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# Designs for the visual analysis of spatio-temporal origin-destination flow data

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*RESUME.* Certains environnements de visualisation proposent une analyse visuelle de données de flux origine-destination, permettant d'explorer leurs composantes spatiales et temporelles en partant d'une vue d'ensemble de la distribution spatiale et temporelle des données, puis de se concentrer sur certains secteurs/périodes d'intérêt. Cependant, les dimensions temporelles et spatiales de la donnée y sont souvent représentées séparément, rendant difficile l'identification de patterns spatio-temporels, spécifiques à une région et période données, lors d'une vue d'ensemble. Dans ce papier, nous nous inspirons de deux approches : celle de Flow Map Blue avec la proposition de carte de flux interactive permettant de changer l'échelle de la carte tout en changeant la granularité des flux représentés, et celle des Growth Ring Maps avec la proposition de représenter une distribution temporelle dans des données spatialement agrégées au moyen du design des symboles représentant ces agrégats. Nous essayons de les combiner afin de proposer une analyse visuelle exploratoire de la distribution spatio-temporelle de flux origine-destination, permettant d'identifier lors d'une vue d'ensemble des patterns particuliers à certaines zones et périodes, puis de focaliser l'analyse sur l'échelle spatio-temporelle où ces patterns sont observés. Nous proposons différents designs, 1. permettant d'étendre l'approche des Growth Ring Maps aux cartes de flux multi-échelles, 2. représentant une nouvelle approche pour représenter les flux internes à un nœud dans une carte de flux, 3. permettant de résoudre le problème de perception de l'aire des symboles dans les Growth Ring Maps.

*MOTS-CLES:* visualisation, données de flux origine-destination, données spatio-temporelles, analyse visuelle.

*KEYWORDS:* visualization, origin-destination flow data, spatio-temporal data, visual analysis

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## 1. Exploratory visual analysis of origin-destination flow data

Some visualization environments allow an exploratory visual analysis of origin-destination (OD) flow data, through the possibility to change the spatial or temporal scale, or to filter the flow data according to their spatial/temporal/thematic components. Flow Map Blue (Boyandin, 2024), which proposes a dynamic change of the flow granularity according to the map scale through a spatial aggregation of the dataset nodes for different zoom levels, allows a spatial exploration of OD flow data: the user can have an overview of global exchanges between main sectors, before “diving” into specific sectors, to explore flows at a finer scale or inside these sectors (Schneiderman, 1996). This environment, as well as others (Côme et al., 2019, Menin et al., 2020, Cuenca et al., 2020), proposes to combine a cartographic representation of flow data with a complementary representation of the data temporal distribution through different kinds of charts. These interactive dashboard environments allow making an overview of the global temporal and spatial distributions of the flows, and focusing on the spatial distribution of flows at specific periods selected on the temporal charts. This combination itself however doesn't allow identifying spatio-temporal patterns happening at specific times and places, without exploring successively spatial distributions at specific periods or temporal distributions for specific origin-destination pairs. The animation of the temporal filtering can be used to identify such patterns, but the need to memorize a lot of different sequences makes difficult an overview analysis. Some approaches allow such kind of overview of the data spatio-temporal distribution. The Space Time Cube (Kapler et Wright, 2005) offers a global visualization of the spatio-temporal structure of data such as OD flow data. Other works propose a *small multiple* approach, using a collection of flow maps (Boyandin et al., 2012) representing the spatial distribution of data at specific temporal periods. Examples of the reverse approach exist, proposing collections of temporal charts related to a series of origin-destination pairs (Boyandin, 2013). The example of Flowstrates (Boyandin et al., 2011) proposes a similar approach: a collection of temporal charts represents the evolution of flows, for a series of origin-destination pairs represented in a synchronized cartographic representation. These approaches have in common to integrate the representation of both temporal and spatial dimensions into the same graphic space. If we look at punctual spatio-temporal event data, an interesting approach to combine space and time in the same graphic space is the Growth Ring Maps (GRM) approach (Bak et al., 2009). It represents spatially aggregated punctual events by concentric rings glyphs, the thickness of each ring representing the proportion of events, of the same spatial aggregate, occurring during the same specific period. This approach allows then identifying spatial and spatio-temporal concentrations of events in a cartographic representation, and combined with the possibility to dynamically change spatial and temporal scales and event aggregation granularities (Gautier et al., 2021), it offers a way to visually explore the spatio-temporal distribution of punctual event data. In this paper, we propose to extend the GRM approach to a multiscale OD flow map representation, in order to allow a visual analysis of the spatio-temporal distribution of OD flow data.

## 2. Extending the GRM approach to multiscale OD flow maps

We propose a multiscale visualization of OD flows using the aggregation strategy of Flow Map Blue: flow data (in our case study, bicycle-sharing travels in New York) correspond to individual flows between original nodes (the bicycle-sharing stations), nodes being spatially aggregated and exchanges between nodes recalculated for different map zoom levels. Between two nodes, the bi-directional flow is represented according to the number of travels by the thickness of two semi-arrows, like in Flow Map Blue, as it has been described by Tobler (1987). At the node level, we propose two designs: 1. we represent each node by a glyph formed by two semi-circles, whose area represents the number of incoming (left semi-circle) and outgoing (right semi-circle) travels (Figure 1-A); 2. we represent the number of travels internal to a node (*self-loop flows*, Andrienko, 2011, Boyandin, 2013) by the area of a central circle surrounded by two semi-rings, whose area represents the number of incoming (left semi-ring), and outgoing (right semi-ring) travels (Figure 1-B).

