DEEP MOVE : HUMAN MOBILITY

Introduction -

The study of human mobility is crucial due to its impact on several aspects of our society, such as disease spreading, urban planning, well-being, pollution, and more. The proliferation of digital mobility data, such as phone records, GPS traces, and social media posts, combined with the predictive power of artificial intelligence, triggered the application of deep learning to human mobility. Human mobility prediction based on deep learning is a field of study that seeks to forecast where individuals will go and when they will do so using deep learning techniques. Deep Move is one of the popular frameworks for human mobility prediction based on deep learning.

Deep Move is a deep learning model that uses recurrent neural networks (RNN) to model the temporal dynamics of human mobility. The model takes as input the historical trajectories of individuals, and predicts their future locations at different time intervals.
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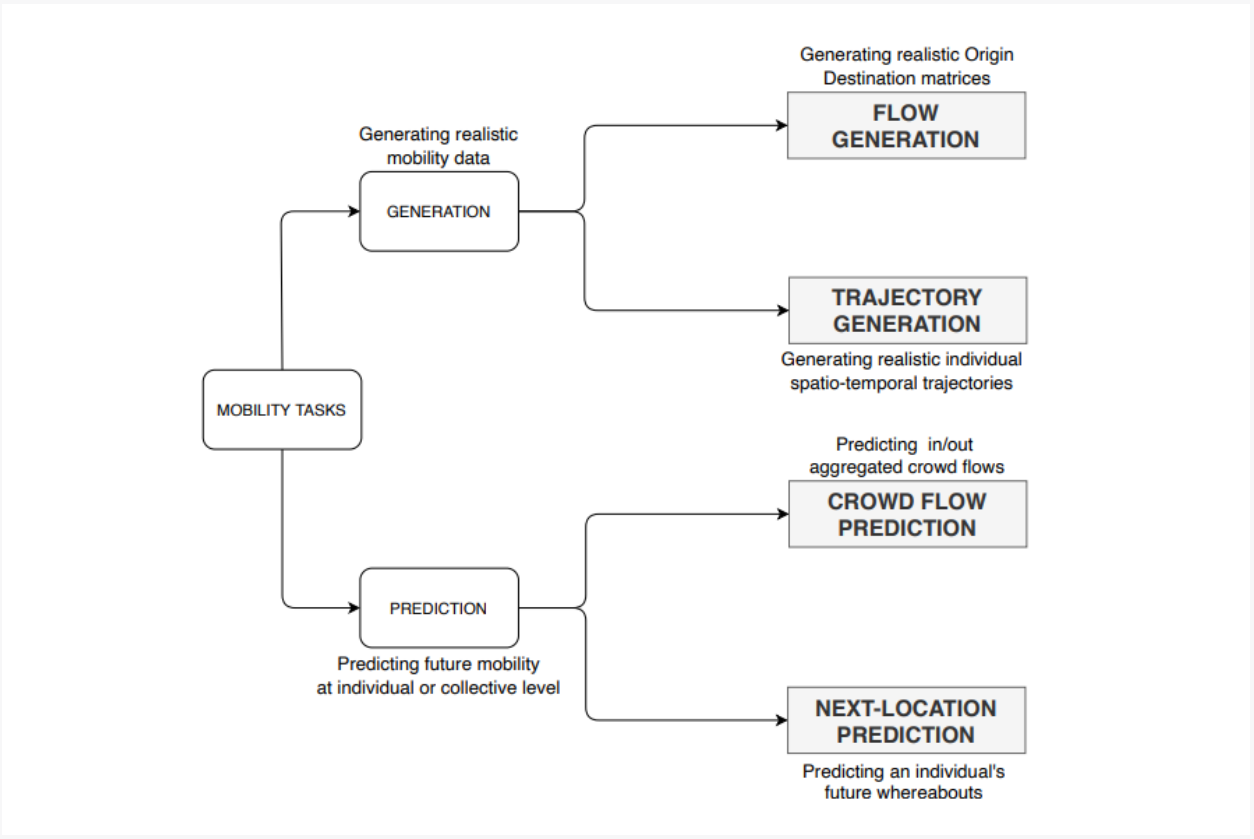
To train the model, the trajectories of individuals are first preprocessed to extract features such as the distance traveled, the speed, the direction, and the time of day. These features are then used to construct a sequence of inputs for the RNN, with each input consisting of the features at a specific time step.

The RNN then learns to predict the future location of an individual based on the sequence of inputs. The output of the model is a probability distribution over all possible locations, which can be used to predict the most likely future location.

Deep Move has been shown to outperform other state-of-the-art models for human mobility prediction, with high accuracy and fast training times. It has a variety of applications in fields such as transportation planning, urban development, and public safety.

