Mapping trajectories and flows: Facilitating a humancentered approach to movement data analytics

Somayeh Dodge & Evgeny Noi, noi@ucsb.edu MOVE Lab: http://move.geog.ucsb.edu/

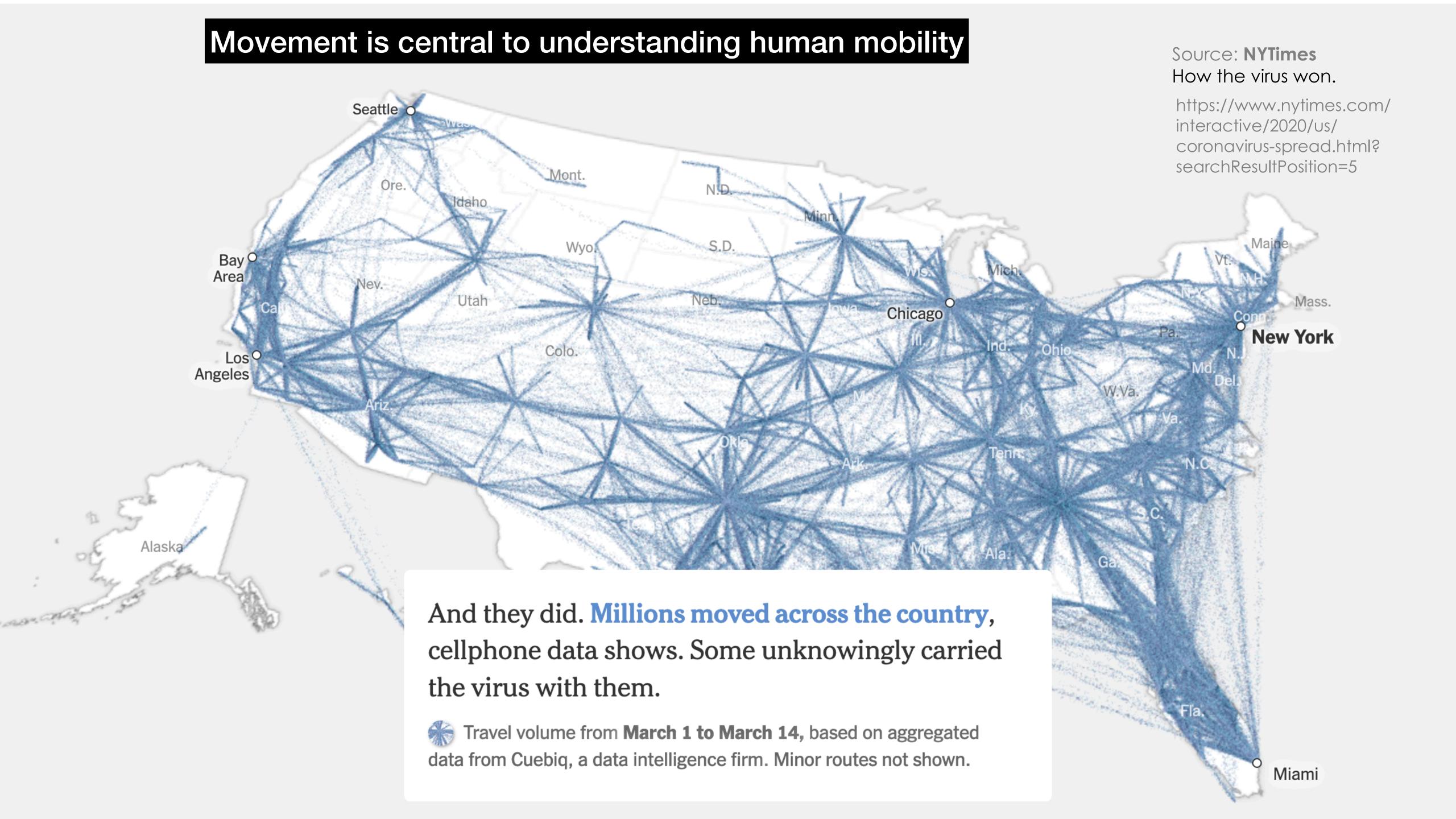
Department of Geography
University of California Santa Barbara



