members. It provides a space for sociabilities (Ukrainian festivities), organizing for the children whose parents might be interested in, classes of Ukrainian history, geography and language/literature. It is in the process of organizing a Ukrainian folklore group.



## Present



**Figure 18-** The *Junta de Freguesia* building where *Drusba* is located and two of the children that attend the Saturday morning classes.

The Ukrainian do not work within their own community the way the Chinese immigrants do. They are always employed by Portuguese employers. As a result they learn how to speak Portuguese much quicker than the Chinese immigrants do. Also, their social network goes beyond the community members, something that does not happen so widely within the Chinese community.

What can be said is that within certain spheres of sociability, the Chinese community is much more visible than the Ukrainian community: to the phenotypical difference one must add the active playing of the ethnic difference within their commercial enterprises, namely the restaurants and the small shops that are always identified from the outside with Chinese motifs. The Ukrainians are not so phenotypically distinguishable from the local population as the Chinese are. Also, their ability to quickly learn the local language and to do it very proficiently, adds to their invisibility. However, almost any Porto inhabitant will have either personal acquaintance or know someone who employs or works with Ukrainian citizens, making this presence quite 'visible'. Also, while the very initial presence of the first Chinese male immigrants resulted in the first mixed marriages, that is a rare situation within the community. Chinese immigrants still tend to marry within their ethnic group, while in relation to the Ukrainian presence there are already cases of mixed marriages and offspring.

## 4. NETWORK MODELS AND SELF-EVOLVING SYSTEMS

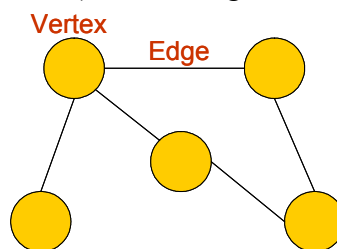
### 4.1 BACKGROUND MATERIAL

Research on networked systems has attracted the attention of a diversity of scientific communities which include computer and control scientists, physicists, biologists, economists, and mathematicians. The theoretical developments have been accompanied by an impressive application pull which results not only from technological

developments such as the World Wide Web but also from the realization of the importance of the network society (Castells 2000).

The network perspective is now pervasive in scientific developments in apparently unrelated fields. For example, Milner (Milner 1996) argues that a rich conceptual development, that gives a distinct character to the principles and concepts underlying computing, is in progress. He claims that the distinct and unifying theme encompassing the new developments is what he calls *Information flow* – “...information flow - not only the volume and quantity of flow, but the structure of the items which flow and the structure and the control of the flow itself”. In this context the notion of dynamic reconfiguration plays a crucial role: “dynamic reconfiguration is a common feature of communicating systems ... the notion of link, not as a fixed part of the system but as a datum that we can manipulate, is essential for understanding such systems”. It does not come as a surprise that these topics arise for example in the study of social and economic networks: “Network structure is important in determining the outcome of many important social and economic relationships. For example, networks play a fundamental role in determining how information is exchanged...” (Jackson and Watts 2002).

The modeling challenges raised by a network system are better understood when we consider the lack of expressiveness presented by a formal model of a simple network. Consider a formal graph model. A graph is a pair  $(E, V)$  where  $V$  is the set of vertices (nodes) and  $E$  is the set of edges (links) linking those vertices (see Figure 19). The edges can be directed or undirected (i.e. inducing a direction for graph traversal or not).



**Figure 19 Graph model.**

A modeling question concerns the interpretation of the graph. For example, the graph may represent relations among entities which, in the context of societal systems, could be individuals, companies, or other institutions. A relation between two individuals is represented by a non-directed and (thus reciprocal) link. Figure 20 illustrates these concepts with a model of a small village: unsociable inhabitants live in this village; usually, they contact only with their neighbors, but some of them attend the church (Dorogovtsev and Mendes 2002).

