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# Tourist Guide and Map, Aizawl and the Graphical Law

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**Abstract**

We study the names of the places in the Tourist Guide and Map, Aizawl, designed, cartographed, printed and published by Indian Map Service, Jodhpur, Rajasthan, India, in the year 2016.We draw the natural logarithm of the number of names, normalised, starting with a letter vs the natural logarithm of the rank of the letter, normalised. We conclude that the Tourist Guide and Map, Aizawl, can be characterised by the magnetisation curve, BP(4, βH=0), in the Bethe-Peierls approximation of the Ising Model, in the presence of four nearest neighbours and in the absence of external magnetic field, H= 0.

**Keywords:** Aizawl, Map, Ranking, Magnetisation, Ising Model, the Bethe-Peierls approximation

## Introduction

Aizawl is the capital of Mizoram, a state in the north-eastern part of India. We look into one tourist map of this state. This is the Tourist Guide and Map, Aizawl, designed, cartographed, printed and published by Indian Map Service, Jodhpur, Rajasthan, India, and distributed for the North-East Region by the United Publishers, [1], way back in the year 2016. We study the names of the places on this map. We count the number of the names of the places in the Tourist Guide and Map, Aizawl, one by one, to probe for the magnetic field pattern. We have started considering magnetic field pattern in, [2], in the languages we converse with. We have studied there, a set of natural languages, [2], and have found existence of a magnetisation curve under each language. We have termed this phenomenon as the Graphical Law. Then, we moved on to investigate, in [3], into dictionaries of five disciplines of knowledge and found the existence of a curve of magnetisation under each discipline. This was followed by finding of the graphical law in references from, [4], to, [82].

We describe how the graphical law is hidden within the names of places appearing in the Tourist Guide and Map, Aizawl, [1], in this article. The planning of the paper is as follows. We give an introduction to the standard curves of magnetisation of Ising model in the section II. In the section III, we describe analysis of the names of the places of the Tourist Guide and Map, Aizawl, [1]. The section IV is Acknowledgment. The last section is Bibliography.

## Magnetisation

**Bragg-Williams Approximation:** Let us consider a coin. Let us toss it many times. Probability of getting head or, tale is half i.e. we will get head and tale equal number of times. If we attach value one to head, minus one to tale, the average value we obtain, after many tossing is zero. Instead let us consider a one-sided loaded coin, say on the head side. The probability of getting head is more than one half, getting tale is less than one-half. Average value, in this case, after many tossing we obtain is non-zero, the precise number depends on the loading. The loaded coin is like ferromagnet, the unloaded coin is like paramagnet, at zero external magnetic field. Average value we obtain is like magnetisation, loading is like coupling among the spins of the ferromagnetic units. Outcome of single coin toss is random, but average value we get after long sequence of tossing is fixed. This is long-range order. But if we take a small sequence of tossing, say, three consecutive tossing, the average value we obtain is not fixed, can be anything. There is no short-range order.

Let us consider a row of spins, one can imagine them as spears which can be vertically up or, down. Assume there is a long-range order with probability to get a spin up is two third. That would mean when we consider a long sequence of spins, two third of those are with spin up. Moreover, assign with each up spin a value one and a down spin a value minus one. Then total spin we obtain is one third. This value is referred to as the value of long-range order parameter.

Now consider a short-range order existing which is identical with the long-range order. That would mean if we pick up any three consecutive spins, two will be up, one down. Bragg-Williams approximation means short-range order is identical with long-range order, applied to a lattice of spins, in general. Row of spins is a lattice of one dimension.

Now let us imagine an arbitrary lattice, with each up spin assigned a value one and a down spin a value minus one, with

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an unspecified long-range order parameter defined as above by L = 1/N $\sum_i \sigma_i$ where, $\sigma_i$ is i-th spin, N being total number of spins. L can vary from minus one to one. N = $N_+$+$N_-$, where, $N_+$ is the number of up spins, $N_-$ is the number of down spins. L = $\frac{1}{N}$ ($N_+$-$N_-$). As a result, $N_+$ = $\frac{N}{2}$ (1 + L) and $N_-$= $\frac{N}{2}$ (1-L). Magnetisation or, net magnetic moment, M is μ$\sum_i \sigma_i$ or, μ($N_+$-$N_-$) or, μNL, $M_{max}$ = μN. $\frac{M}{M_{max}}$= L. $\frac{M}{M_{max}}$ is referred to as reduced magnetisation. Moreover, the Ising Hamiltonian, [83], for the lattice of spins, setting μ to one, is $-\varepsilon\sum_{n.n} \sigma_i \sigma_j - H\sum_i \sigma_i$, where n.n refers to nearest neighbour pairs. The difference of energy, ΔE, if we flip an up spin to down spin is, [84], 2εγ$\bar{\sigma}$+ 2H, where γ is the number of nearest neighbours of a spin. According to Boltzmann principle $\frac{N_-}{N_+}$equals exp(− △E/$k_B$ T), [85]. In the Bragg-Williams approximation, [86], $\bar{\sigma}$=L, considered in the thermal average sense. Consequently,

