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What can location-based social media reveal on human migration patterns in Europe?

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ABSTRACT

Numerous visualisation methods have been proposed, including Origin-Destination maps to represent movement patterns gathered from social media; however, visual clutter remains a persistent issue due to complex data dimensionality. Besides, most Origin-Destination maps fail to illustrate the temporal dimension of social network phenomena within the geographical environment. To tackle this issue, we propose the visualisation method for geo-located Facebook social-media data while emphasising the time aspect. Based on the citizen-generated data for the European Union (EU), we estimated the EU citizens' residing or travelling across the EU member states as a means of current and previous destinations to reveal the extent of the hypothetical human migration. The proposed methodology consists of Origin-Destination maps implemented within the time geography framework as a model to support the process of analysis for decision-making. The generated visualisation allows comprehension of the scale of human movement distribution internally within the EU from a space–time perspective.

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Social media; time geography; human migration; flow mapping

1. Introduction

Understanding mobility processes closer to real-time events through the data gathered from online social media platforms is an effective way of gaining knowledge into global migration patterns from a data visualisation perspective (Herdağdelen et al., 2016). Data produced from information and social media networks such as Twitter, Facebook, Instagram, etc., offer the best advantages of user-generated data via the Marketing Application Programming Interface (API) and Ads Manager Interface. We also posit that these cost-effective unique sources of data represent an opportunity to fill the time gap between official data providers and the latest trends in worldwide discussed topics within politics (Felmlee et al., 2020), migration (Mukherjee et al., 2022; Spyratos et al., 2019), diseases (Araújo et al., 2017), etc. to gauge and reveal public opinion and behavioural patterns. For instance, Facebook (FB) social network datasets can tackle profound research questions on demographic and gender issues (Rama et al., 2020), refugee crises (Jurić, 2022), human migration (Osorio Arjona & García Palomares, 2020), etc. Naturally, each of those studies used a different method and technique to analyse and visualise complex social-media relationships between intertwined space, time and data characteristics. However, only a limited number of research applications have used Origin-Destination (OD) flow maps to display the changing appearance of social media activities over space and time between geographic locations, and even more limited studies have focused on using the time geography concept with a combination of OD maps to visualise ongoing dynamic processes (Huang & Wong, 2015; Osorio Arjona & García Palomares, 2020). To address this void, we focus on self-declared geo-located social media data and aim to develop an application showing internal migration flows within the European Union (EU) to understand the mobility characteristics of different EU nations. Besides, like Osorio Arjona and García Palomares (2020) and Huang and Wong (2015), we also offer the time geography concept (Hägerstrand, 1970), for better visual encoding and interpretation of spatio-temporal aspects of the data. Though differing from everyone, we will apply a user-generated Facebook social network dataset since, to the best of our knowledge, no OD flow maps were yet constructed with a combination of time geography framework and Facebook data to enhance analysis and sensemaking of the spatio-temporal characteristics of social media communication

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patterns. Thus, the article foremost proposes a visualisation method for the integrated use of the Facebook network as a new source of data with the traditional OD visualisation method and the time geography concept to examine the potential of generated information. In addition, it suggests using the novel approach to address interesting research questions such as: When and where are the largest and the smallest migration flows accumulated, and how do they change over time? It is remarkable that with posed questions, we do not intend to provide definitive answers but to offer a new perspective on account of further possibilities for potential interdisciplinary research.

Accordingly, in the next sections, we discuss relevant scientific works using online social media to identify and describe the data representation methods used. Furthermore, we provide details on the data collection and processing method as well as a discussion on the proposed methodology for the implementation process of the Facebook social-media dataset within the time geography framework. Finally, we provide a results analysis with constructive and unconstructive aspects of the proposed visual solution. Lastly, we draw conclusions and possible suggestions for future improvements.

2. Mobility patterns in geo-located social media

Geo-located social media networks opened up new possibilities for understanding and measuring human mobility patterns on an unprecedented scale. As a result, it caused the accumulation of a significant amount of scientific work over the last decade to reflect real-time events reported on Twitter (Felmlee et al., 2020), Facebook (Alexander et al., 2019; Zagheni et al., 2017), Flicker and Panoramio (Figueroa-Alfaro & Tang, 2017), etc. A plethora of data visualisation methods largely support those scientific studies to facilitate data analysis and exploration processes. For instance, for a profound human migration crises analysis, Mukherjee et al. (2022) used a grid cell modelling method paired with colour hues to display the Twitter dataset and compare global mobility patterns across different nations of the EU. Gabrielli et al. (2014) also used geo-tagged tweets to analyse activity distribution within a geographical space through a semantic OD matrix and chore diagrams. In comparison, other authors suggested modelling and density concentration-oriented methods for the analyses of user-generated social datasets (Felmlee et al., 2020). On the other hand, highly interactive analytical displays with linked views, as suggested by Pezanowski et al. (2022) and Mukherjee et al. (2022), can improve data analysis and assist the user in uncovering spatio-temporal patterns. However, the seamless representation of spatio-temporal components remains challenging.

