Miguel, Amblard, Barceló & Madella (eds.) Advances in Computational Social Science and Social Simulation
Barcelona: Autònoma University of Barcelona, 2014, DDD repository <http://ddd.uab.cat/record/125597>

DITCH: A Model of Inter-ethnic Partnership Formation

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Abstract—**This paper describes an agent-based model of inter-ethnic partnership formation. Inter-ethnic marriage, both a cause and a consequence of immigrant integration, is generally used to imply that the social distance between groups is low and, by extension, that community cohesion is high. Using a descriptive agent-based modelling approach, we seek to investigate the processes of partner selection in diverse communities, focusing on individual preferences, opportunities for contact, and group norms to uncover how these may lead to differential rates of inter-ethnic marriage.**

I. Introduction

OVER the past decade social scientists have become increasingly interested in what insights the science of complex physical and biological systems seem to provide for our understanding of social systems and practices. The "Social Complexity of Immigration and Diversity" (SCID) project has attempted to integrate the apparent advances of complexity science approaches through the development of Agent-Based Models (ABMs) of the complex social phenomena under considerations.

In this paper, we use ABMs to model inter-ethnic partnerships, seen as a both a cause and consequence of immigrant integration [1] and inter-group relations [2], in Britain. We draw our rules on existing sociological evidence stating that both individual-level preferences (via assortative mating [3]), opportunities for contact (via diversity, group size, population size and sex ratios [4] [5]), and family and kin networks [6] [7] are important drivers of inter-ethnic partner choice. Such influences have been measured quantitatively in Britain [8] [9], but never to our knowledge in a dynamic setting as can be provided by ABM.

Marriage 'markets' lend themselves readily to agent-based modelling – they allow the exploration of the ways in which 'bottom-up' psychological inputs (individual agents choosing specific mates) lead to 'top-down' demographic outcomes (population level patterns of marriage and mate selection) [10]. The emergence of meso-level social processes, which are neither directly scalable from individual preferences nor readily predictable from population-level patterns, appears to be a key feature of marriage processes, and has been of some interest to agent-based modellers in the past [11], [12].

The work reported in this paper is part of the "Social Complexity of Immigration and Diversity" (SCID) project and has been funded by the EPSRC within the "Complexity Science for the Real World" framework.

II. Related Work

Existing agent-based models of marriage have tended to concentrate on the emergence of population-level patterns from a relatively small set of agent preferences. One of the earliest models [13] used a single generic rankable trait to explore partnering mechanisms. Later models, such as MADAM (Marriage and Divorce Annealing Model) [14] and the 'Wedding Ring' model [11], included a number of generic mate relevant traits and heuristic processes such as social pressure and aspiration. Matching in these models is homophilic (and, therefore, assortative) and involves elements of satisficing (i.e. agents do not wait to find a 'perfect' mate, rather one who is 'good enough'). Walker & Davis [12] produced a model of inter-ethnic marriage rates in New Zealand and, unlike previous models, utilised unit-level micro data from the New Zealand census. The model considers a fixed cohort of single 18-30 year olds, assigning male agents a random social network of female potential partners. Partnerships are formed between the best-matched agents with regard to similarity of age and education levels, a stochastic attraction factor and a macro 'social pressure' mechanism. Whilst this is the most sophisticated agent-based analysis of the dynamics of inter-ethnic marriage, it consistently over-estimates the rate of exogamy when compared to census data, which indicates '... that there is some degree of ethnic preference that is not being captured by the model' [12: 6.4].

III. Model Description

Our approach with developing the DITCH ("Diversity and Inter-ethnic marriage: Trust, Culture and Homophily") model has been to start with a simple model that includes only processes and data essential to modelling (inter-ethnic) partnership formation, but which can be easily extended when necessary. The model is therefore constrained to simulating a cohort of – at model initialization -- single agents aged 18-35 years who search for a suitable partner within their social network.

In the current model version agents are characterised by five traits:

1. Gender (male or female). This is initialised randomly, with 50% chance each of being male or female.
2. Age (18-35). This is initialized according to an age distribution taken from the UK Census 2001.
3. Ethnicity (one of four discrete values representing abstract ethnicities: w, x, y, z). This is initialized randomly according to the proportions specified via a model parameter (*eth-proportions*).
4. Compatibility (a real number between 0 and 1 modelling "chemistry" between agents; the closer their compatibility scores, the more compatible are the agents). This is initialized uniformly randomly between 0 and 1.
5. Education (an integer in [0,4] representing education level with 0: none, 1: level 1 (some GCSEs), 2: level 2 (GCSEs), 3: level 3 (A-Levels), 4: level 4/5 (university degrees)). This is initialized according to distributions particular to ethnic group and gender taken from the UK Census 2001. Each abstract ethnicity (w, x, y, z) is assigned an ethnic group via the model parameters *ethnicity-w*, *ethnicity-x*, *ethnicity-y*, *ethnicity-z*.