ln $\frac{1+L}{1-L}$ = 2 (γεL+H)/($k_B$ T) = 2 (L+H/γε)/(T/(γε/$k_B$)) =2(L+c)/(T/$T_c$) (1)

Where, c = H/εγ. $T_c$ = εγ/$k_B$, [87]. T/$T_c$ is referred to as reduced temperature. Plot of L vs T/$T_c$ or, reduced magentisation vs. reduced temperature is used as reference curve. In the presence of magnetic field, c ≠ 0, the curve bulges outward. Bragg-Williams is a Mean Field approximation. This approximation holds when number of neighbours interacting with a site is very large, reducing the importance of local fluctuation or, local order, making the long-range order or, average degree of freedom as the only degree of freedom of the lattice.

To have a feeling how this approximation leads to matching between experimental and Ising model prediction one can refer to FIGURE 12.12 of the book, [84]. W. L. Bragg was a professor of Hans Bethe. Rudlof Peierls was a friend of Hans Bethe. At the suggestion of W. L. Bragg, Rudlof Peierls following Hans Bethe improved the approximation scheme, applying quasi-chemical method.

**Bethe-Peierls Approximation in Presence of Four nearest Neighbours, in Absence of External Magnetic Field:**

In the approximation scheme which is improvement over the Bragg-Williams, [83], [84], [85], [86], [87], due to Bethe-Peierls,[88], reduced magnetisation varies with reduced temperature, for γ neighbours, in absence of external magnetic field.

$$(\ln \gamma/(\gamma-2))/(\ln (\text{factor}-1)/D) = T/T_c \qquad (2)$$

Where, D=$factor^{((\gamma-1)/\gamma)}$-$factor^{(1/\gamma)}$ and factor=($1+\frac{M}{M_{max}}$)/( $1-\frac{M}{M_{max}}$). For γ=4 i.e. for four nearest neighbours, ln$\frac{\gamma}{\gamma-2}$ is 0.693.

In the following, we describe datas generated from the Equation 1 and the Equation 2 in the table, Table-1, and curves of magnetisation plotted on the basis of those datas. BW stands for reduced temperature in Bragg-Williams approximation, calculated from the Equation 1. BP(4, βH=0) represents reduced temperature in the Bethe-Peierls approximation, for four nearest neighbours, computed from the Equation 2. The data set is used to plot Figure 1. Empty spaces in the table, Table-1, mean corresponding point pairs were not used for plotting a line.

**Table 1:** Reduced magnetisation vs reduced temperature datas for Bragg-Williams approximation, in absence of and in presence of magnetic field, c=H/γε =0.01, and Bethe-Peierls approximation in absence of magnetic field, for four nearest neighbours.

| BW(c=0) | BW(c=0.01) | BP(4, βH=0) | Reduced Magnetisation |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0.435 | 0.439 | 0.563 | 0.978 |
| 0.439 | 0.443 | 0.568 | 0.977 |
| 0.491 | 0.495 | 0.624 | 0.961 |
| 0.501 | 0.507 | 0.630 | 0.957 |
| 0.514 | 0.519 | 0.648 | 0.952 |
| 0.559 | 0.566 | 0.654 | 0.931 |
| 0.566 | 0.573 | 0.7 | 0.927 |
| 0.584 | 0.590 | 0.7 | 0.917 |
| 0.601 | 0.607 | 0.722 | 0.907 |
| 0.607 | 0.613 | 0.729 | 0.903 |
| 0.653 | 0.661 | 0.770 | 0.869 |
| 0.659 | 0.668 | 0.773 | 0.865 |
| 0.669 | 0.676 | 0.784 | 0.856 |
| 0.679 | 0.688 | 0.792 | 0.847 |
| 0.701 | 0.710 | 0.807 | 0.828 |
| 0.723 | 0.731 | 0.828 | 0.805 |
| 0.732 | 0.743 | 0.832 | 0.796 |
| 0.756 | 0.766 | 0.845 | 0.772 |
| 0.779 | 0.788 | 0.864 | 0.740 |
| 0.838 | 0.853 | 0.911 | 0.651 |
| 0.850 | 0.861 | 0.911 | 0.628 |
| 0.870 | 0.885 | 0.923 | 0.592 |
| 0.883 | 0.895 | 0.928 | 0.564 |
| 0.899 | 0.918 |  | 0.527 |
| 0.904 | 0.926 | 0.941 | 0.513 |
| 0.946 | 0.968 | 0.965 | 0.400 |
| 0.967 | 0.998 | 0.965 | 0.300 |
| 0.987 |  | 1 | 0.200 |
| 0.997 |  | 1 | 0.100 |
| 1 | 1 | 1 | 0 |