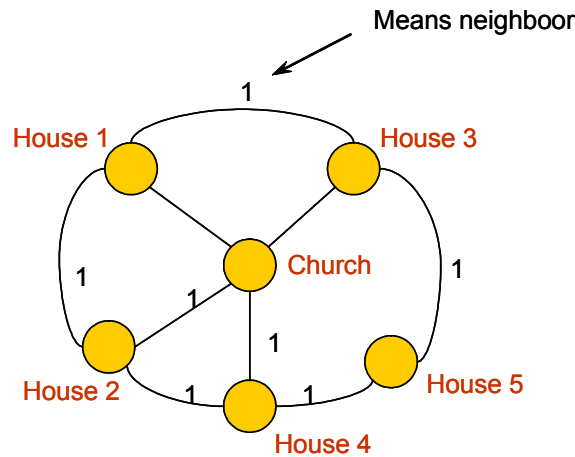


Figure 20 Small world model

The structure of a graph can be captured by the “adjacency” matrix (Figure 21). The adjacency matrix is a  $n \times n$  matrix, where  $n$  is the number of nodes of the graph. The matrix is built as follows: the  $(i, j)$  entry of the matrix (where  $i$  represents the  $i$ -th row and  $j$  and  $j$ -th column) is 1 if there is a link connecting nodes  $i$  and  $j$ , and 0 otherwise. The square of the adjacency matrix (which is obtained from the multiplication of the matrix by itself) has an interesting property: a non-zero  $(i, j)$  entry means that there is a path of length two connecting nodes  $i$  and  $j$  (by length it is meant the number of edges connecting which compose the path). Similarly, a non-zero entry in the  $(i, j)$  entry of the  $k$ -th ( $k \leq n$ ) power of the adjacency matrix means that there is a path of length  $k$  connecting nodes  $i$  and  $j$ .

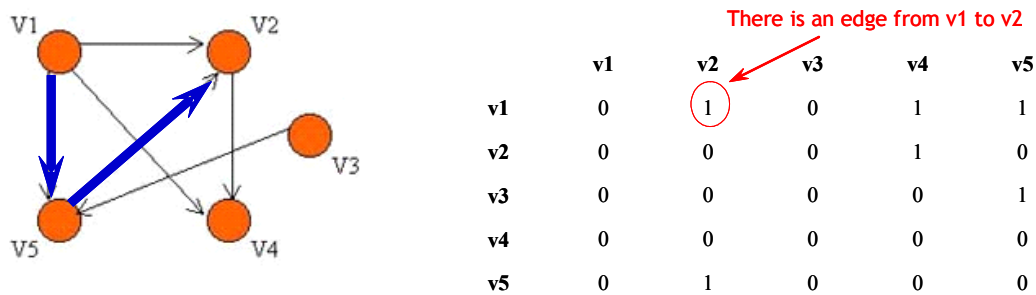


Figure 21 Adjacency matrix

Another concept of interest for analysis concerns the connectedness of a graph which is related to the structure of the graph. The degree of connectivity of a node is the number of edges leaving the node. A graph is fully connected if every pair of nodes can be connected by a path. A fully connected graph has a degree of connectivity 1 if the removal of at least one link results in two disconnected graphs. Connectedness can be used to evaluate the “strength” of a social network or the level of integration of the community in an urban system.

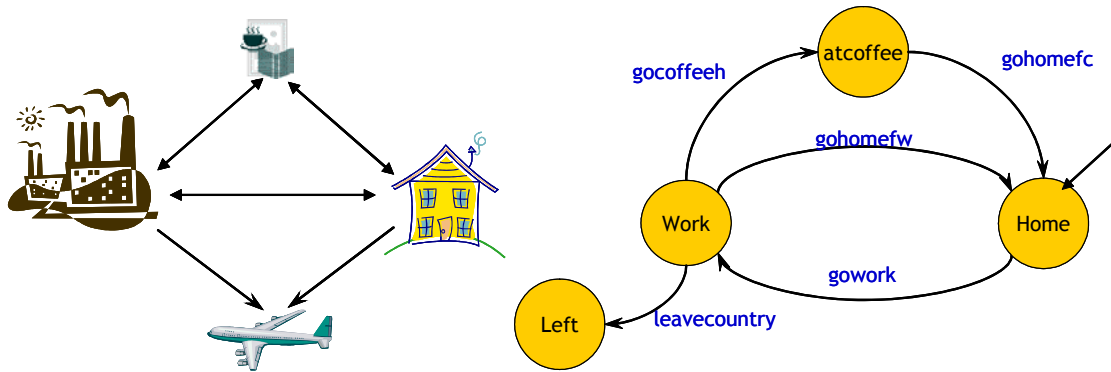
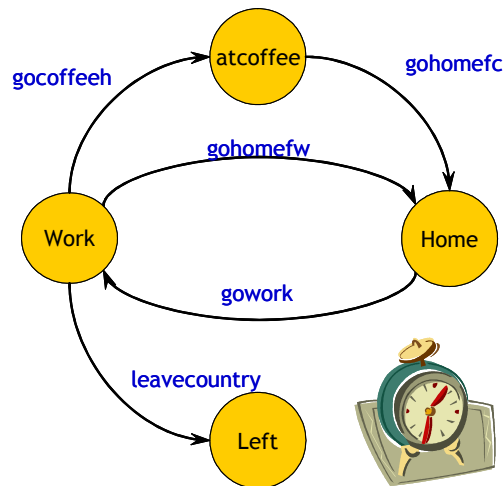