The other aspect researchers are implying to handle the representation of spatio-temporal relationships within the OD flow movements is the time geography concept introduced by Hägerstrand (1970). The time geography model displays movement activities through three-dimensional representation, where two horizontal axes represent space, and the third vertical axis shows time. The original concept was created to simultaneously examine human activities over space and time, recognising that these two factors are interconnected and cannot be studied separately. Considering the timing of events in conjunction with their locations allows for a comprehensive exploration of various events. Using this framework, Osorio Arjona and García Palomares (2020) offered the space–time path as the solution to obtain knowledge on how Twitter microblogging platform users are interacting with surrounding urban land use over space and time. Similarly, Huang and Wong (2015) also used the time geography concept to model human mobility patterns using aggregation and spatio-temporal clustering techniques for the Twitter dataset. Their generated cone-based space–time path model describes individuals' variability of activity patterns considering the information uncertainty. Although, like Osorio Arjona and García Palomares (2020), they were also limited to a small sample of trajectories to archive desirable results. Moreover, such probability-based generated representation might be challenging for planning and decision-making.

Differing from Twitter information network datasets, the Facebook social network dataset has never been analysed or visualised within the time geography framework, although actively used in the modelling and statistical analysis of human movements as presented by Docquier et al. (2022) and Herdağdelen et al. (2016). Their applications demonstrate a visualisation approach for understanding human mobility patterns, though, differing from them, this research intends to focus on visualising origin-destination movements in the EU to reveal activity patterns between member countries. The intention is to uncover the trends and changes occurring over space and time in relation to the human migration processes. We believe the suggested method can be a valuable solution for various use cases to benefit from geo-located social network datasets.

3. Dynamic representation of social media network

3.1. Data collection

The dataset was generated via an advertising API platform using the R Studio code developed specifically to

focus on active online users living outside of their country of origin and, thus, considered hypothetical migrants. The dataset has been collected through standard CSV format twice a month since October 2020, although here we focus on the year 2021. The first batch of data is generated at the beginning of a month on the first and second working days, while the second batch is collected after the 15th of a month on the first and second working days. The generated dataset contains demographics on social media users' age and gender. The code also gathered data on the user's current location, country of previous residence based on the self-reported hometown, the IP address, and the network structure of the friendships. Data collection emphasised the Monthly Active Users (MAU) who logged into social media within the last 30 days and Daily Active Users (DAU) who log into Facebook on average daily. Both MAUs and DAUs were estimated and collected through the code developed by pySocialWatcher described by Araújo et al. (2017). In addition, the variable descriptions of gender, age, location, and lived-in status were used to estimate a person who 'lived in country X' but now lives abroad (Herdağdelen et al., 2016; Spyratos et al., 2019). Since we do not possess accurate information on the country of origin, in this research, we refer to 'lived in country X' as the place of the previous destination.

3.2. Data cleaning and enriching

According to Facebook regulations (Spyratos et al., 2019), the minimum number of MAU users that marketing API can query increased from 20 to 1000, which resulted in a data loss within the generated dataset. This can easily lead to a biased judgement and conclusion since it must represent the underlying population. To overcome this challenge, we have adopted the method proposed by Gendronneau et al. (2019) and obtained the missing estimated MAU and DAU values for the groups.

3.3. Map design

Implementation of the visual representation began by connecting generated IP addresses to the centroids of country polygons where users had logged into the location-based online social media. First, this resulted in the structured dataset, with previous and current destination coordinates, time, and gender information of the social media users, and then the OD network flows plotted on the 2D map. In order to comprehend the overall trends in the distribution of network connections between the EU countries, we deployed treemap representation as the preliminary approach. Our goal was to enhance the visual perception of the displayed information within the tree maps by combining colour and size visual variables to represent absolute values. Although, the primary representation we relayed was the time geography concept since it allows us to understand the spatio-temporal distribution of the connecting flows by displaying their co-relations between different EU member states. The representation of space–time networks is complemented with a 2D map representation within the multiple-linked view frame for better orientation purposes (Figure 1). The space–time cube (STC) representation uses a range of exaggeration techniques (linear, areal, logarithmic, etc.) to enhance the 3D visual perception of data and allow knowledge extraction from displayed network representation. For instance, areal exaggeration involves scaling the cube's horizontal and vertical axes to make differences in spatial and temporal extents well visible, and linear exaggeration involves stretching the cube's vertical axis to allow values to be more distinct. While radius exaggeration increases the size of the tubes to enhance their visibility in relation to the quantitative data characteristics. As a result, the cube intuitively generates a 3D visual environment that enables the user to view data representation from multiple perspectives when interactively manipulating and rotating.

The base map of the cube provides a spatial overview of the trajectory distribution and allows enhancement of flow distribution positioning across the EU. Facebook network of previous-current destinations is notably displayed and conversed by the 2D map representation, although it does not allow comprehension of the time component. Differing from it, the STC does communicate the time aspect of the data insights instantaneously by giving the notion of the duration and intensity of the network connections during the year 2021 within the EU states.

The base map used in the STC application can be moved along the time axis to allow investigation of the exact media network communication activities over space–time. Network connections are represented in 2D and 3D maps based on the existing qualitative and quantitative information using absolute values and the combination of size and colour visual variables adapted from Kveladze et al. (2019) and Colorbrewer 2.0. Besides, data exploration and manipulation tools for selection and filtering from time, space, and data characteristics perspectives provide flexible data analysis options to comprehend the full extent of the behavioural patterns in generated representations to avoid visual clutter. Accordingly, the generated flow map is fully interactive on the 3D map, enabling the selection of group or individual flows to comprehend variations in communication between countries over space and time. The base map designed and imported from Mapbox is also interactive and allows individual countries to be selected, highlighted, and filtered for better visual exploration. One can also enhance the base map by