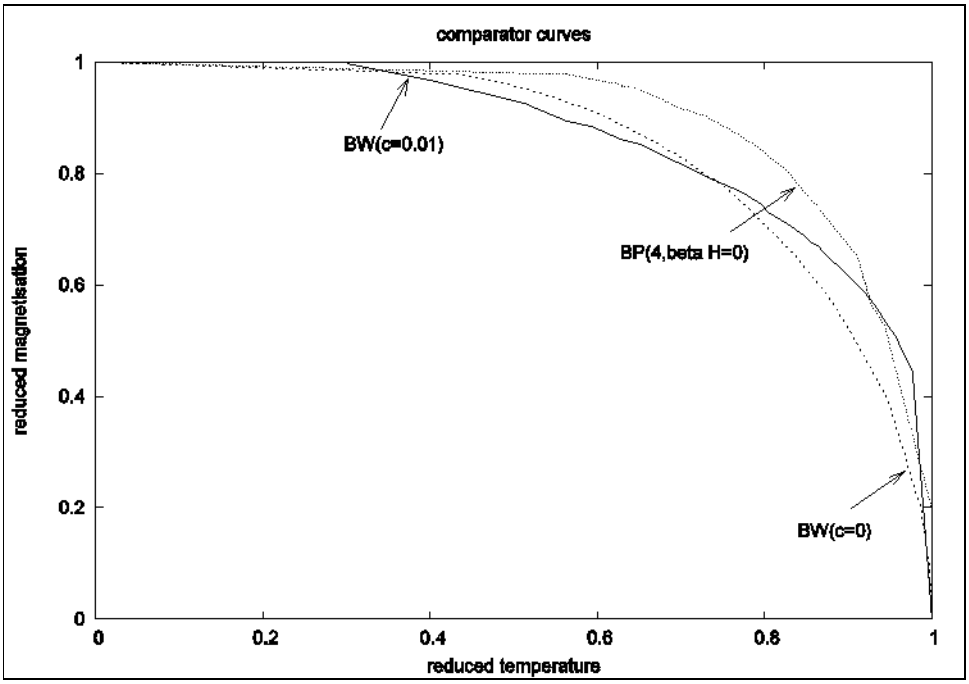


**Fig 1:** Reduced magnetisation vs reduced temperature curves for the Bragg-Williams approximation, in the absence (broken line) of, BW(c=0) and the presence (inner in the top) of, BW(c=0.01), the external magnetic field, $c=\frac{H}{\gamma\epsilon}=0.01$, and the Bethe-Peierls approximation in the absence of external magnetic field, for four nearest neighbours (outer in the top).

**Analysis of the Names of the Places in the Tourist Guide and Map, Aizawl:**

Counting one by one the names of the places in the Tourist Guide and Map, Aizawl, [1], starting with different letters, leads us to the table, Table-2.

**Table 2:** The number of the names of the places of Aizawl along the English letters, in the Tourist Guide and Map, Aizawl

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 25 | 31 | 22 | 3 | 5 | 18 | 10 | 8 | 4 | 17 | 10 | 31 | 12 | 0 | 11 | 1 | 24 | 33 | 23 | 5 | 9 | 1 | 0 | 4 | 10 |

Largest number of places in Aizawl, are with names starting with the letter S. Next comes the places with names starting with the letter C, followed by places with the names starting with the letter B,.. To visualise we plot the number of names of the places, [1], against the respective starting English letters, in the figure, Figure2.