Figure 22 Finite state machine model of Sam's life

The graph models described so far account for static relations, i.e. relations which do not change with time. The introduction of directed links and different semantics provides the modeling mechanisms for a graph representation of a finite state machine. A finite state machine (*FSM*) models systems which evolve through a finite set of states. Formally a FSM is  $(Q_0, V, E, T, Q_f)$ , where  $V$  and  $E$  are defined as before,  $Q_0$  represents the initial state of the system,  $Q_f$  the set of final states, and  $T$  is the transition relation expressing how the system evolves from a given state (or node) to another state. Execution terminates when the state of the system reaches one of the states in  $Q_f$ . Figure 22 depicts a FSM model of Sam's life. There is an initial state (home) and a final state (left), and transitions modeling his daily life. From this graph it becomes clear the notion of trajectory of the system: it is the sequence of the states traversed while the system evolves, or, if we attach labels to the transitions, the string of labels in the path (eg. *Gowork, gohomefw, gowork, gocoffeh, gohomefc, gowork...*).

The concepts of reachability and observability are essential for the analysis of dynamic systems. The concept of reachability is related to the following question: is it possible for at least one trajectory of the system to reach a given state when the system departs from another state? The concept of observability is better understood if we introduce the idea of an external observer. Some of the transition labels may not be "seen" by the observer. The problem of observability is related to the following question: is it possible for the observer to infer the behavior of the system from the observation of trajectories from which some of the event labels were removed. For example, with respect to Figure 22, consider the case of an observer who is not able to "observe" the event labels *gocoffeh, gohomefc*. Is it possible for the observer to infer Sam's behavior from what he observes?

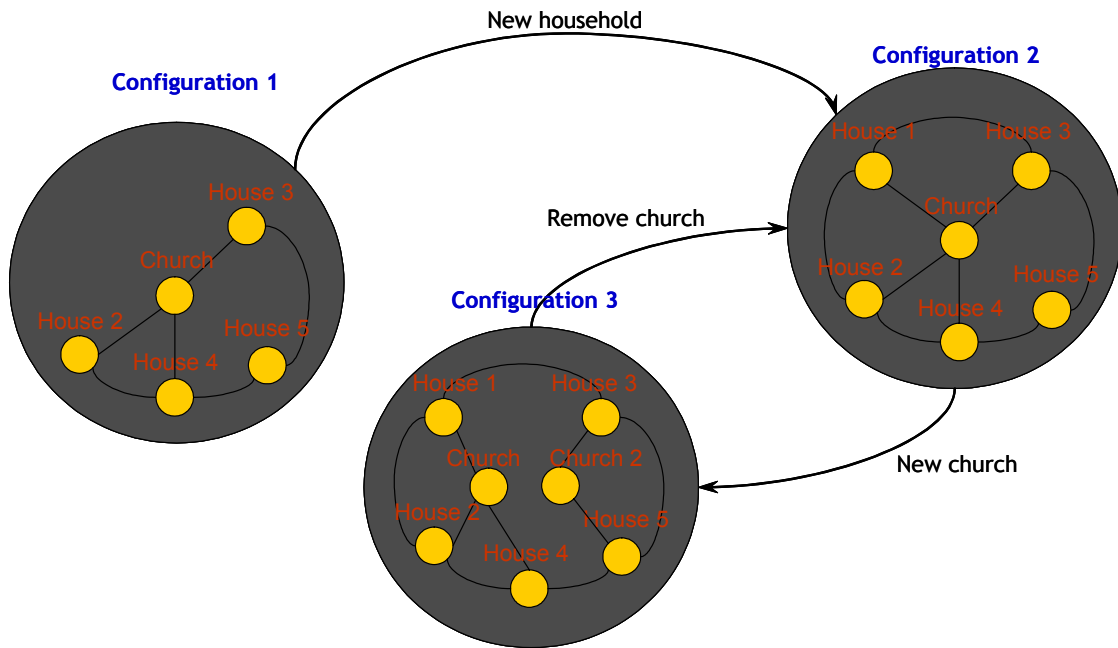
This FSM setup can be extended to encompass the problem of supervisory control. This problem is better understood if we introduce the notion of controller which can enable or disable transitions in the FSM. By enabling and disabling transitions it is meant the ability to block (or unblock) the system to take these transitions. Then it is possible to introduce the notion of "bad" states, i.e. states which should be avoided. The control problem consists in deriving a strategy for the controller to prevent the trajectories of the system to enter the "bad" states. The strategy consists of selectively enabling and disabling transitions of the system. This is the case of regulatory actions in societal systems.