Agents also have preferences for partners with certain traits. These are expressed as follows:

1. Gender: opposite gender. (We assume a strictly heterosexual world for now.)
2. Age: a range of +-2 to 10 years centered on the agent's own age. This is initialized randomly.
3. Ethnicity: a preference value for each of the four represented ethnicities, with a slight bias towards the agent's own ethnicity. These are initialized randomly with values between 0 and 1; making sure that the agent's own ethnicity receives the highest value.
4. Compatibility: a range of +- 0.05 to 0.5 centered on the agent's own compatibility value. This is initialized randomly.
5. Education: Instead of having a preference for a particular education level, we assume that agents prefer their potential partner to not differ too much from their own education level. Education preference is therefore expressed as a preference for the difference in education level (from 0 to 4). This is initialized via a normal distribution with mean 0 and standard deviation between 0 and 4 (set via the model parameter *sd-education-pref*).

Agents employ their social network to look for potential partners. Since agents are 18-35 years old at model initialization, at least some of the social links between agents need already be established. These can be ties with friends, family, neighbours or colleagues; the model does not differentiate between different types of links. To start agents off with a plausible social network newly created agents are trying to find an empty cell on the grid next to one of their own ethnicity. Only if that is not possible, they pick a random free cell. This results in clustering of minorities. Agents then form links with some of their neighbours. After this, a Schelling-like segregation is run for 50 ticks to let agents segregate according to age and then form links with some of their neighbours again. This attempts to achieve a social network where agents have cross-ethnic links to agents of a similar age ("school friends") and same-ethnic links to agents of a wider age range ("family", "neighbours").

The social network changes over time with agents forming new links and dropping old links. Each tick an agent has a chance of 50% to form a new link with either the most similar (with regard to age, ethnicity and education) friend of a randomly picked friend (95%) or a random stranger (5%). There is also a small chance (5%) to drop a randomly picked link (except for marriage links).

Agents utilise their social network to find potential partners of the opposite gender and within their preferred age range. Each tick, agents who are still single and not currently dating anyone start looking in their immediate links (level 1) and widen their search further outwards (level 2: friends of friends, level 3: friends of friends of friends, etc.) if they cannot find at least 3 potential partners. They then choose one of those 3 potential partners randomly to go on a "blind" date. The depth of the search (level 1, 2, 3…) is determined by the model parameter *love-radar*.

During a date, the two agents determine if they are satisfied with their potential partner based on the 'public' traits gender, age, ethnicity and education. While the suitability of gender and age have already been determined in the partner search, each agent now checks if their partner's ethnicity and education level are acceptable. This is the case if the difference in education falls within an agent's preferred difference and if a random number in [0,1] is smaller than the agent's preference value for their partner's ethnicity (the preference values for ethnicities are thus interpreted as probabilities).

If both agents are satisfied with their partner they will start dating, i.e. they will not continue to look for potential partners. The duration of the dating period follows a normal distribution with mean *mean-dating* and standard deviation *sd-dating* (both model parameters).

After the dating period is over, agents proceed to the next stage: they try out for marriage. This means, that they reveal their compatibility value to each other. If both agents' partner's compatibility score lies within their preferred range, the agents have a high chance of partnering:

$$1 - |compatibility_1 - compatibility_2|.$$

As compatibility scores get closer the probability increases towards 1. This process is derived from 'the mate searching game' [15]. If agents partner successfully, they remain in the model to keep the social network intact, but are no longer available as potential partners for others.

Agents update their preferences based on their dating experiences. An unsuccessful blind date will widen the preferred age range slightly (by 0.1) and negatively affect the preference for the other agent's ethnicity (reduced by 0.01), whereas a successful date will boost the preference value for the other's ethnicity by 0.01 (to a maximum of 1.0). After an unsuccessful marriage test the agents will expand their preferred compatibility range scores slightly (by 0.05) to mimic the idea that unsuccessful dating events encourage us to become less fussy in our preferences. The influence of dates on preferences can be controlled via the model parameter *update-threshold*. If this is set to values > 1 the change in preferences only happens after the specified number of (un-)successful dates.