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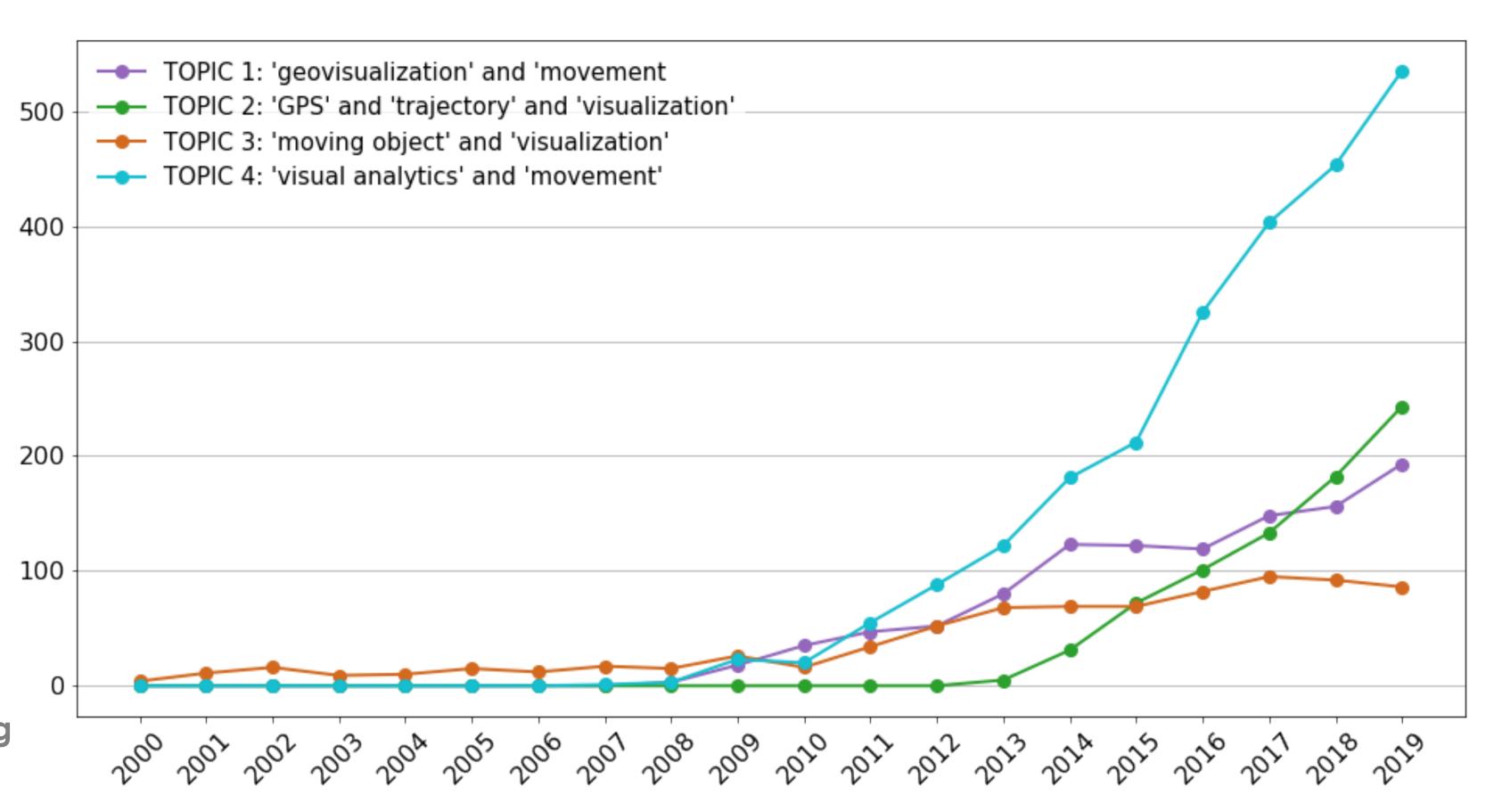






