What's that new word?: Diffusion as an analogy for the cultural evolution of language

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April 18, 2013

Contents

1 Introduction

Language has been called everything from the basis of human culture, to the instinct that sets our species apart from the others. It is the most precise, directed, and timeless means we have of conveying information and ideas to each other.

The smallest meaningful units of language are words, and the word-composition of a language tends to be a product of the history, geography, and culture of the society that produced it. Nowhere is this more apparent than in English, with its rich tradition of words borrowed from all over the world during the Colonial era.

New words, after they are introduced in a language, take some time to spread before they become part of the standard vocabulary. This is readily apparent when we come across headlines stating how the Oxford English dictionary has now included the words 'curry', or 'masala' in its latest edition, reflecting how they have become an integral part of the language.

With some analysis, the patterns underlying this process can be identified, and we can begin to discover the laws governing this process. In this paper, diffusion will be used as a model.

2 A Model for Diffusion

2.1 Introduction

The word diffusion comes from the Latin *diffundere*, meaning "to spread out". Diffusion occurs in the presence of concentration gradients, and particles diffuse away from a region of high concentration, due to which the concentration gradient becomes zero over time.
In fluids, diffusion is the result of the Brownian motion of the diffusing particles. In mathematics, such a motion is termed a 'random walk', which is defined as a path consisting of successive steps, each of which is random.
Each diffusion process is governed by a ***driving force***, a quantity whose gradient is proportional to the flux of the diffusing substance.

2.2 Driving forces

In the diffusion of fluid molecules, the concentration gradient of the diffusing particles is the driving force. The particles spread against the concentration gradient, i.e., away from a region of high concentration and towards a region of low concentration.

2.3 Mathematical models

The best mathematical models we have for diffusion are Fick's first and second laws. Fick's First law can be stated as follows:

$$J = -D\frac{\partial \phi}{\partial x}$$

Here, J is the diffusion flux (the amount of substance diffusing through a unit area in a unit time interval), D is the "diffusion coefficient", ϕ is the concentration of the diffusing substance, and x is the position variable.

2.3.1 Diffusion coefficient

The diffusion coefficient or diffusivity is a characteristic of the interaction between a pair of species. As apparent from Fick's law, the value of the diffusion coefficient is directly proportional to the speed of diffusion. In gases, the diffusivity is related to the pressure as follows:

$$\frac{D_{P1}}{D_{P2}} = \frac{\rho_{P2}}{\rho_{P1}}$$

where P1 and P2 are the two pressures, and ρ is the mass density of the gas at the appropriate pressure.

2.4 Fick's Second Law

Fick's Second law describes the change in concentration with time. It states that

$$\frac{\partial\phi}{\partial t} = D\frac{\partial^2\phi}{\partial x^2}$$

where ϕ, t, and x have their usual meanings.

3 Applying Diffusion to Words

3.1 Assumptions and postulates

The spread of words from one person to another in the course of social interaction is an extremely complex process, and the number of factors influencing whether one person begins using a word he/she has heard from another is so great that such an analysis would be futile. Instead, the analysis becomes easier when we deal with whole populations, and we can deal with probabilities instead.
The following assumptions are made in this analysis:

1. For each word, there is a pre-determined value of the probability that a person who hears the word will start to use it. This value shall be defined as the word's "catchiness". The catchiness of the word is an inherent property of it, arising by virtue of the word's construction. Factors like pronounceability and etymology probably influence the value of catchiness. This shall be denoted by the symbol κ in the analysis. From the definition, the allowable values of κ are 0 to 1.

2. After a sufficiently long time from the point of invention, a word reaches its saturation point, beyond which the number of new users is negligible. If the population comprises of n people, the saturation population is given by κn.

3. The likelihood of a word's adoption is proportional to the concentration of that word in society. The more often we hear a word, the more inclined we are to use it.

3.2 Why do new words arise?

The main reasons which lead to the coinage of new words are as follows:

1. Techonological, scientific, or other social developments which lead to new human experiences indescribable by the current vocabulary. New words are then invented for these, and with the increasing popularity of the technology under consideration, the words pass from the realm of jargon to that of common speech. For example, words such as RADAR, coined to describe a particular technology, are now in common parlance.

2. Changes in geography, culture, and social outlook.

   (a) One such reason can be cultural differences between multiple languages. Old words are changed in order to suit the attitudes and needs of various populations. Consider for example the contrasting profanities from Quebecois French, spoken in the French-speaking areas of Canada, and European French. Profanities in European French tend to be mainly sexual or scatological in nature, for example, "Merde!" ("shit!"), while the initially more religious population of Quebec evolved a profanity lexicon based around religious imagery, where "Tabarnak!" (a church tabernacle) is considered offensive.