This model has been implemented in NetLogo, using a monthly time step.

IV. Preliminary Results

This section provides some sample results and parameter tests to illustrate how the current model is functioning and its relative accuracy when compared to validation data. These results and tests are based on runs using scenarios derived from sample areas representing different typologies of ethnic diversity within local and urban authorities in England & Wales, based on the number of ethnic groups and the proportion of the population from a 'White: British' background. Within the sample areas the four largest ethnic groups were selected (if over 1% of overall population) and their proportions weighted to add to 100%. The sample areas are as follows (with weighted ethnic group proportions):

- *Super-diverse* sample: Newham, London
  Sample populations: White: British (WB): 30.5%; Asian/Asian British: Indian (A/ABI): 25.1%; Asian/Asian British: Bangladeshi (A/ABB): 22%; Black/Black British: African (B/BBA): 22.4%
  Inter-ethnic marriage rate (2011 UK Census): 21.13%

- *Cosmopolitan* sample: Trafford, Greater Manchester
  Sample population: WB: 90.2%; White: Other (WO): 3.2%; A/ABI: 3.1%; Asian/Asian British: Pakistani (A/ABP): 3.5%
  Inter-ethnic marriage rate: 12.81%

- *Bifurcated* sample: Bradford, W. Yorkshire
  Sample population: WB: 71.1%; WO: 3.3%; A/ABI: 2.9%; A/ABP: 22.7%
  Inter-ethnic marriage rate: 8.09%

- *Parochial* sample: Cheshire West & Chester
  Sample population: WB: 98%; WO: 2%
  Inter-ethnic marriage rate: 6.33%

- *National*: England and Wales
  Sample population: WB: 90%; WO: 5%; A/ABI: 2.8%; A/ABP: 2.2%
  Inter-ethnic marriage rate: 10.47%

A. Finding 1: Homophilic networks increase the number of marriages across all scenarios and reduce the rate of inter-ethnic matches

Fig. 1 illustrates how moving from a random social network (blue) to one based on age and ethnicity (red) increases the overall number of marriages; this is likely to be due to the initial sorting process in assigning homophilic social networks, which brings suitable matches 'closer' to each other – increasing the probability of them dating and marrying. All figures show the results of 30 runs of 120 ticks (10 years) each with the parameter *love-radar* set to 1 for runs 1-10, 2 for runs 11-20 and 3 for runs 21-30.

However, whilst homophilic networks increase the overall number of marriages, they decrease both the mean proportion and variance of cross-ethnic matches (see Fig. 2). This is due again to the higher level of homophily – ensuring that agents are more likely to date (and, thus, marry) co-ethnics, and reducing the element of chance (variance) in the nature of initial social networks.

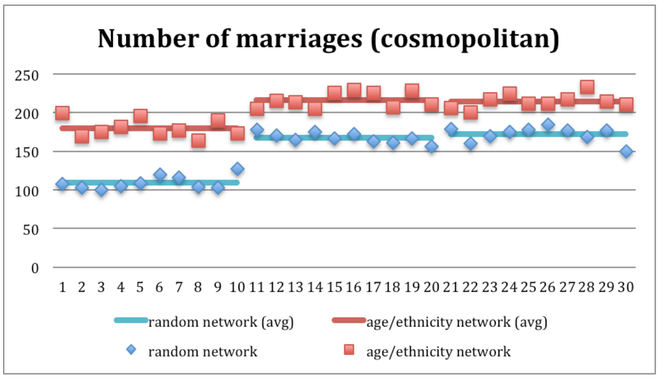

Fig. 1: Number of marriages using a random social network (blue) or a social network applying homophily based on age and ethnicity (red; see section III).

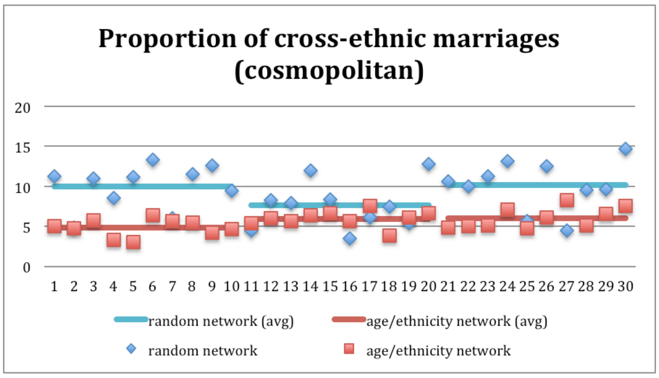

Fig. 2: Proportion of cross-ethnic marriages using a random social network (blue) or a social network applying homophily based on age and ethnicity (red).