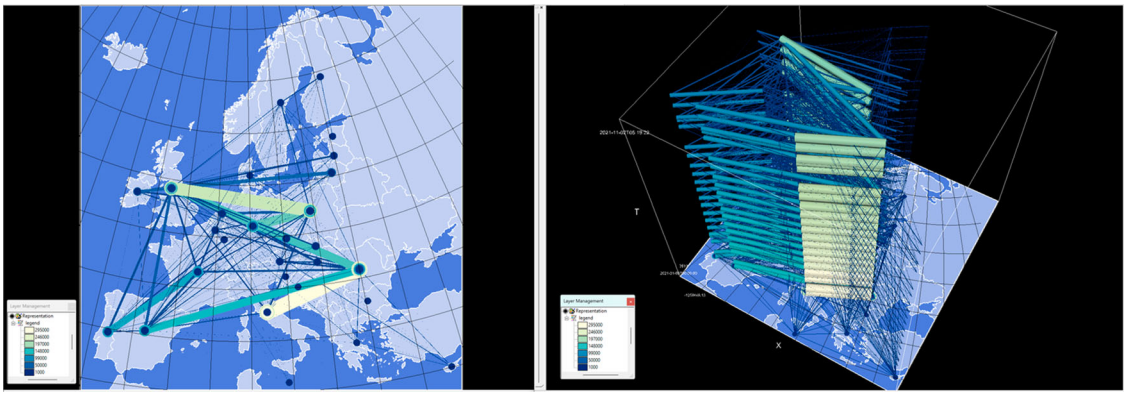

Figure 1. The distribution of Facebook social media connections among EU countries between the 8th of January and the 2nd of November 2021 are plotted and displayed on the 2D map (left) and 3D STC (right), where flow trajectories that appear larger in size and lighter in colour indicate a higher number of connections, while smaller-sized and darker-coloured trajectories suggest lower connections. Besides, proportional symbols on the 2D map and base map of the STC reflect the same information as flow trajectories to showcase the extent of connectivity patterns amongst countries.

applying transparency or modifying and re-designing its elements by complementing them with other relevant geographical information, such as capital cities.

4. Results

The treemap in Figure 2 illustrates the trends in previous and current destination distributions for each gender group based on the total number of social media users over 2021 between countries. The overall distribution of connections in the EU for larger countries is higher compared to smaller countries. Surprisingly, it reveals that female hypothetical migrants exceed the number of male hypothetical migrants, although both groups have similar trends regarding the destination countries. For instance, female network connections from Romania and Poland to the United Kingdom and Italy reach

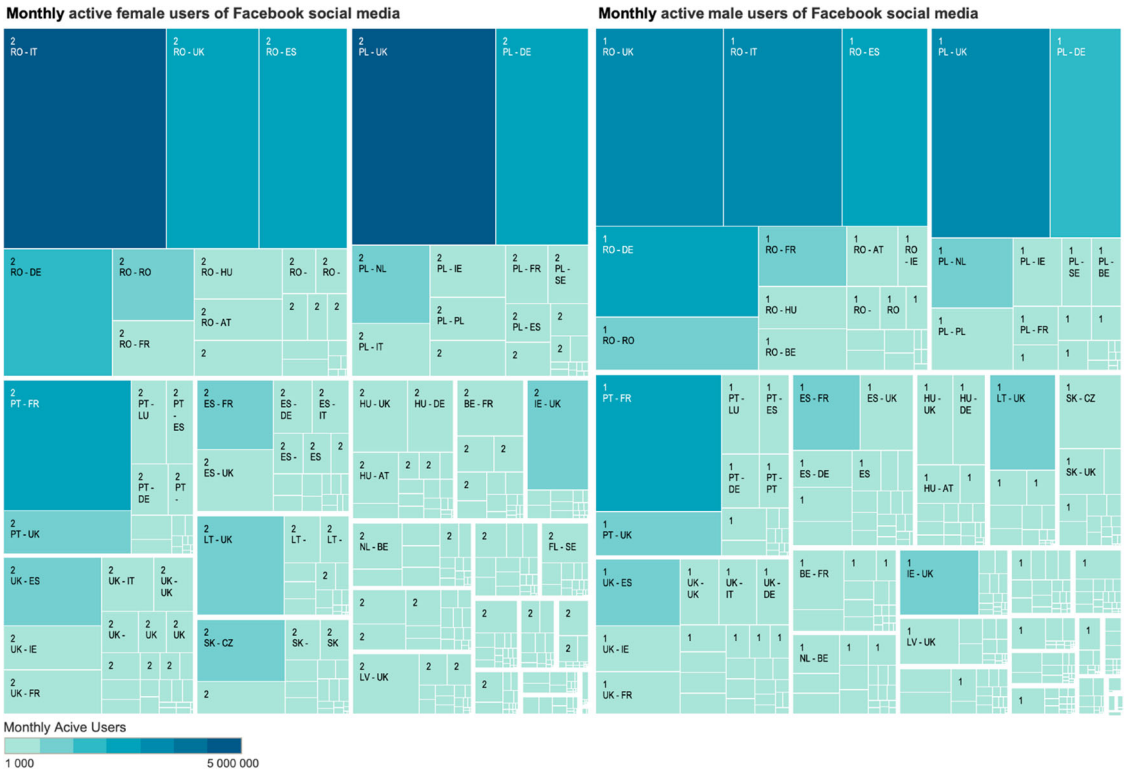

Figure 2. The treemap represents the distribution of Facebook social media connections from 8th of January and the 2nd of November 2021 within EU countries, where number 1 on the right square indicates male users and number 2 on the left square indicates female users. The country codes on the squares indicate first, previous, and then current destinations, i.e. RO - IT. The white colour of the letters indicates more than 2,000,000 MAU connections, and black indicates less than 2,000,000 MAU connections. The darker the blue colour, the higher the connections, and vice versa; the lighter the blue, the lower the connections. The size of the rectangles indicates the absolute number of network connections between EU countries.