Applications -



i) Transport planning and spatial economics, to reduce inequalities and to design more sustainable communities, and the modeling of epidemic spreading patterns.

ii) Analysis of networking protocols such as mobile ad hoc networks. Urban planning, computational epidemiology.

iii) Object recognition, image classification and segmentation, movement & event recognition.

iv) Predicting Citywide Human Mobility : Predicting citywide human mobility is critical to an effective management and regulation of city governance, especially during a rare event (e.g. large event such as New Year's celebration or Comiket).Classical models can effectively predict routine human mobility, but irregular mobility during a rare event (precedent or unprecedented), which is much more difficult to model, has not drawn sufficient attention.
v) Disaster response and relief efforts: Human mobility research can help identify the transportation-related challenges faced during disasters and emergencies, and can inform the development of effective and efficient response and relief efforts.

vi) Environmental sustainability: Human mobility research can contribute to the development of transportation systems that are more environmentally sustainable, such

as the adoption of low-carbon transportation modes and the reduction of greenhouse gas emissions.

vii) Economic development: Human mobility research can inform economic development strategies, such as the identification of transportation-related barriers to job access and the development of more efficient transportation systems that support economic growth.

vii)Public health: Human mobility research can contribute to the understanding of the relationship between transportation and public health outcomes, such as air pollution exposure, physical activity, and access to healthcare. This knowledge can inform the development of policies and interventions that promote healthier and more equitable transportation options.

Human mobility researches in India

Human mobility research in India encompasses a wide range of topics, including migration patterns, urbanization, transportation, and public health. Here are some of the notable research works on human mobility in India:

1. "Migration and Urbanization in India" by Ravindra H. Dholakia: This paper examines the relationship between migration and urbanization in India. It discusses the various factors that influence migration patterns in the country, such as economic opportunities and social factors.
2. "Mobility, migration and health outcomes in India" by Niveditha Devasenapathy et al.: This study explores the impact of migration on the health outcomes of individuals in India. It found that migrants have higher rates of mental health problems and are more susceptible to infectious diseases.
3. "Transportation and Mobility in India: The Challenges and Opportunities" by Sudhir Gota and Anupam Nanda: This paper discusses the challenges and opportunities for transportation and mobility in India. It examines the current state of transportation infrastructure in the country and offers recommendations for future development.
4. "Urbanisation, mobility and infrastructure in India" by Jagan Shah: This study examines the relationship between urbanization, mobility, and infrastructure in India. It discusses the challenges facing urban areas in the country and offers recommendations for improving infrastructure and mobility.

5. "Public Transport System in India: Challenges and Solutions" by B. Sudhakara Reddy: This paper discusses the challenges facing the public transportation system in India. It examines the various modes of public transportation in the country and offers solutions for improving their efficiency and effectiveness.

→ A Research By Assistant Professor of IITD on Human Mobility :

[1] Road traffic measurement in developing regions

Developed countries usemagnetic detectors and roadside camerasfor trafficmonitoring at important road junctions. In his PhD thesis, He built novel sensing technologies to measure the density of non-laned traffic, common in developing countries. used noise levels and speeds computed from Doppler shift of vehicle sounds, to give 70-80% accuracy in differentiating two congestion classes (high vs. low) [MOBISYS10]. At Microsoft Research India (MSR-I), processed images from road side cameras to compute traffic densities and speeds and quantify the density-speed relations (called the fundamental curves in transportation engineering) for the first time in non-laned traffic [DEV13].

He also used two Zigbee radios on opposite sides of the road, one sending and the other receiving packets, to classify traffic states using variation in radio signal strength (RSSI). This novel technique gave 90-95% accuracy in differentiating five congestion classes (empty road, fast traffic, moderate, slow and standing traffic). Arrays of these radio pairs were used to to estimate queue lengths at traffic signals [SENSYS12]. In collaboration with traffic control authorities in Bengaluru and Mumbai, He deployed these sensors across many roads for months, to understand accuracies across roads and seasons [SECON11] .

In non-laned traffic of developing countries, two and three wheelers often percolate through larger vehicles to get ahead in traffic queues and wait less. Vehicle type agnostic travel time estimates are, therefore, less useful to plan routes and inform commuters. He collaborated with a Masters student from IIIT-Delhi, to automate vehicle type classification using inertial sensors in smartphones. His Android app detected the vehicle type processing accelerometer, compass and gyroscope signals, to show customized route plans. This system was able to achieve above 90% vehicle classification accuracy, evaluated over 1500+ Km of driving data, on two urban road stretches in Delhi [MOBIQUITOUS14].

With recent advances in deep learning and availability of embedded GPU platforms for efficient processing, we are currently training deep net models with non-laned traffic videos collected during his PhD. The goal is to get vehicle counts, with vehicle type classification, in real time, on embedded platforms. This is joint work with an Indian startup Altigreen, which needs traffic density estimates to predict the emission reduction percentage possible with their hybrid car engines.