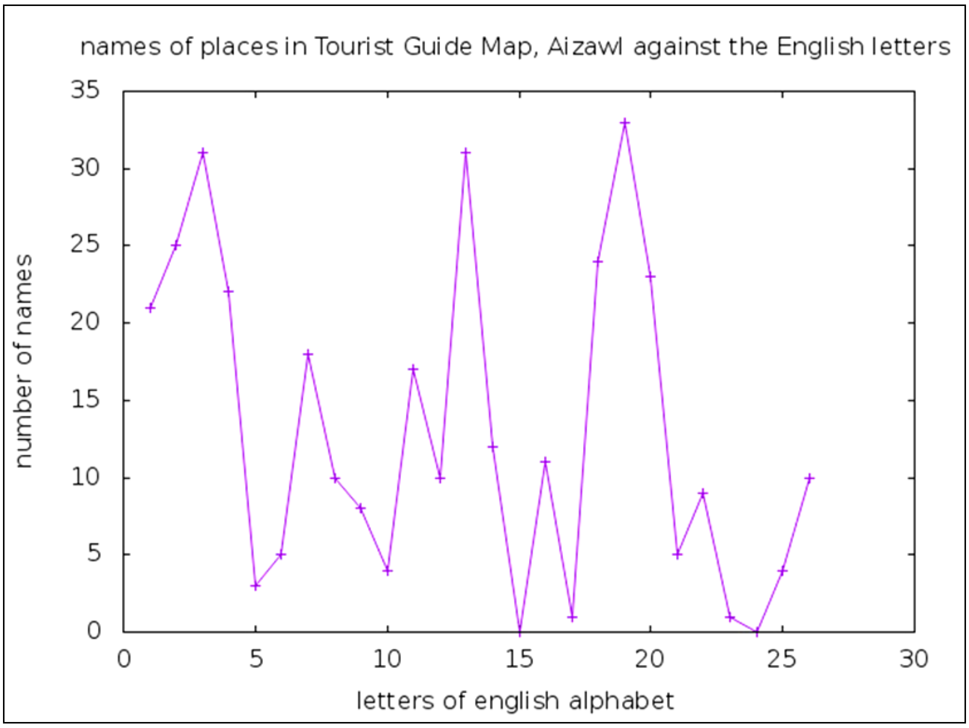


**Fig 2:** Vertical axis is the number of the names of the places, in Aizawl, [1], and horizontal axis is the respective letters, the names are starting with. Letters are represented by the sequence number in the English alphabet.

For the purpose of exploring graphical law, we assort the letters according to the number of names of the places beginning with, in Aizawl, in the descending order, denoted by f and the respective rank, denoted by k. k is a positive integer starting from one. The lowest value of f is one. The corresponding rank, k, denoted as $k_{lim}$ is eighteen. As a result both $\frac{lnf}{ln f_{max}}$ and $\frac{lnk}{lnk_{lim}}$ varies from zero to one. Then we tabulate in the adjoining table, Table-3, and plot $\frac{lnf}{lnf_{max}}$ against $\frac{lnk}{lnk_{lim}}$ in the figure, Figure3. We then ignore the letter with the highest number of names of places starting with, tabulate in the adjoining table, Table-3, and redo the plot, normalising the lnf s with next-to-maximum $lnf_{n\text{-}max}$, and starting from k=2 in the figure, Figure4. This program then we repeat up to k=6, resulting in the figures up to Figure8.

**Table 3:** The names of the places in the Tourist Guide and Map, Aizawl: ranking, natural logarithms, normalization.

| k | lnk | $\frac{lnk}{lnk_{lim}}$ | f | lnf | $\frac{lnf}{lnf_{max}}$ | $\frac{lnf}{lnf_{nmax}}$ | $\frac{lnf}{lnf_{2nmax}}$ | $\frac{lnf}{lnf_{3nmax}}$ | $\frac{lnf}{lnf_{4nmax}}$ | $\frac{lnf}{lnf_{5nmax}}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 33 | 3.497 | 1 | Blank | Blank | Blank | Blank | Blank |
| 2 | 0.69 | 0.239 | 31 | 3.434 | 0.982 | 1 | Blank | Blank | Blank | Blank |
| 3 | 1.10 | 0.381 | 25 | 3.219 | 0.921 | 0.937 | 1 | Blank | Blank | Blank |
| 4 | 1.39 | 0.481 | 24 | 3.178 | 0.909 | 0.925 | 0.987 | 1 | Blank | Blank |
| 5 | 1.61 | 0.557 | 23 | 3.135 | 0.896 | 0.913 | 0.974 | 0.986 | 1 | Blank |
| 6 | 1.79 | 0.619 | 22 | 3.091 | 0.884 | 0.900 | 0.960 | 0.973 | 0.986 | 1 |
| 7 | 1.95 | 0.675 | 21 | 3.045 | 0.871 | 0.887 | 0.946 | 0.958 | 0.971 | 0.985 |
| 8 | 2.08 | 0.720 | 18 | 2.890 | 0.826 | 0.842 | 0.898 | 0.909 | 0.922 | 0.935 |
| 9 | 2.20 | 0.761 | 17 | 2.833 | 0.810 | 0.825 | 0.880 | 0.891 | 0.904 | 0.917 |
| 10 | 2.30 | 0.796 | 12 | 2.485 | 0.711 | 0.724 | 0.772 | 0.782 | 0.793 | 0.804 |
| 11 | 2.40 | 0.830 | 11 | 2.398 | 0.686 | 0.698 | 0.745 | 0.755 | 0.765 | 0.776 |
| 12 | 2.48 | 0.858 | 10 | 2.303 | 0.659 | 0.671 | 0.715 | 0.725 | 0.735 | 0.745 |
| 13 | 2.56 | 0.886 | 9 | 2.197 | 0.628 | 0.640 | 0.683 | 0.691 | 0.701 | 0.711 |
| 14 | 2.64 | 0.913 | 8 | 2.079 | 0.595 | 0.605 | 0.646 | 0.654 | 0.663 | 0.673 |
| 15 | 2.71 | 0.938 | 5 | 1.609 | 0.460 | 0.469 | 0.500 | 0.506 | 0.513 | 0.521 |
| 16 | 2.77 | 0.958 | 4 | 1.386 | 0.396 | 0.404 | 0.431 | 0.436 | 0.442 | 0.448 |
| 17 | 2.83 | 0.979 | 3 | 1.099 | 0.314 | 0.320 | 0.341 | 0.346 | 0.351 | 0.356 |
| 18 | 2.89 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