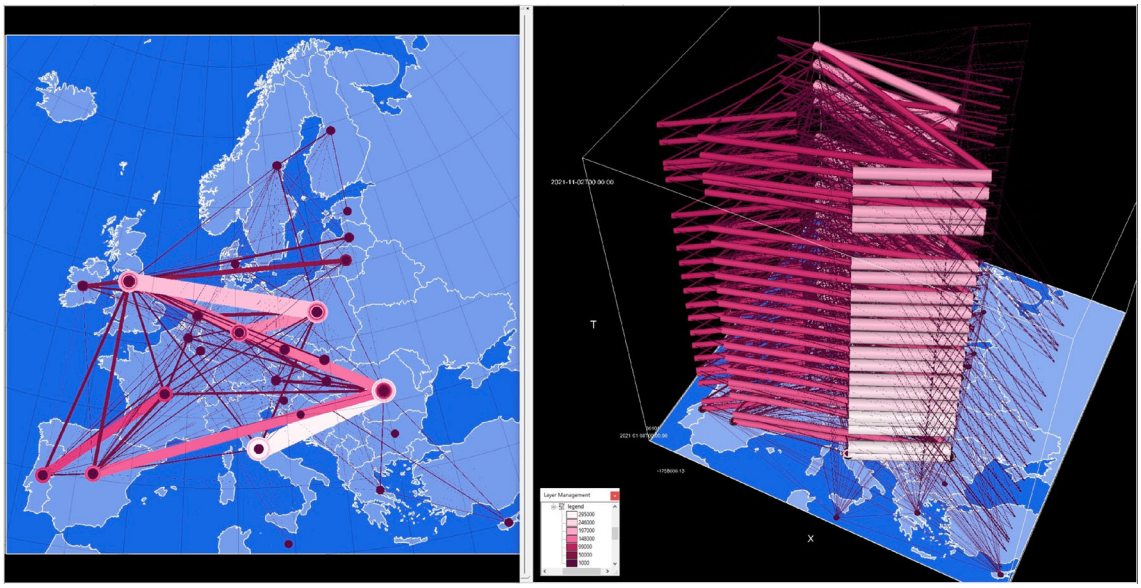

Figure 3. Online social media communication patterns for Female MAUs in the EU from the 8th of January till the 2nd of November 2021. The 3D STC (right) and 2D map (left) display patterns where larger and light-pink-coloured trajectories indicate many connections, while smaller and darker-pink-coloured trajectories suggest a small number of connections. The proportional symbols plotted on the 2D map and base map of the STC offer the same information on female communication patterns in each country. See the video 1 here or in Supplemental Materials.

5,000,000 MAUs compared to male network connections that do not exceed 3,500,000 MAUs. One could assume that the male population is more active in leaving the country for work or tourism purposes and relocating elsewhere in Europe, or perhaps, in this case, females are better and more active social media users. Although it is obvious that Romanian FB users, in general, greatly exceed in online network activities and, therefore, in hypothetical migration compared to other EU countries. Similar patterns can be observed in the STC representation in Figure 3 (see also video 1 in Supplemental Materials), where the temporal distribution of the larger or smaller quantities of the network connections during different months shows dynamic changes in female media communication patterns. For example, in the case of Romania and Italy, the media communication patterns are very intense by the beginning of the year. While throughout 2021, those patterns are decreasing in intensity.

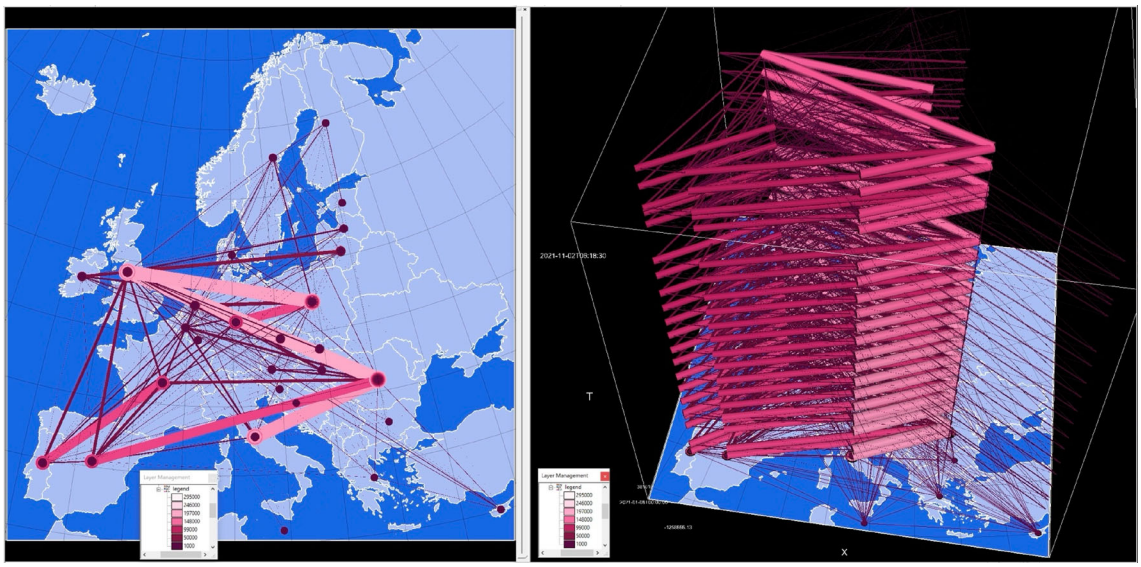

Figure 4. Online social media communication patterns for Male MAUs in the EU between the 8th of January and the 2nd of November 2021. The 3D STC (right) and 2D map (left) display patterns where larger and light-pink-coloured trajectories indicate many connections, while smaller and darker-pink-coloured trajectories suggest a small number of connections. The proportional symbols displayed on the 2D map and base map of the STC offer the same information on male communication patterns in each country. See the video 2 here or in Supplemental Materials.