   (b) Special slang terms may be introduced in small, exclusive groups, both as a means of furthering cohesion between members and as a way of identifying members amidst non-members. Such words have a higher chance of spreading between members and a lower chance of spreading froma member to a non-member. As an example, the word "pounce", used by quizzers (mainly Indian college quizzers) to indicate that they know the answer to a question posed to another team will be considered.

(c) The increased intermingling between cultures speaking different languages can result in the spread of words from different languages. Depending on physical proximity, words denoting the same thing, but originating from different languages may be popular in different geographical areas.

4 Diffusion of Code Words

Many groups have words unique to them, which help members identify and bond with each other. Examples of these include gang slang words. Consider for example the rival American gangs, the Bloods and the Crips. Each gang has its own slang terms, and a member of one gang doesn't use the slang of another. Due to this, the diffusion occurs at different rates among different people.

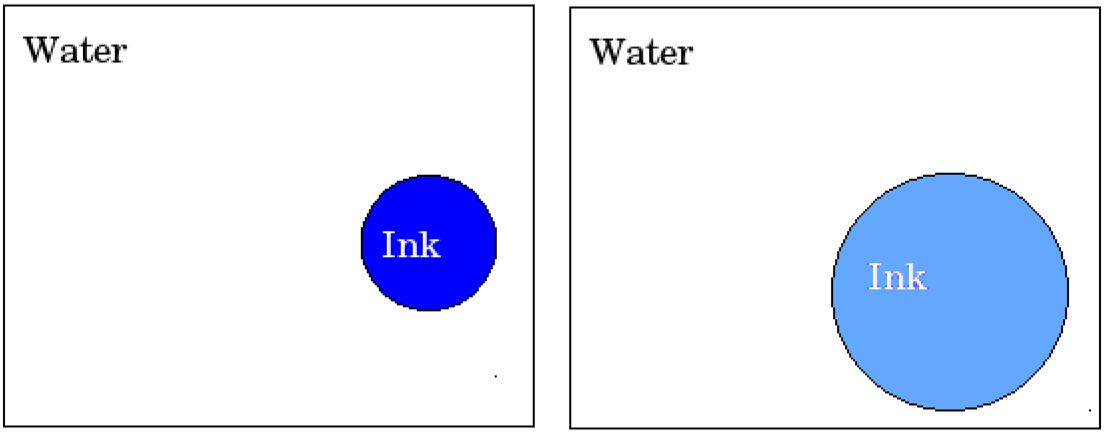
To model this, we can consider it as a case of a substance diffusing into a heterogeneous mixture of 3 liquids. Consider a new word introduced into the Bloods group. The remaining Bloods in the area will be favourably disposed towards the word, and the Crips unfavourably so. The non-gang population in the region is neither favourably nor unfavourably disposed towards adopting the word in common speech.
Applying Fick's 1st law to this case, we can write

$$J = -D_{med}\frac{\partial \phi}{\partial x}$$

where J, in place of the flux, is the number of new users gained in unit time (the propagation rate),
x is the distance measurer, D_{med} is the diffusivity of the word, and
ϕ is a quantity we shall define as the word's "diffusion pressure".

4.1 Word pressure, ϕ

The word pressure ϕ is a measure of the tendency of a word to propagate, i.e., the social pressures on adopting the use of the word. It is related to, but different from the word's catchiness, κ. To understand the role it plays in diffusion, consider the diffusion of coloured inks in water in the two scenarios shown:



In each case, although the quantity of ink added to the water is the same, the pellet on the right is more concentrated than the pellet on the left. Although both containers will have the same concentration of water once the diffusion process is complete, the diffusion will initially be faster in the container on the left, since the concentration gradient of the ink is greater.
Similarly, while the catchiness dictates the final state, the unsteady state dynamics of word diffusion is determined by the word pressure.

4.1.1 Relationship between word pressure and catchiness

To obtain the relationship between ϕ and κ, we can use the definition of the propagation rate, J.