Using visualization to facilitate knowledge discovery from Movement data

Web of Science



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Movement data

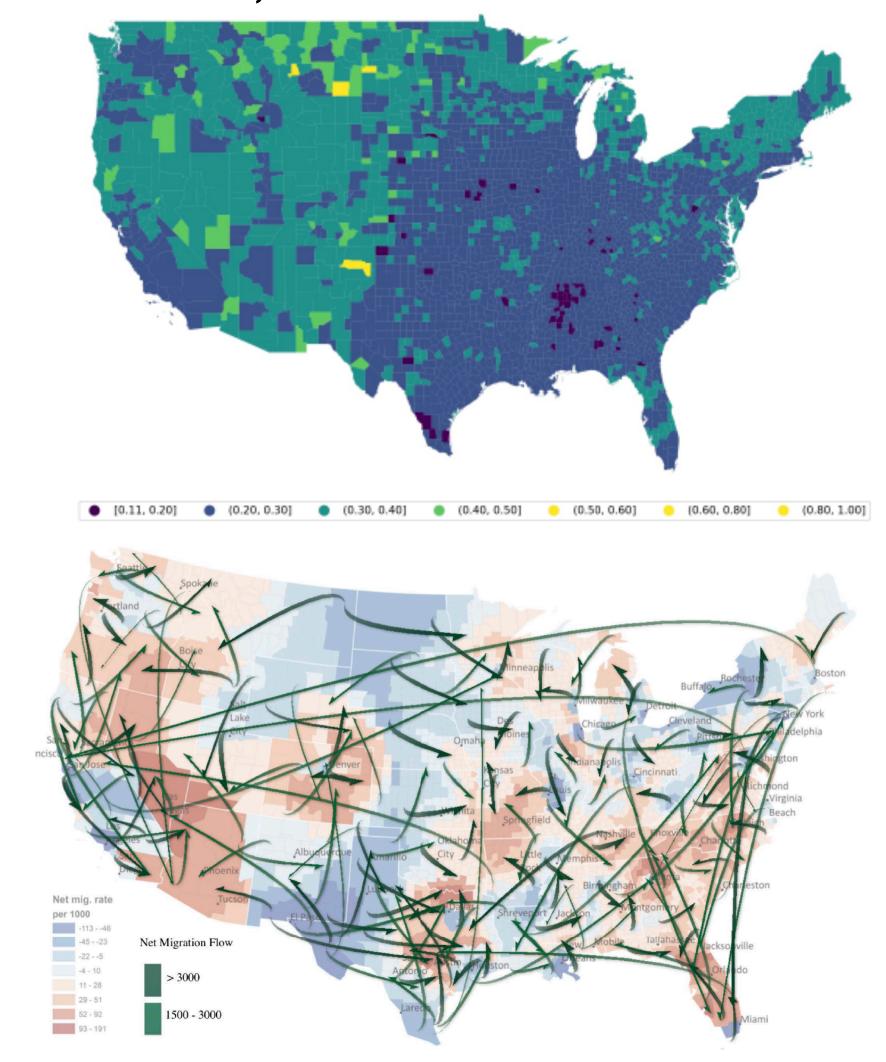
Individual Trajectories (Lagrangian perspective)



Xavier & Dodge (2014)

GPS Trajectories of 9 adult albatrosses (90 min resolution), annotated with wind speed (m/s) and wind direction, 6-hour, 2.5°, U/V-wind components NCEP Reanalysis 2 using Env-DATA