[2] Human mobility measurement, both outdoor and indoor :

Walkable access to facilities like grocery, public transport, banks and doctors, can significantly increase the urban quality of life. They devised a method to quantify walkability, using Google Maps Places and Distance APIs [ICWSM16]. Dividing a city in 200mx200m square grid, we counted facilities within walking distance at each grid point. They used this scalable method to characterize walkable access within cities. We also compared walkability across 25 cities around the world, quantifying differences between European, American, Asian and developing countries. These analyses are currently under submission in the PLOS ONE journal.

Indoor localization is useful for retail applications like targeted advertising. Wi-Fi based indoor localization is popular, but needs creation of a data set comprising Wi-Fi measurements at known locations. During a summer internship at MSR-I, They devised a method to automatedly crowd-source this calibration data [MOBICOM12] [US Patent 9,310,462]. The only input necessary was a floor-map of the site. Sampling accelerometer and compass sensors on participating smartphones, while simultaneously taking Wi-Fi scans, the system employed particle filtering to localize each scan and gradually build the calibration database for the venue.

In a stopgap position at SMU Livelabs, He worked on monitoring shopper group dynamics for retail applications. In [SENSYS14], They detected groups in data collected from 258 shopping episodes of 154 volunteers, in two large shopping complexes in Korea and Singapore, and the shopping areas of the Changi International Airport. As the users stopped and walked, took turns in the corridors or climbed up and down the escalators, their accelerometer, compass and barometer signals showed the same temporal changes respectively. They clustered these correlated time-series as groups and obtained 80% recall with 97% precision, even in venues with limited or no indoor localization infrastructure.

The success and failure of human mobility research in India can be evaluated in different ways based on the research questions, goals, and outcomes of individual studies. Here are some possible examples:

Success :

1. Improved understanding of migration patterns: India has a vast and diverse population, and migration plays a crucial role in shaping social, economic, and political dynamics in the country. Human mobility research in India has contributed to a better understanding of migration patterns, the factors that drive migration, and the impact of migration on individuals and communities.
2. Development of innovative transportation solutions: India faces significant challenges in transportation and mobility, such as traffic congestion, air pollution, and inadequate public transit. Human mobility research has contributed to the development of innovative

transportation solutions, such as bike-sharing systems, electric vehicle programs, and improved public transit.
3. Increased awareness of health outcomes: Human mobility research in India has shed light on the impact of migration and urbanization on public health outcomes, such as mental health, infectious diseases, and chronic illnesses. This has raised awareness among policymakers and health practitioners about the need for interventions to address these issues.

Failure :

1. Limited impact on policy: Despite the significant contributions of human mobility research in India, there is a gap between research findings and policy implementation. The complex and diverse nature of migration, urbanization, and transportation challenges in India requires a multi-disciplinary approach that involves stakeholders from various sectors, including government, academia, civil society, and the private sector.
2. Inadequate research funding: Human mobility research in India suffers from a lack of sustained funding and support. Many research studies are often conducted as one-time projects or in a limited timeframe, which may lead to incomplete or insufficient data collection, analysis, and dissemination.

Human Moblity Researches in USA

Human mobility research in the USA is a broad field of study that covers various topics, including migration, transportation, urbanization, and public health. Here are some notable research works on human mobility in the USA:

1. "Migration in the United States: A Historical Perspective" by Walter Nugent: This paper examines the history of migration in the USA. It discusses the different waves of migration to the country, including the colonial era, the 19th and early 20th century, and post-World War II.
2. "Transportation and Mobility in the United States: Current Trends and Future Challenges" by Susan Shaheen and Elliot Martin: This study explores the current trends and future challenges for transportation and mobility in the USA. It discusses the various modes of

transportation in the country, such as cars, public transit, and emerging mobility services.
3. "Urbanization and Public Health in the United States" by J. Aaron Hipp et al.: This paper examines the relationship between urbanization and public health in the USA. It discusses the impact of urbanization on physical activity, air quality, and access to healthy food.
4. "Racial and Ethnic Disparities in Mobility and Access to Transportation in the United States" by Brian D. Taylor and Evelyn Blumenberg: This study explores the disparities in mobility and access to transportation among different racial and ethnic groups in the USA. It discusses the challenges facing minority communities in accessing transportation services and offers recommendations for improving mobility equity.
5. "The Geography of Jobs: Mapping the Recovery" by Martha Ross et al.: This report examines the geographic distribution of jobs in the USA and the challenges of employment access for low-income workers. It discusses the need for better transportation infrastructure and improved regional planning to improve job access and reduce inequality.