Since J is the number of new users gained per unit time, the total number of new users gained in time dt is Jdt. Multiplying both sides of the Fick's first law equation with dt and integrating between the limits of 0 to ∞, we get:

$$\int_0^\infty J dt = \int_0^\infty -D_{med} \frac{\partial \phi}{\partial x} dt$$

Since

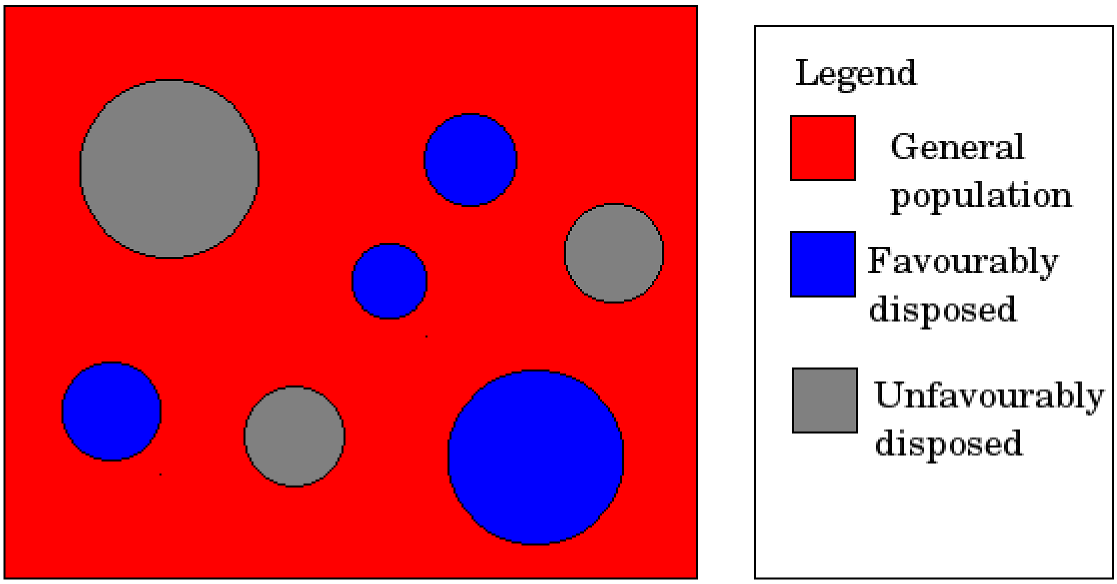
$$\int_0^\infty J dt = \kappa n$$

we can write

$$\int_0^\infty \frac{\partial \phi}{\partial x} dt = -\frac{\kappa n}{D_{med}}$$

The quantity on the right is a constant for any given interaction, and so this is the final equation relating word pressure and catchiness.

4.2 Analysis of code word propagation



Using the above definitions, we can see that in the case of the Bloods/Crips gang slang, there are three different media, each with a different value of D_{med}. Considering, as stated above, a new word introduced by the Bloods, let us denote D_1, D_2, and D_3 as the diffusivities of the word among the Bloods, the Crips, and the regular population respectively. Then we have the following relations:

$$\kappa_2 \approx 0$$

(since the rival gang avoids using the word), and

$$\kappa_1 \ggg \kappa_3$$

(since the other Bloods are more likely to incorporate the word into their speech than the general public.) Also, D_1has a very large value when compared to D_2, and D_3. Each isolated group can be thought of as being "seeded" by the introduction of the word from the outside. While the word spreads slowly among the general population, its spread stops in a Crips neighbourhood, and accelerates and quickly spreads in a Bloods neighbourhood.

5 The Diffusion of a Technical Term

The diffusion of newly invented technical terms is one of the simplest cases to study, because the requirement for the word is new, and there are no alternatives to it. The diffusion can then be modelled analogously to an ideal gas, A, diffusing into a container filled with another gas, B. The number of particles of B is given by n, the total population. The ratio of the number of particles of A to those of B is given by κ, the catchiness of the word.

Since the rate of the word's adoption is proportional to the number of people already using it, we can write