**Figure 23 Timed automata**

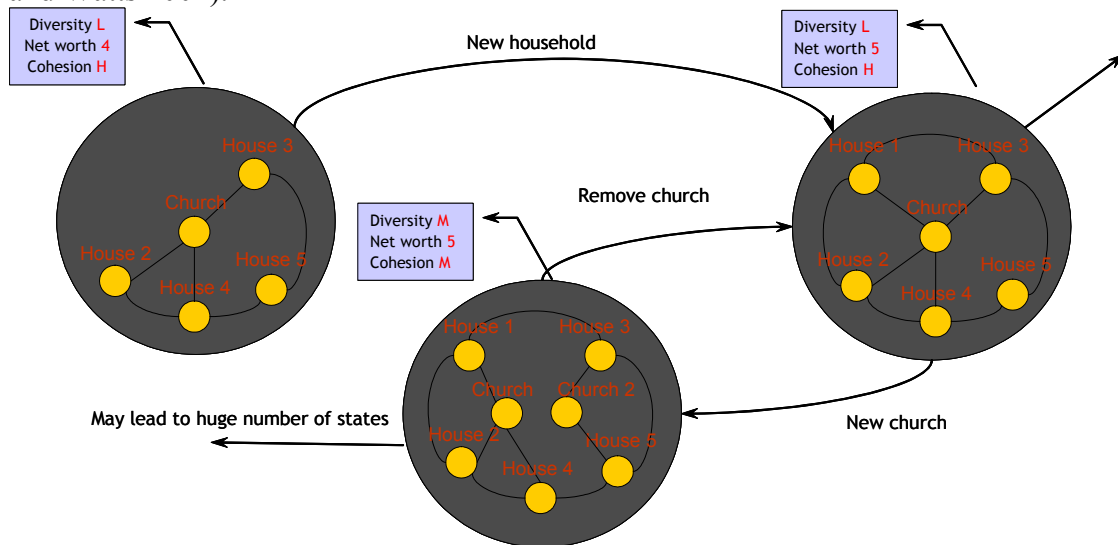
The notion of time is absent in the basic FSM machine model – the behavior of the FSM concerns sequences of states or of event labels. Timed automata (Figure 23) model the passage of time in addition to the state transitions of a FSM. This is done by associating “clocks” to each node. By doing this it is possible to associate to each edge conditions which depend on the values of a clocks. For example it is possible to model the fact that a system transitions between two states when the value of the clock associated to the initial state is greater than a given number. The “trajectories” of the system now include time. For example with respect to the previous example now we have: *Gowork (8.00)*, *gohomefw (18.00)*, *gowork (8.00)*, *gocoffeeh (18.00)*, *gohomefc (20.00)*, *gowork (8.00)*... Hybrid automata have more expressive power than timed automata in the sense that we are able to consider continuous time models other than clocks. Lee and Varaiya (Lee and Varaiya, 2002) is a good introductory text to these concepts. In some modeling frameworks the hybrid automaton is specialized by augmenting it with the notion of input and output variables/actions (for the continuous and discrete case respectively). This framework defines the notion of external behavior, i.e. the discrete and continuous interactions between the automaton and the environment. Researchers have used dynamic networks of hybrid automata *DNHA* to model dynamic interactions. Informally, *DNHA* allow for interacting automata to create and destroy links among themselves and for the creation and destruction of automata.

