Equivalent Electrical Circuit Networks Representing Human Flow in Big Cities

Keywords: Human mobility, GPS data, Electrical circuit network

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Motivation.
Research on human mobility in cities has traditionally relied on data obtained through fixed-point observations and questionnaire surveys. Recently, the availability of GPS data from smartphones has significantly advanced research on human flow. Many people leave home in the morning, travel by train or car, and arrive at their workplace. Research methodologies analyzing individuals' origins and destinations form the foundation of network research in this field. We are pursuing a novel research approach to construct equivalent electrical circuit networks representing these human flows [1].

Approach and Methodology.
Our key assumption is that moving individuals are virtually assigned a unit charge. That is, a charge is generated when leaving the origin, and the charge disappears upon arrival at the destination when movement ceases. This enables us to replace human flow with electric current and construct an equivalent electrical circuit to describe that current. Divide the city map into a grid of units of length (e.g., 1 km) square, and observe the current within each grid cell at 0.5-hour intervals. Then, we estimate the resistance values and electric potentials within the grid-like electrical circuit network describing that current [2]. Furthermore, we have analyzed how resistance values and other parameters are transformed through renormalization group methods that coarsen the lattice unit length by a factor of two, and are also investigating the characteristics of electrical circuit networks when the observation scale is altered [3].

Results.
Fig.1a shows the observed currents in the morning rush hour which is directly calculated from the GPS data. Fig.1b-e show corresponding electrical properties, conductivity, voltage, charge and electrical potential [3]. Fig.2 shows the spatial distribution of energy dissipation rate which coincide with the highly congested regions [2].

Conclusions and Outlook.
The equivalent electrical circuit model developed in this research can be applied to any city for which similar GPS data is available, and is expected to serve as a foundational technology for analyzing urban human flow networks. It enables the demonstration of application examples to other cities, the characterization of points of interest within cities, and the numerical simulation of changes in human flow when new urban transport systems are introduced.

The GPS data used in this study was purchased from a data provider company (Agoop) that processed it with consideration for privacy.

References

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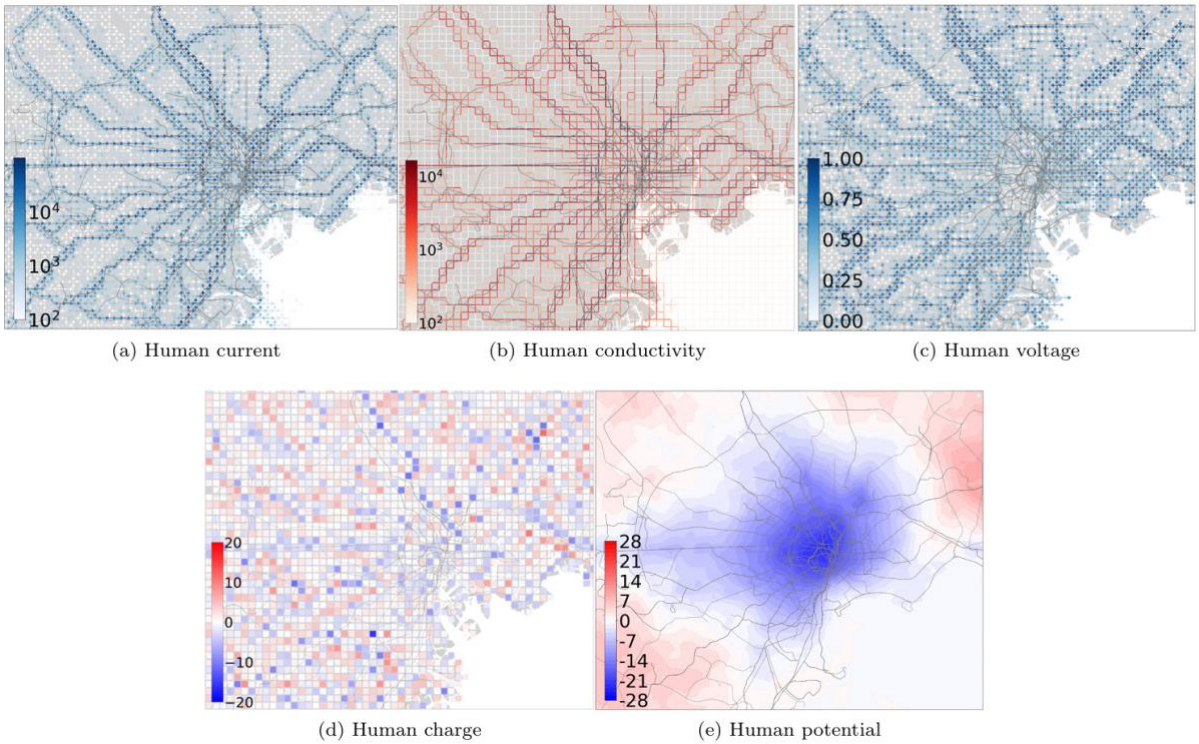

Figure 1. **Electrical properties of human flow of Tokyo in the morning rush hour**

(a) Current, (b) conductivity, (c) voltage, (d) charge, (e) potential [Fig.2 in ref. 3]

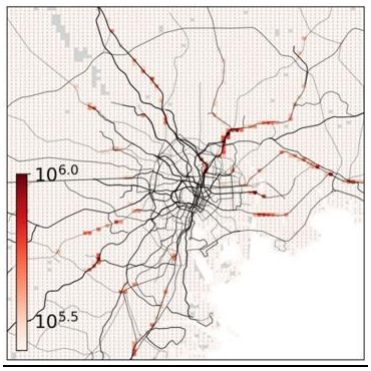

Figure 2. **Electrical energy dissipation rate of Tokyo in the morning rush hour**

The high energy dissipation rate regions coincide with highly congested regions [Fig.2d in ref. 2]