Aggregate Movement / Flows (Eulerian perspective) March 1, 2020

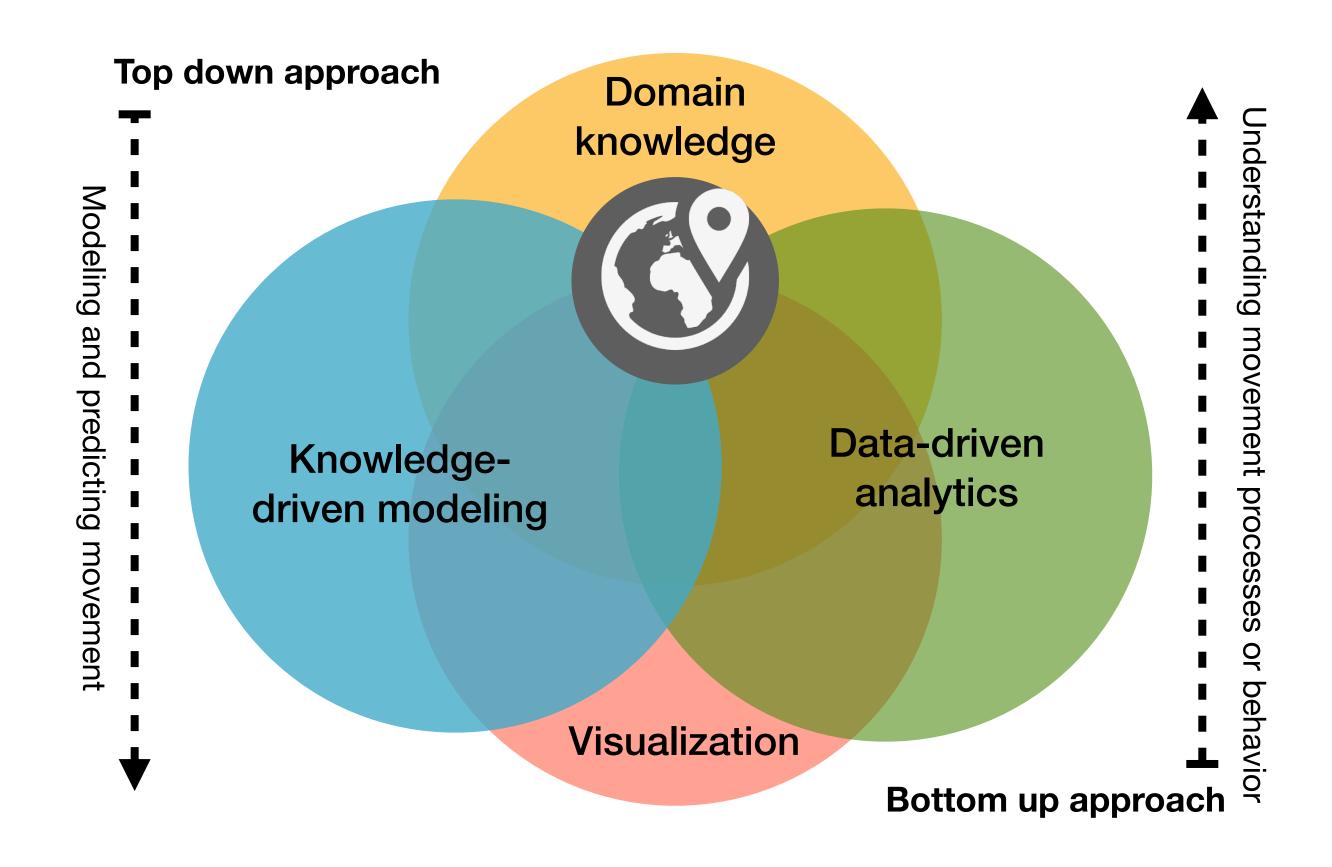


US Migration: "Smoothed net migration flows for age 25-29, with population threshold = 1,000,000. The background map shows the net migration rate for age group 25-29." Guo, 2014