The success and failure of human mobility research in the USA can be evaluated in different ways based on the research questions, goals, and outcomes of individual studies. Here are some possible examples:

Success :

1. Improved transportation infrastructure: Human mobility research in the USA has contributed to the development of transportation infrastructure that is more efficient, sustainable, and equitable. This has led to the improvement of public transit systems, the adoption of clean energy technologies, and the expansion of transportation alternatives.
2. Increased focus on mobility equity: There is a growing awareness of the importance of mobility equity in the USA, which means ensuring that all people have access to safe, affordable, and reliable transportation. Human mobility research has contributed to this focus by examining the disparities in mobility and access to transportation among different communities and identifying strategies to reduce these disparities.
3. Enhanced mobility for underserved communities: Human mobility research has helped to identify the transportation needs of underserved communities in the USA, such as low-income, elderly, and disabled individuals. As a result, there has been an increased focus on providing more equitable transportation options, including accessible public transit, paratransit services, and mobility-on-demand solutions.

4. Improved understanding of the impact of transportation on public health: Research has contributed to a better understanding of the link between transportation and public health outcomes in the USA. This has led to increased awareness of the health impacts of transportation-related issues, such as air pollution, traffic accidents, and physical inactivity, and the need for interventions to address these issues.
5. Enhanced understanding of the relationship between transportation and urban development: Research has also contributed to a better understanding of the relationship between transportation and urban development in the USA. This has led to the development of more sustainable and livable cities that prioritize the needs of pedestrians, cyclists, and public transit riders over cars.

Failure :

1. Persistent mobility disparities: Despite the progress made in transportation infrastructure and mobility equity, there are persistent mobility disparities in the USA, particularly for low-income and minority communities. These disparities result from historical and structural factors, such as segregation, urban planning, and discriminatory policies.
2. Limited attention to health outcomes: While there has been some research on the impact of mobility on public health outcomes in the USA, there is still a need for more attention and resources to be devoted to this issue. For example, air pollution, traffic accidents, and physical inactivity are major public health concerns that are linked to mobility and transportation in the USA, and more research is needed to understand and address these issues.

Human Mobility Researches in Japan

In Japan, research on human mobility has explored a wide range of topics, including transportation systems, urbanization, and the impact of demographic trends on mobility patterns. One area of particular interest is deep movement research, which uses mobile phone and other data to understand the movement of individuals and groups in greater detail.

Here are a few examples of research on human mobility and deep movement in Japan:

i) "Modeling human mobility patterns using mobile phone data" by Junichi Murata, Takeshi Sakaki, and Kentaro Toyama. This research project, conducted at the University of Tokyo, analyzed data from mobile phones to better understand patterns of human mobility in Tokyo. The study found that mobility patterns were highly predictable and followed certain patterns depending on the time of day and location.

ii) "The impact of urbanization on human mobility in Japan" by Ayako Hiramatsu and Tatsuya Nakamura. This research project, conducted at Kobe University, explored the relationship between urbanization and mobility patterns in Japan. The study found that as urbanization increased, the use of private cars for transportation also increased, leading to higher levels of traffic congestion and air pollution.

iii) "Deep movement: An emerging paradigm for understanding human mobility" by Koji Eguchi and Masanori Takami. This article, published in the Journal of Geography, explores the concept of "deep movement," which involves analyzing detailed data on human movement to gain insights into the underlying factors driving mobility patterns. The authors argue that this approach has the potential to significantly advance our understanding of human mobility in Japan and other countries.

Overall, research on human mobility and deep movement in Japan is an important area of study for understanding the complex factors that drive mobility patterns in an urbanized and technologically advanced society.

Future of Human Mobility and Deep move

The future of deep move and human mobility research is promising, as technological advancements and the increasing availability of data make it possible to better understand patterns of movement and transportation usage. Here are a few trends that are likely to shape the future of this field:

i) Greater use of big data: As more data becomes available from sources like mobile phones, GPS devices, and social media, researchers will have more opportunities to analyze patterns of human mobility in greater detail. Big data analysis techniques, such as machine learning and data mining, are likely to play an increasingly important role in this field.

ii) Increased emphasis on sustainability: With concerns about climate change and environmental sustainability on the rise, there will be a greater focus on understanding patterns of mobility and transportation usage in the context of sustainability. Deep move research can help identify opportunities for reducing greenhouse gas emissions and improving the sustainability of transportation systems.

iii) Greater use of interdisciplinary approaches: To fully understand the complex factors that shape patterns of human mobility, researchers will need to take a multidisciplinary approach that draws on expertise from fields like urban planning, geography, and computer science. Collaboration between researchers in different fields is likely to be an important trend in the future of deep move and human mobility research.

Overall, the future of deep move and human mobility research is likely to be characterized by an increased emphasis on using data and advanced analytical techniques to better understand patterns of movement and transportation usage. As technology and data continue to evolve, this field will have the potential to generate valuable insights into the complex factors that shape mobility patterns and inform the development of more sustainable and efficient transportation systems.

Project Report →

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