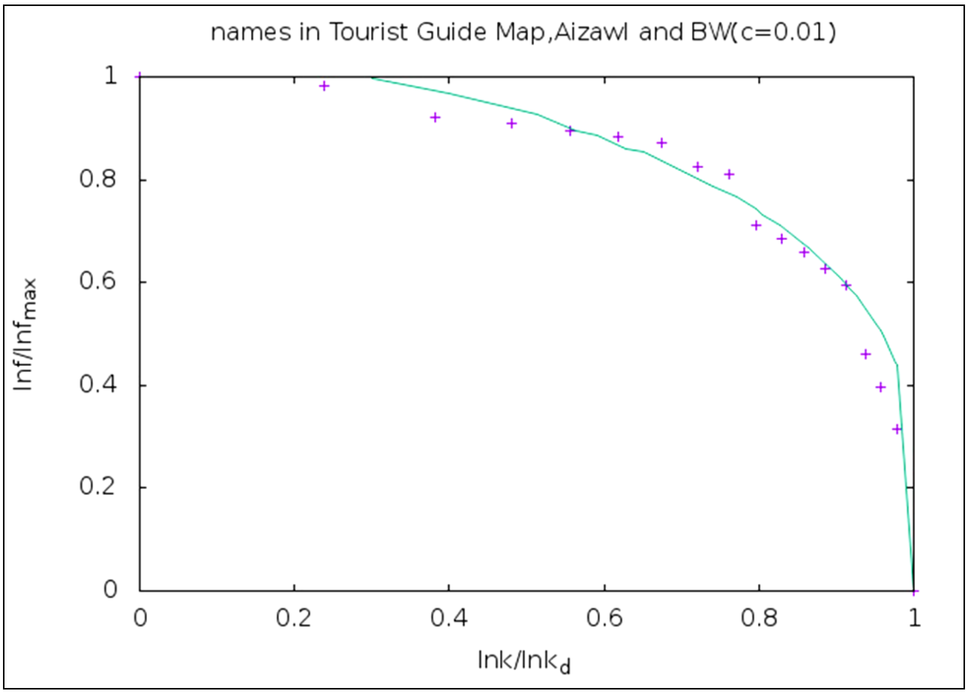


**Fig 3:** The vertical axis is $\frac{lnf}{ln f_{max}}$ and the horizontal axis is $\frac{lnk}{ln k_{lim}}$. The + points represent the names of the places in the Tourist Guide and Map, Aizawl,[1], with the fit curve, BW(c=0.01), being the Bragg-Williams curve of the Ising Model, in the presence of external magnetic field, $c=\frac{H}{\gamma\varepsilon}=0.01$.