B. Finding 2: Increasing the 'love-radar' from 1 to 2 increases the number of marriages in all scenarios and reduces variance, but not the mean average of inter-ethnic marriages (though this effect is dampened in homophilic networks)

The 'love-radar' controls the social distance an agent will look for a potential partner. A setting of 1 indicates agents will only look for 'dates' amongst those one node away from them (effectively close friends). This group will be exhausted quickly and only occasionally refreshed through social network growth. A setting of 2 indicates agents will expand their search for 'dates' to two nodes away (effectively friends of friends), thus significantly increasing their dating pool. Increasing the 'love-radar' further seems to have little additive effect.

The key change can be seen at tick 11 in Fig. 3 – note also the effect is substantially more pronounced in the random network (blue) runs, where similar agents are more likely to be socially removed from one another.

C. *Finding 3: Different areas have different rates of inter-ethnic marriage and, where there is a substantial ethnic minority, these rates map well to 'real world' data*

The four sample areas behaved broadly as expected, with the inter-ethnic marriage rate increasing as the proportion of minority ethnic groups grows (see Fig. 4). However, whilst the 'real-world' inter-ethnic marriage rate matched well with the rates in bifurcated and super-diverse samples, it was less accurate in areas with a number of small minority ethnic groups. This may be caused by the proportional increase in the majority population where a large number of small ethnicities are removed from the weighted sample (such as in the 'cosmopolitan' and 'national' scenarios). This suggests we can be broadly satisfied with the model performance so far on this measure. However, whether the model fares as well in more subtle measures is still to be explored in more depth.

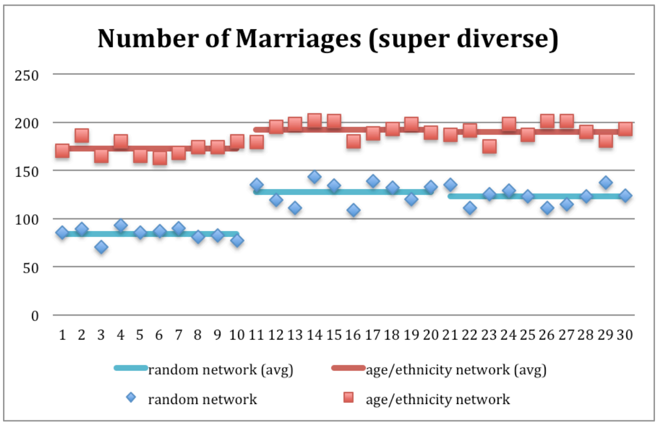

Fig. 3: Number of marriages using a random social network (blue) or a social network applying homophily based on age and ethnicity (red).

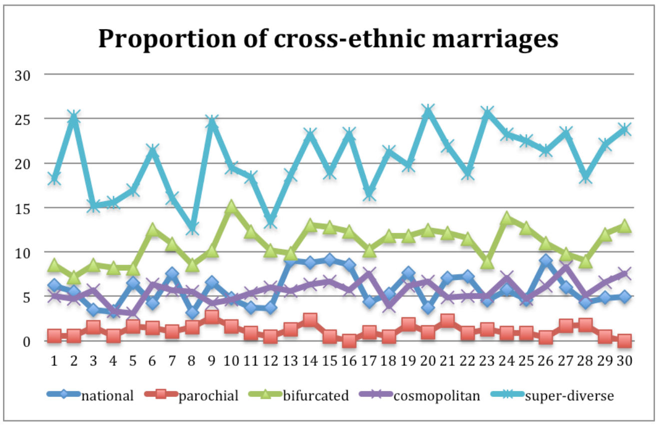

Fig. 4: Proportion of cross-ethnic marriages across the five different scenarios.

V. Conclusion and Outlook

The current model appears to be already relatively well matched to 'real-world' data. As Finding 1 shows, social networks and homophily play a large part in this, especially in social groups which practise a 'free market' model of marriage where any individual is free to partner with any other member of that social group. However, anthropologists have long recognised the importance of 'culture-based marriage norms', which restrict the available choice of partner to some extent and thus may have a profound impact on the emergence and development of inter-ethnic partnering within a mixed community. Our next step will therefore be to add marriage norms to the existing model to allow us to investigate what effects contact and marriage rules have on the inter-ethnic marriage rate.

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