Modeling Refugee Migration

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March 5, 2016

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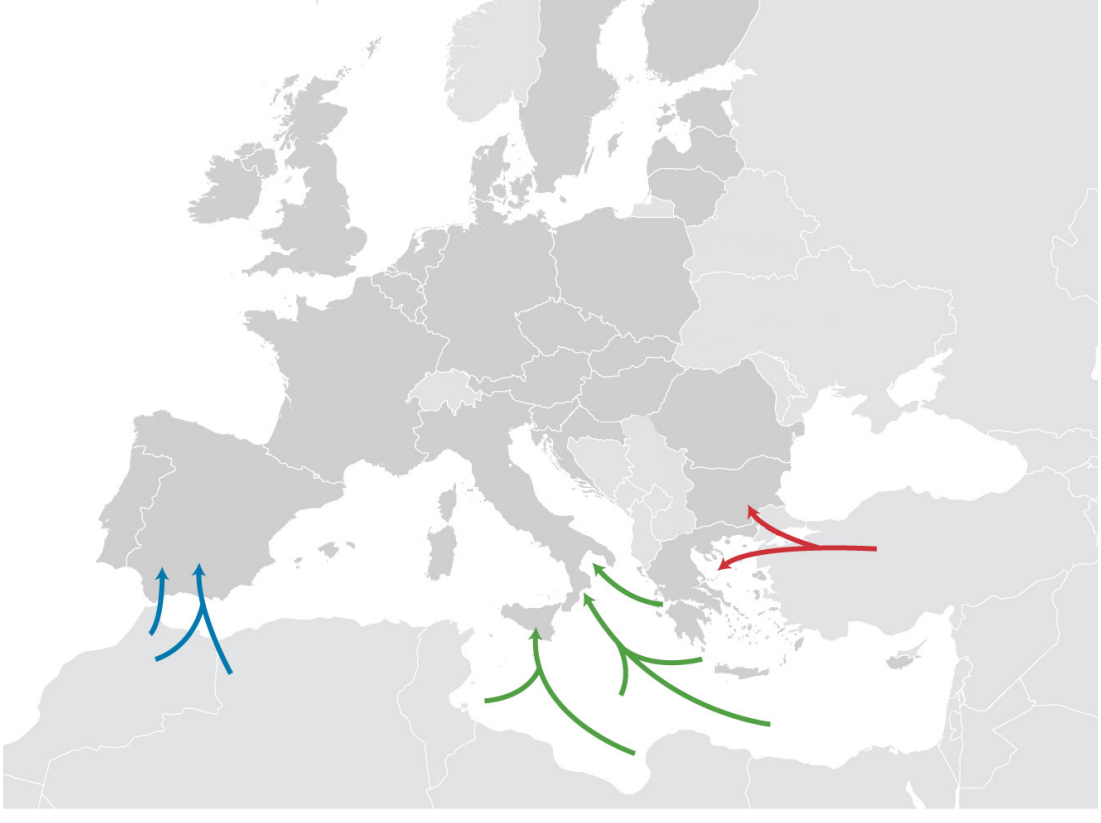
- According to the UNHCR, more than 10 million people make up the current refugee population, hailing from countries like Syria, Afghanistan, Sudan and Eritrea.
- Predicting how these large populations will migrate to safe haven destinations will help governments and organizations to cope with the current crisis.

- General migration patterns exist, but are very dynamic.
- Limited resources, transportation capacities, health problems, and lack of safe travel conditions can all dramatically alter refugee behavior.

Main Refugee Migration Routes



Once the refugees have reached gateway nations like Turkey, Greece, and Italy, how do they disperse in the rest of Europe?

- Haven countries and sources of refugees are nodes in a network
- Edges connecting nodes have capacities

The Network


Sweden
14
Norway
12
Finland
13
Estonia
Latvia
Lithuania
Moscow
Москва
North Sea
Baltic Sea
United
Kingdom
Denmark
Netherlands
Berlin
Poland
Warsaw
Belarus
London
Germany
8
Belgium
Prague
Czech Rep
Paris
Vienna
Slovakia
Ukraine
Austria
Moldova
Hungary
France
10
7
6
Romania
Croatia
Serbia
Black Sea
Italy
9
Bulgaria
Georgia
Caspian Sea
Uzbekistan
Madrid
Rome
Azerbaijan
Tyrrhenian Sea
Spain
11
Greece
5
Turkey
4
Turkmenistan
Syria
Tunisia
Mediterranean Sea
Lebanon
1
Afghanistan
2
Iraq
3
Israel
Jordan
Iran

Flow rates in the network can be expressed as a Markov chain transition matrix, **Q**. If we assume **Q** to be stationary, refugee distributions at time **t** are given by

$$\mathbf{d_t} = \mathbf{d_0}\mathbf{Q}^{\mathbf{t}}$$

In order to determine the values of **Q** we took data from the statistics agency Eurostat on the number of political asylum applications in a region relative to the total population of refugees present.

Non-Stationary Transition Matrices

We allow **Q** to change with time. Thus the refugee distributions are now given by

$$\mathbf{d_t} = \mathbf{d_0} \prod_{\mathbf{i}=\mathbf{1}}^{\mathbf{t}} \mathbf{Q_i}$$

Flow Matrix	1	2	3	4	5	6	7	8	9	10	11	12
1: Syria	0.125			0.82	0.035							
2: Afghanistan		0.45		0.5								
3: Iraq			0.008	0.99								
4: Turkey				0.598	0.4							
5: Greece					0.0015	0.541	0.221		0.221			
6: Hungary						0.25	0.748					
7: Austria							0.1	0.898				
8: Germany								0.756		0.0698		0.023
9: Italy								0.5	0.101	0.487		
10: France										0.717	0.281	
11: Spain											0.99	
12: Norway												0.628
13: Sweden												0.058
14: Finland												

Algorithmic Implementations

- Capacity checks
- Backflows

Stochastic Parameters

Rather than considering capacities and the initial flow values to be strictly deterministic, we allowed them to be generated by appropriate distributions. We considered the mean population distribution in our final analysis.

Applications

- Distribution Analysis
- Policy Recommendations
- General Migration Problems

Conclusion

The refugee migration problem is a very dynamic one. Oversimplification of the true variation in human behavior can seriously threaten the validity of a migration model. We used non-stationary Markov chains simulate very complex network interactions in an algorithmic fashion.