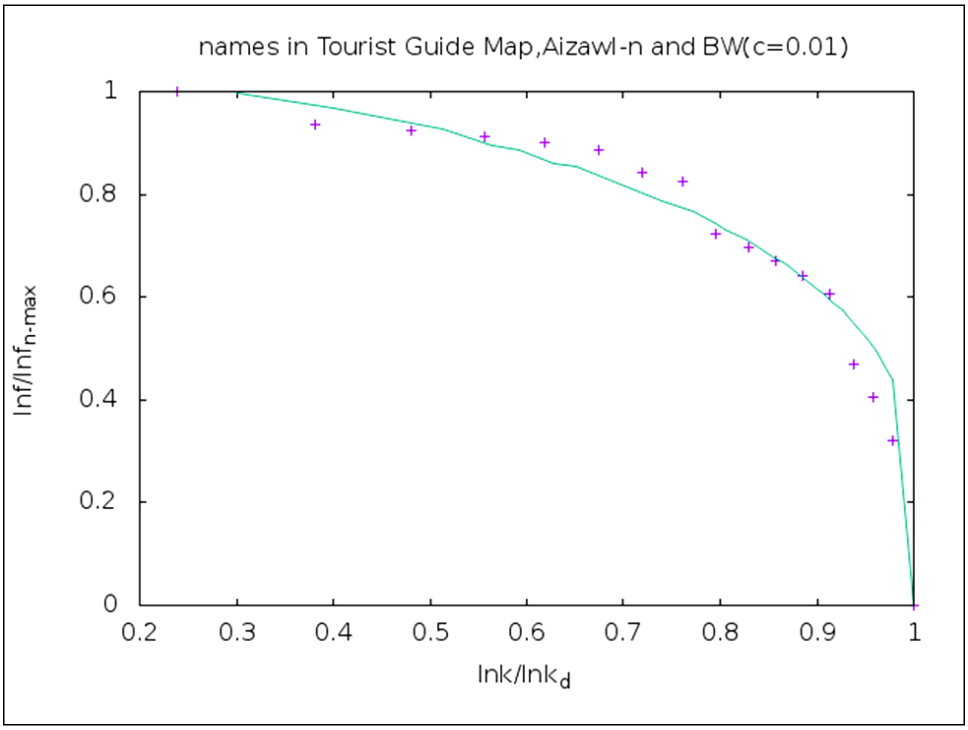


**Fig 4:** The vertical axis is $\frac{\ln f}{\ln f_{n-max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the names of the places in the Tourist Guide and Map, Aizawl, [1], with the fit curve, BW(c=0.01), being the Bragg-Williams curve of the Ising Model, in the presence of external magnetic field, $c=\frac{H}{\gamma\epsilon}=0.01$.

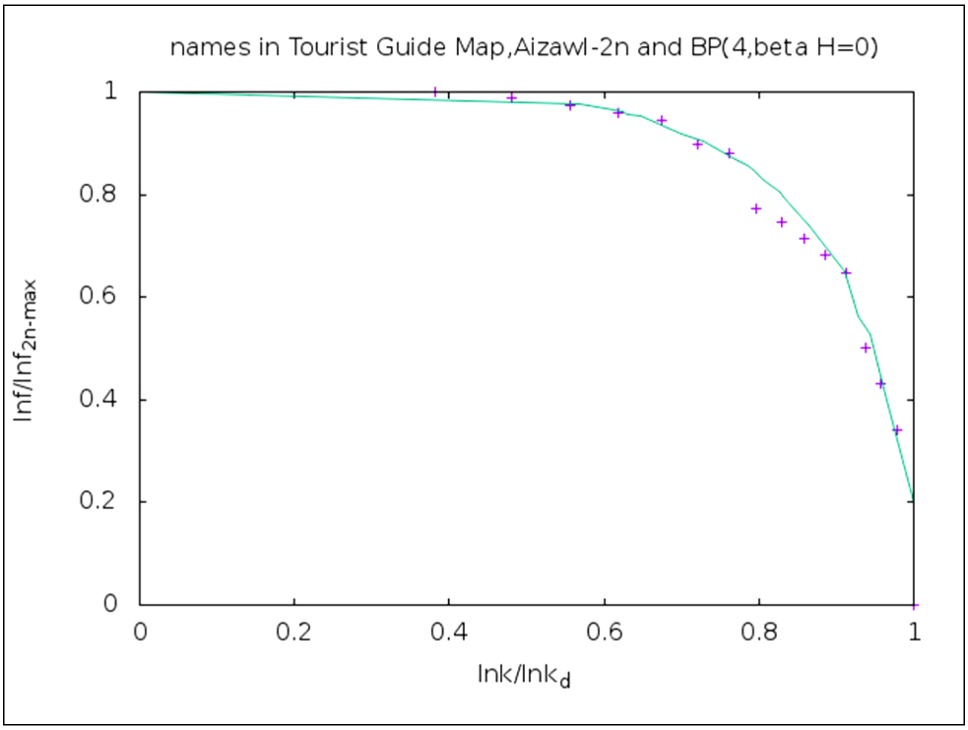


**Fig 5:** The vertical axis is $\frac{\ln f}{\ln f_{2n-max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$.The + points represent the names of the places in the Tourist Guide and Map, Aizawl, [1], with the fit curve being the Bethe-Peierls curve, BP(4, βH=0), of the Ising Model, in the presence of four nearest neighbours and in the absence of external magnetic field, H= 0.