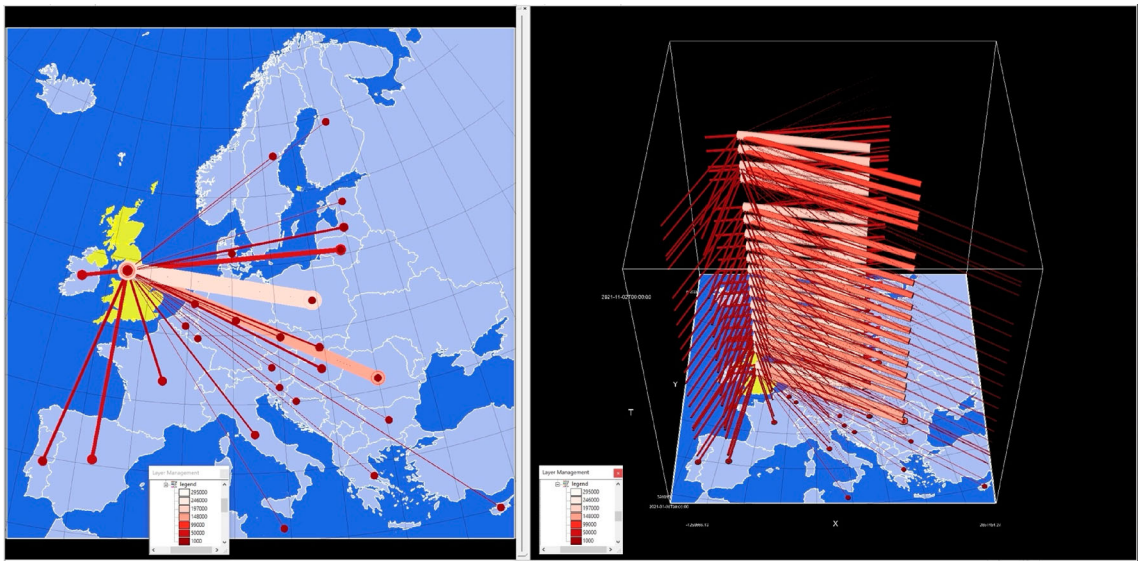

Figure 5. UK as a preferred destination for female FB MAUs from the 8th of January till the 2nd of November 2021. The 3D STC (right) and 2D map (left) showcase the origin-destination flows for the UK as a country of preferred destination where larger and light-orange-coloured trajectories indicate connections with the most communication patterns. While small size and darker-orange-coloured trajectories suggest a lower number of connections. The proportional symbols mapped on the 2D map and base map of the STC show the same information for individual countries. See the video 3 here or in Supplemental Materials.

It is remarkable that this pattern at the beginning of 2021 could be related to the COVID-19 pandemic restrictions since it significantly influenced human behavioural patterns in online social media during the lockdown, i.e. people became more active and dependent on social media for exchanging news, lifestyle, etc. While later, when restrictions were loosened, human mobility increased, and online media communication activities decreased.

Besides, we also believe that such long-distance communications have something to do with the economic situations resulting in a possible migration within the EU states rather than tourism-related movements. This recommendation is based on the data that shows small variations in the volume of social networking between countries throughout the year rather than distinctive patterns during the holiday seasons. For instance, distinctively intensive and steady flows between Romania–Italy and Poland–the UK amongst females indicate hypothetical migration between countries. Besides, one can also observe clearly visible communication patterns between