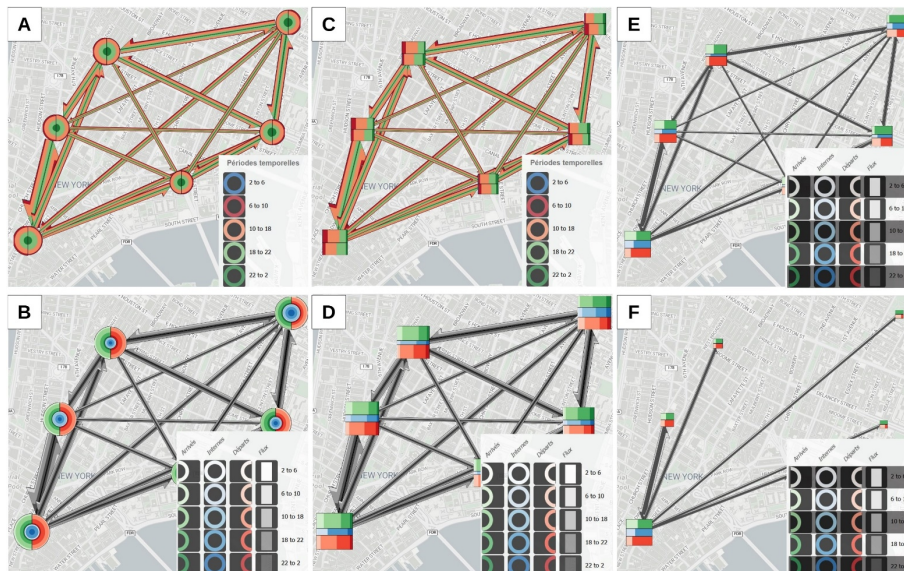


FIGURE 1. Different designs to represent the spatio-temporal distribution of bicycle-sharing travels in New York.

According to the GRM approach, each of these symbols are composed of sub-symbols of different colours, whose size represents the proportion of travels related to the corresponding link or node and occurring during the same period: semi-arrows are divided into several parts parallel to their length, circles are divided into several concentric rings, semi-circles and semi-rings into concentric semi-rings. We propose several linear or cyclic temporal classifications, using regular temporal extents or

specific periods (ex: 5pm-8pm versus the rest of the day). Depending on the design, different colour palettes are proposed. When self-loop flows are not represented, arrows and nodes are using the same palettes: linear and cyclic periods are respectively represented with sequential and chromatic circle-based palettes, while categorical colour palettes are used to distinguish particular temporal periods from the others (Brewer, 1994). When self-loop flows are represented, the three parts of the node glyph are coloured with a distinctive hue (green, blue and red for respectively incoming, internal, and outgoing travels). The concentric rings or semi-rings which compose each part are coloured with a sequential palette of the corresponding hue: the same period is represented in the income/internal/outcome part of the glyph by a green/blue/red colour with the same level of saturation. The different parts of the arrows are coloured with a grey palette with the same levels of saturation. We also propose two related styles in order to tackle an issue regarding the GRM approach, which is the difficulty to interpret and compare areas of different rings, especially if their contours have different radius. We propose a node treemap-based glyph, similar to those representing temporal distribution in grid-aggregated data in GridViz (Gaffuri, 2024). Nodes are represented by square symbols, whose area represents the sum of all related travels (Figure 1-C and Figure 1-D). These squares are vertically divided into two (three) rectangles, whose area represents the number of incoming, (internal,) and outgoing travels, the proportion of these categories being then represented by the vertical length of the rectangles. Each of these rectangles are horizontally divided into several sub-rectangles, whose area represents the number of corresponding incoming/internal/outgoing travels occurring during the same period. These sub-rectangles bear different colours, according to the chosen temporal scale and colour palette. Finally, these designs aiming to provide an overview visualization of the spatio-temporal distribution of flows, are combined with interaction modalities aiming to focus on specific regions and periods, to allow an exploratory analysis. Users can modify the map scale and node granularity, the temporal scale, the chosen design, show/hide data related to specific periods (travels occurring during 6-10h and 18-22h periods in Figure 1-E), and select specific nodes to highlight (selecting travels related to Financial District during previous selected periods in Figure 1-F).

## Conclusion

The different designs we propose intervene at different levels. First, they represent a possibility to extend the GRM approach to uni or multiscale OD flow maps, allowing the identification of spatio-temporal patterns during an overview visualization of the global distribution of flow data. Second, we propose another way to co-visualize the magnitude of self-loop flows with the magnitude of incoming and outgoing flows at the node level, which can help the user to identify on which region it can be interesting to zoom in, using a multiscale OD flow map. Third, we propose a treemap-based design which can represent a way to tackle the difficulty of area perception in Growth Ring Maps. These designs are still at a proposition level. Controlled experiments are to be conducted in order to conclude about their efficiency in flow data spatio-temporal distribution analysis, in comparison with animated map or small multiples.

These propositions are a first step of ongoing work about urban mobility visualization, in which the possibility to identify spatio-temporal patterns represents a particular asset. A manipulation of our visualizations by domain experts could also give us feedback about the possible contribution of our designs for urban mobility analysis.

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