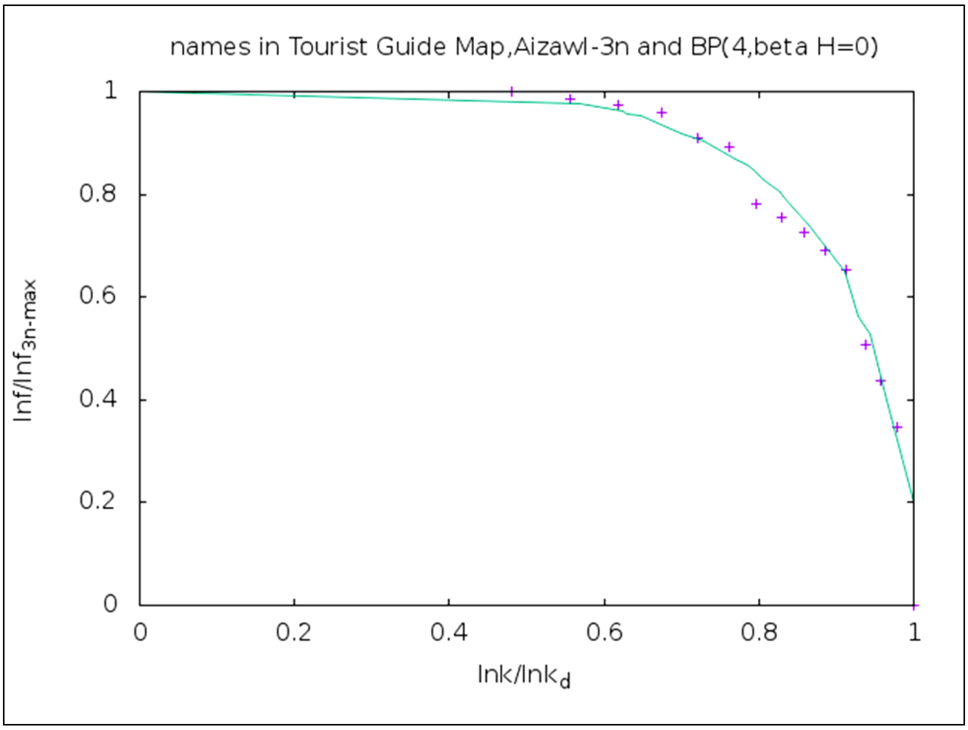


**Fig 6:** The vertical axis is $\frac{\ln f}{\ln f_{3n-max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the names of the places in the Tourist Guide and Map, Aizawl, [1], with the fit curve being the Bethe-Peierls curve, BP(4, βH=0), of the Ising Model, in the presence of four nearest neighbours and in the absence of external magnetic field, H= 0.