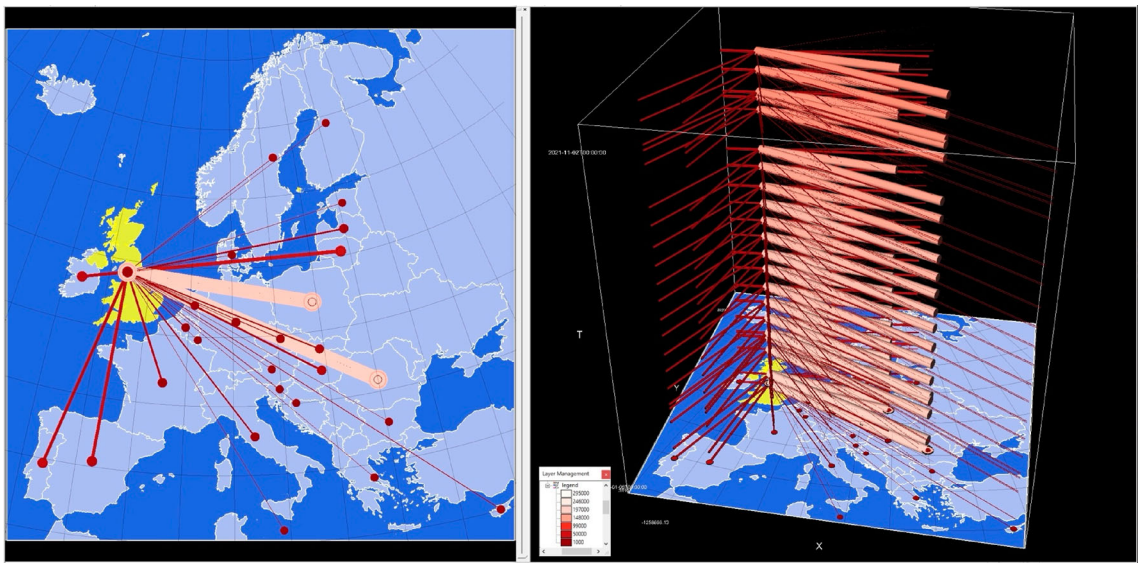

Figure 6. UK as a preferred destination for male FB MAUs between the 8th of January and the 2nd of November 2021. The 3D STC (right) and 2D map (left) display the UK as a country of preferred destination where larger and light-orange-coloured trajectories indicate connections with the most communication patterns, and small size and darker-orange-coloured trajectories suggest a lower number of connections. The proportional symbols plotted on the 2D map and base map of the STC illustrate the same information as flow trajectories. See the video 3 here or in Supplemental Materials.

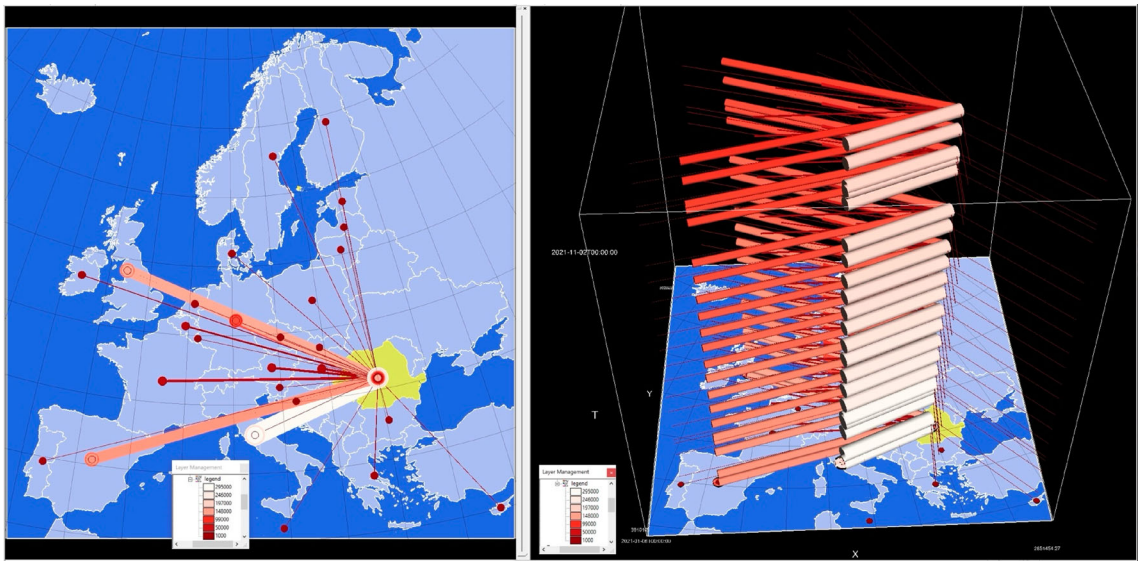

Figure 7. Romania as a country of the previous destination for female FB MAUs from the 8th of January till the 2nd of November 2021. The 3D STC (right) and 2D map (left) display Romania as a country of the previous destination where larger and light-orange-coloured trajectories indicate connections with the most communication patterns. At the same time, the small size and darker-orange-coloured trajectories suggest a lower number of connections. The proportional symbols displayed on the 2D map and base map of the STC illustrate the same information as flow trajectories. See the video 3 here or in Supplemental Materials.

Poland and Germany, between Romania and Spain, and Portugal and France.

Different media communication patterns can be observed for male MAUs in Figure 4 (see video 2 in Supplemental Materials). Here, the media communication flows between the same countries reveal relatively low activity compared to females. Although the STC shows the exact flow network but different intensities of the connections between countries over the year. For instance, compared to females, the majority of the males from Romania communicate equally with Italy and the UK, while males from Poland prefer the UK, just like Polish females.

The other interesting aspect is to observe the most preferred destination countries through FB media network flows. The STC representation in Figures 5 and 6 (see video 3 in Supplemental Materials) shows the UK as a current destination for females and, respectively, for males. According to Figure 5 (see also video 3 in Supplemental Materials), the UK is the most popular and preferred destination for Polish female FB social media users, whereas we know from Figure 3 that