A human-centered approach to movement analytics

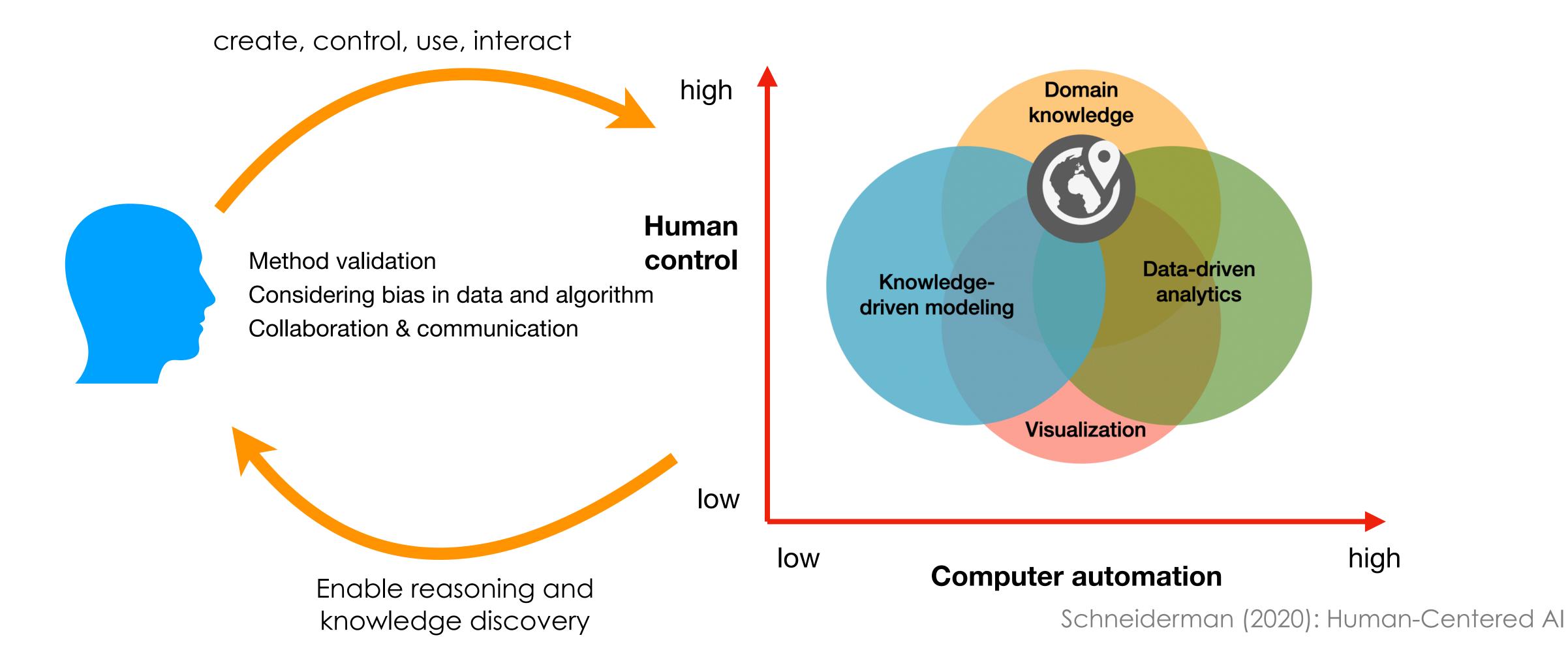
TO UNDERSTANDING AND PREDICTING MOVEMENT



Dodge S. (2021), A Data Science Framework for Movement. Geographical Analysis, the GA 50th Anniversary Special Issue, 53 (1), pp. 855 –876.



A human-centered approach to movement analytics





Data Visualization to create, interact, use, validate generate facilitate humancentered Movement inform Analytics Data-driven analytics & modeling-The 'human' create, interact, specialized users, control, use, validate lanalysts, developers l relation movement to context assist patterns enable quantitative reasoning inference & knowledge construction Cartographic mapping & information visualization interact, use general users