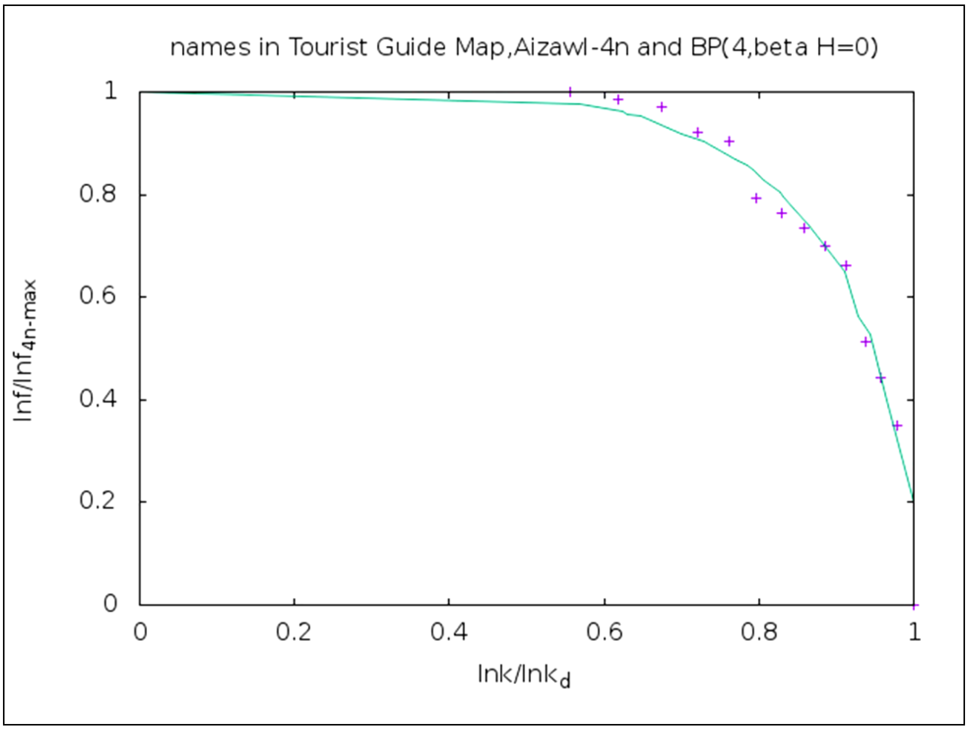


**Fig 7:** The vertical axis is $\frac{\ln f}{\ln f_{4n-max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the names of the places in the Tourist Guide and Map, Aizawl, [1], with the fit curve being the Bethe-Peierls curve, BP(4, beta βH=0), of the Ising Model, in the presence of four nearest neighbours and in the absence of external magnetic field, H= 0.

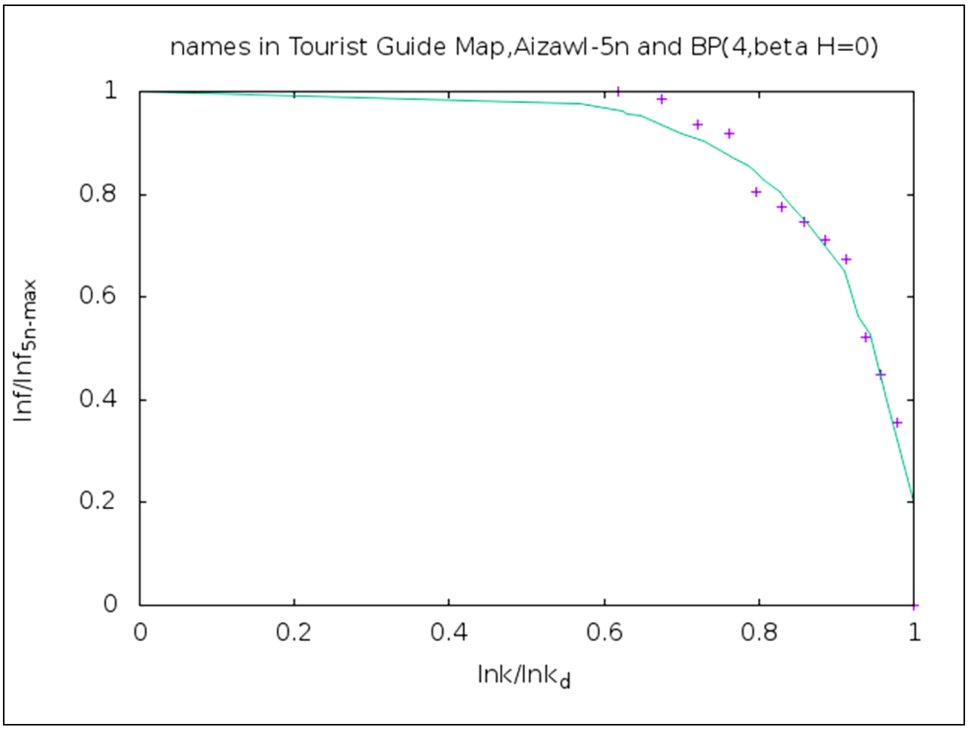


**Fig 8:** The vertical axis is $\frac{lnf}{ln f_{5n-max}}$ and the horizontal axis is $\frac{lnk}{ln k_{lim}}$. The + points represent the names of the places in the Tourist Guide and Map, Aizawl, [1], with the fit curve being the Bethe-Peierls curve, BP(4, beta βH=0), of the Ising Model, in the presence of four nearest neighbours and in the absence of external magnetic field, H= 0.

**Conclusion**

From the figures, Figure3-Figure8, we observe that there is a curve of magnetisation, behind the names of the places, in the Tourist Guide and Map, Aizawl, [1],. This is the magnetisation curve, BP(4,beta βH=0), in the Bethe-Peierls approximation of the Ising Model, in the presence of four nearest neighbours and in the absence of external magnetic field, H= 0.Moreover, the associated correspondence is,

$\frac{lnf}{ln f_{2nmax}} \leftrightarrow \frac{M}{M_{max}}$ and lnk ↔ T,

k corresponds to temperature in an exponential scale, [90].

**Acknowledgment**

We have used gnuplot for plotting the figures in this paper.

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