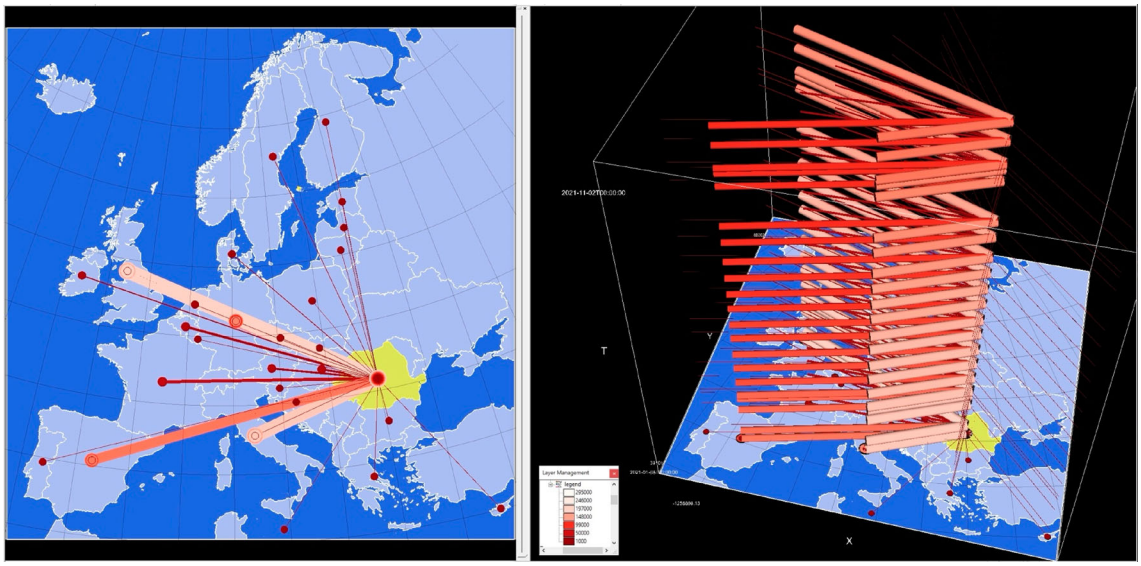

Figure 8. Romania as a country of the previous destination for male FB MAUs between the 8th of January and the 2nd of November 2021. The 3D STC (right) and 2D map (left) display Romania as a country of the previous destination where larger and light-orange-coloured trajectories indicate connections with the most communication patterns, and small size and darker-orange-coloured trajectories suggest a lower number of connections. The proportional symbols shown on the 2D map and base map of the STC illustrate the same information as flow trajectories. See the video 3 here or in Supplemental Materials.

UK is only a secondary choice for Romanian females. Although unlike females, the UK is a top destination amongst Romanian and Polish males.

According to Figures 3 and 4, Poland and Romania display the most intensive FB social network communication flows for previous destination countries compared to other countries. To gain a more comprehensive understanding of the distribution of Facebook communication flows across EU countries, our research focused on Romania as a country of previous destination or a potential country of origin for both gender groups. Our findings, as displayed in Figures 7 and 8 (see video 3 in Supplemental Materials), provide a clear and insightful view of the social media communication dynamics between Romania and other EU countries.

The representation generated for the Romanian female FB social media users confirmed intense communication between Italy and Romania as we previously mentioned after Figure 3, followed by Spain and the UK (Figure 7).

It also reveals that communication was slightly more intensive at the beginning of 2021 compared to the end of the year when COVID restrictions were loosened. This is probably due to the introduced vaccination passports that allowed people some physical mobility across the EU.

On the other hand, the representation created for the Romanian male FB users in Figure 8 showed three distinctive communication patterns. It is obvious that male MAUs hypothetically tend to migrate to the UK as their primary destination and Italy as their second choice. However, there is also a noticeable communication flow towards Spain and Germany. Like the female FB MAUs, they too show visible intense communication at the beginning of 2021, and then it slowly decreases towards the end of the year. As mentioned above, it is likely linked to the easing of COVID-19 restrictions.

5. Discussion and conclusion

Online social media offers spatially and temporally unrestrained freedom for modern society and accumulates an immense number of human activities that provide an opportunity to estimate human behavioural patterns in a timely manner as a supplement to traditional data sources. Consequently, we proposed using Facebook social media to estimate the hypothetical human migration patterns between EU member states. Based on the fusion of the time geography framework with Facebook social media and flow map visualisation, we generated space–time-oriented visual representations that allowed the detection of the hypothetical migration patterns through the online behaviour of MAUs' across the EU. Initially, we focused on investigating the social media dataset with a treemap to discover the scale of human mobility in different countries. This was followed by the investigation, resulting in spatio-temporal analysis sustained by the 2D and 3D visual representations integrated within the multiple-linked view concept. It is remarkable that we could achieve a detailed explanation of the temporal aspect based on the time geography concept and the space–time cube by displaying the spatio-temporal distribution of the flows. Besides, data manipulation tools such as spatio-temporal zoom and filtering were introduced within the multiple linked views to tackle visual clutter and facilitate flexible data analysis of hypothetical human migration patterns.

Generated multiple linked views proved the usefulness of a cost-efficient real-time Facebook social network dataset since it displays spatial resolution with an accurate login location and proper coverage. On the other hand, the Facebook dataset is not representative due to age, sex, culture, self-reported country of origin, etc. biases, which lead to the challenge of generating previous – current destination flows. Therefore, due to the missing information, the Facebook social network dataset does not reflect the correct amount of the accumulated migration flows between the EU countries but allows us to estimate the migration extent. Despite this challenge, generated flow maps in 2D and 3D STC proved effective since they could reveal the spatial and temporal distribution of mobility patterns between EU countries, thus offering a new perspective on possibilities for interdisciplinary research.

Although the visual representation discussed in this paper proved to be effective for discovering interesting patterns, there are still a few areas that require further attention for improvements in the future that will lead to better results. First, we realised an interesting challenge regarding data visualisation during the inclusion of a legend for the STC view, which should incorporate depth cues to accurately represent the STC's visual content. Furthermore, when the size visual variable smoothly transitions between values, it becomes difficult for the viewer to visually perceive changes in quantitative data values. To address this issue, we utilised a combination of size and colour visual variables to improve information communication. However, this approach requires further refinement and attention. We also recommend using detail-oriented, time-stamped information that will allow exploration of the intensity of the media communication flows during weekdays in future. And lastly, enriching FB data with other relevant behavioural data sources will help to gain comprehensive knowledge on MAUs online behavioural activities to outline possible migration patterns better.