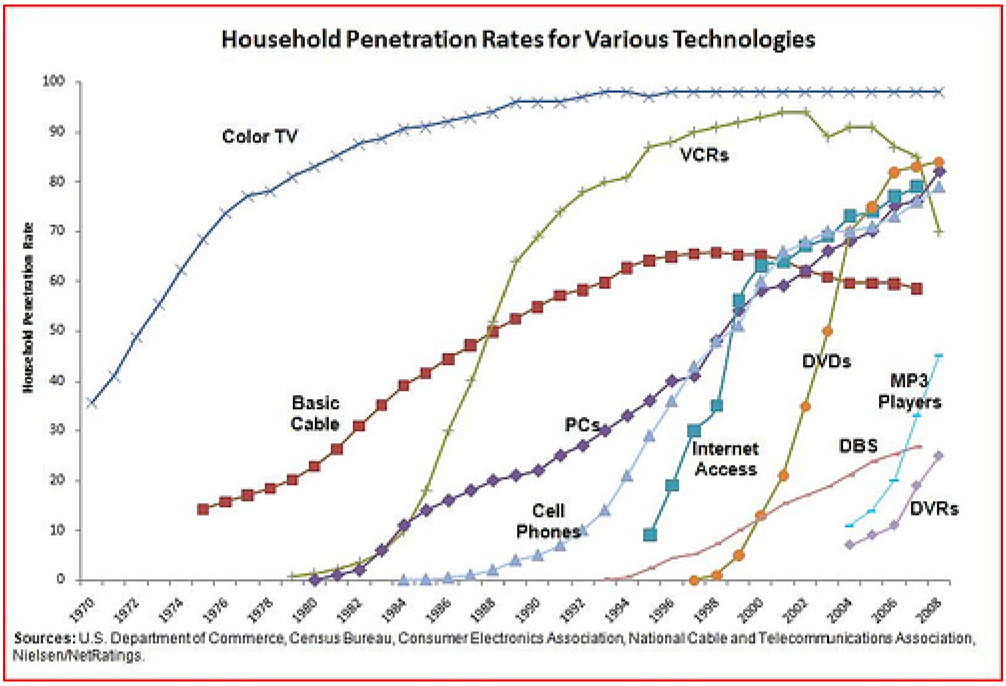
$$\frac{dN}{dt} = rN$$

where N is the number of current users of the word in the population. The upper limit of N is given by κn, and the lower limit is the number of people who introduced it, which must be at least 1.

Upon rearranging and integrating, we get

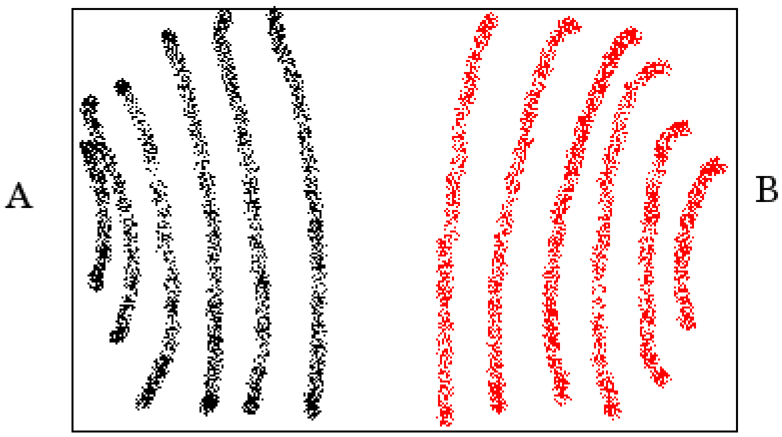
$$N = e^{rt}$$

where r is some appropriate constant of proportionality. This sort of exponential growth is seen in the adoption rates of some of the more recent technologies such as MP3 players and DVRs, as can be seen from the following graph:



6 Competing Diffusion Processes - A Qualitative Analysis

Very often, we have multiple candidate words arising to suit the same purposes. This can be modelled as a set of competing diffusion processes. Consider, for the sake of simplicity, a word which has 2 alternatives, A and B.



The diffusion process in this case will involve, initially, the diffusion of both words separately, following which the first word to attain a majority following will soon become the dominant word, and replace the other word. Hence, such a process would inolve the diffusion of both A and B, followed by the reverse diffusion of one of those words.

7 Further Refinement

The models discussed involve many simplifications which can be removed to make them more accurate. A brief discussion on potential avenues for further research into this topic follows:

- Words sometimes fall out of use, or become archaic and out-dated. There are many reasons for this, and an analysis of the way this happens would be interesting to looks at.
- The catchiness of a word does not always remain contant with time.
  - It may be influenced by other words - a catchier word often tends to dinimish the catchiness of another word.
  - famous usages of certain words by politicians or in television/cinema may affect the catchiness of words and change the values in a matter of days. Cinema catchphrases are a well-known example of this phenomenon.

Acknowledgements

I would like to thank Prof. G K Suraishkumar for giving me the opportunity and encouragement to perform this analysis as part of his Transport Processes and Unit Operations course. All the images in the project are my own work, unless otherwise credited.

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