Two other concepts are of relevance in the analysis of network systems. The first one concerns configurations, i.e. the structure of a system at a given point in time. In terms of graph models this means a graph which encodes the relations among the constituent elements of the system (the nodes are the constituent elements and the edges the relations among them). But the configuration of a real system, i.e. a system which evolves with time, is not static: the system evolves through several configurations which obviously share some properties, for example constituent sub-graphs. The need to represent configurations and their evolution led to the notion of configuration automata: states represent configurations and edges represent transitions among configurations. Figure 24 depicts an illustration of this concept. In this illustration we model the evolution of the small village model. The “trajectories” of the system are now: *Configuration1*, *Configuration2*, *Configuration3*, *Configuration2*, ...



**Figure 24 Configuration automata example**

The other concept is directly related to the notion of configuration. A system may exhibit properties which depend on its configuration. For example the value of a configuration represents the total utility or production of a given configuration (Jackson and Watts 2002).



**Figure 25 Value of configurations**

The evolution of a complex system which goes through several configurations may be guided by external factors, which is the case of supervisory control above described, or by the intrinsic dynamics of the system, which may lead, for example, to the creation of new entities, to changes of configurations and to the emergence of new properties; this happens when some configurations are attained. In turn, the emergence of these properties may lead to different patterns of creation, to other configurations, and to the emergence of other properties. We are in the presence of self-evolving networks.

The mechanisms which guide the behavior of such systems are quite difficult to model (and to identify from its behavior) due to the intricacy of the relations thus established. These may lead to the reinforcement of certain configurations, or to the disruption of the system itself. Moreover, systems are never isolated, and the mechanisms by which systems evolve always depend on interactions with other systems, which can be defined as different for the purpose of analysis. The way in which we can establish two systems as different (as opposed to the idea of one system) can be based on the connectedness properties of the system. For example a network model with two weakly connected components can be modeled as two different systems.

Surprisingly, network models of natural, societal and technological systems exhibit some properties which do not depend on the scale of the system (which is somewhat related to the number of nodes and edges). For example, in networks of scientific citations the degree of connectivity for each node does not vary in a significant way. (Dorogovtsev and Mendes 2002).

#### **4.2. URBAN SYSTEMS AS SELF-EVOLVING NETWORKS**

From the above it is clear that an urban system is a self-evolving network. This happens despite the existence of regulatory actions which are induced by entities of the urban system itself, for example city mayors. In fact, urban systems define interacting networks at several levels of representation: individuals and the roles they play, organizations and institutions which are, to a certain extent, independent of individuals and depend more on the roles played by these individuals, and properties which depend on the configurations of these networks. Urban systems evolve through several configurations, which depend on the societal organization, and also on interactions with the neighboring systems which, for operational purposes, are defined as those with weak connections with the urban system itself. However, it may happen that these weak connections occur only within some sub-networks of the urban system, while other sub-networks do not exhibit the same degree of connectedness. This is the case of family networks as opposed to the case of organizational networks which are becoming more pervasive throughout the world.

### **5. OPEN QUESTIONS**

The self-evolving model of an urban systems leads naturally to several research questions at several levels of abstraction.

- 4) How do we measure the relative strength of interactions in an urban system?
- 5) What are, for a given level of analysis, the sub-networks of interest?
- 6) How do we conceptualize a good pattern of integration?
- 7) How does the “goodness” of integration depend on the properties of the sub-networks of interest?
- 8) Is it possible to define or come up with a taxonomy of configurations (and related properties)?
- 9) What are the rules defining the transition among configurations?

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