Software

RStudio and open-source Python code published on GitHub and QGIS were used to gather and process Facebook social media datasets for analysis and visualisation. The treemap representation was implemented in Python through pandas, matplotlib and squarify libraries. The Space–Time Cube (STC) visual representation is the plugin implemented into the open-source GIS and Remote Sensing software environment Ilwis and fostered by 52°North dedicated to open science and spatial information research. In addition, Mapbox layers were used to build the custom base map and later integrate it into the STC plugin.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The data used in this article is freely available for analysis and visualization to all interested parties on the official website of the FUME project, Zenodo and the DiVA portal.

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References

Alexander, M., Polimis, K., & Zagheni, E. (2019). The impact of hurricane Maria on Out-migration from Puerto Rico: Evidence from Facebook data. *Population and Development Review*, *45*(3), 617–630. https://doi.org/10.1111/padr.12289

Araújo, M., Mejova, Y., Weber, I., & Benevenuto, F. (2017). *Using Facebook Ads audiences for global lifestyle disease surveillance*. WebSci 2017 - Proceedings of the 2017 ACM Web Science Conference (pp. 253–257). https://doi.org/10.1145/3091478.3091513

Docquier, F., Golenvaux, N., Nijssen, S., Schaus, P., & Stips, F. (2022). Cross-border mobility responses to COVID-19 in Europe: New evidence from Facebook data. *Globalization and Health*, *18*(1), 1–17. https://doi.org/10.1186/s12992-022-00832-6

Felmlee, D. H., Blanford, J. I., Matthews, S. A., & MacEachren, A. M. (2020). The geography of sentiment towards the women's March of 2017. *PLoS One*, *15*(6), e0233994. https://doi.org/10.1371/JOURNAL.PONE.0233994

Figueroa-Alfaro, R. W., & Tang, Z. (2017). Evaluating the aesthetic value of cultural ecosystem services by mapping geo-tagged photographs from social media data on Panoramio and Flickr. *Journal of Environmental Planning and Management*, *60*(2), 266–281. https://doi.org/10.1080/09640568.2016.1151772

Gabrielli, L., Rinzivillo, S., Ronzano, F., & Villatoro, D. (2014). From tweets to semantic trajectories: Mining anomalous urban mobility patterns. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) (Vol. 8313, pp. 26–35). https://doi.org/10.1007/978-3-319-04178-0_3/FIGURES/6

Gendronneau, C., Wiśniowski, A., Yildiz, D., Zagheni, E., Fiorio, L., Hsiao, Y., Stepanek, M., Weber, I., Abel, G., & Hoorens, S. (2019). Measuring labour mobility and migration using big data: Exploring the potential of social-media data for measuring EU mobility flows and stocks of EU movers. In *Ep68038*. Publications Office of the European Union. https://doi.org/10.2767/474282

Hägerstrand, T. (1970). What about people in Regional Science? *Papers of the Regional Science Association*, *24* (1), 6–21. https://doi.org/10.1007/BF01936872

Herdağdelen, A., State, B., Adamic, L., & Mason, W. (2016). *The social ties of immigrant communities in the United States*. In WebSci 2016 - Proceedings of the 2016 ACM Web Science Conference (pp. 78–84). https://doi.org/10.1145/2908131.2908163

Huang, Q., & Wong, D. W. S. (2015). Modeling and visualizing regular human mobility patterns with uncertainty: An example using Twitter data. *Annals of the Association of American Geographers*, *105*(6), 1179–1197. https://doi.org/10.1080/00045608.2015.1081120

Jurić, T. (2022). Big (crisis) data in refugee and migration studies - case study of Ukrainian refugees. *Comparative Southeast European Studies*, *70*(3), 540–553. https://doi.org/10.1515/soeu-2022-0048

Kveladze, I., Kraak, M. J., & van Elzakker, C. P. J. M. (2019). Cartographic design and the space–time cube. *The Cartographic Journal*, *56*(1), 73–90. https://doi.org/10.1080/00087041.2018.1495898

Mukherjee, S., Hauthal, E., & Burghardt, D. (2022). Analyzing the EU migration crisis as reflected on twitter. *KN - Journal of Cartography and Geographic Information*, *72*(3), 213–228. https://doi.org/10.1007/s42489-022-00114-6

Osorio Arjona, J., & García Palomares, J. C. J. C. (2020). Spatio-temporal mobility and Twitter: 3D visualisation of mobility flows. *Journal of Maps*, *16*(1), 153–160. https://doi.org/10.1080/17445647.2020.1778549

Pezanowski, S., Mitra, P., & MacEachren, A. M. (2022). Exploring descriptions of movement through geovisual analytics. *KN - Journal of Cartography and Geographic Information*, *72*(1), 5–27. https://doi.org/10.1007/s42489-022-00098-3

Rama, D., Mejova, Y., Tizzoni, M., Kalimeri, K., & Weber, I. (2020). *Facebook Ads as a demographic tool to measure the urban-rural divide*. The Web Conference 2020 - Proceedings of the World Wide Web Conference, WWW 2020 (pp. 327–338). https://doi.org/10.1145/3366423.3380118

Spyratos, S., Vespe, M., Natale, F., Weber, I., Zagheni, E., & Rango, M. (2019). Quantifying international human mobility patterns using Facebook Network data. *PLoS One*, *14*(10), e0224134. https://doi.org/10.1371/journal.pone.0224134

Zagheni, E., Weber, I., & Gummadi, K. (2017). Leveraging Facebook's Advertising Platform to Monitor Stocks of Migrants. Population and Development Review, *43*(4), 721–734. https://doi.org/10.1111/PADR.12102