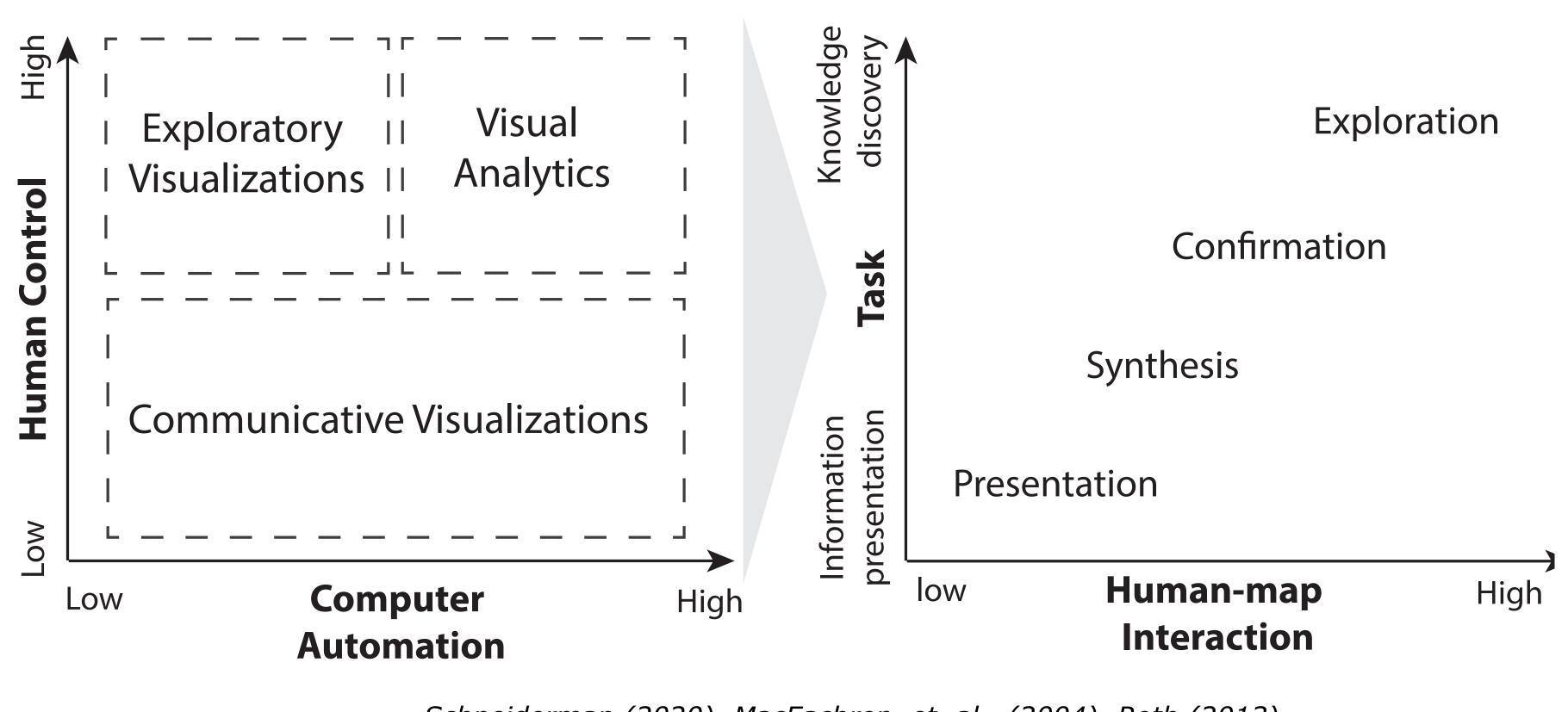
enable visual reasoning, validation, hypothesis generation, collaboration, knowledge discovery cognition & interpretation

Knowledge discovery high **Exploration** Visual Exploratory **Analytics** Visualizations 11 Control Confirmation Human **Synthesis Communicative Visualizations** mation Presentation Infor prese low high **Human-map** Computer low high Interaction **Automation**

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MOVE@ucsb

Visualization to facilitate human-centered knowledge Discovery



Schneiderman (2020), MacEachren et al., (2004), Roth (2013)

presenting exploration exploration private funknowns interaction interaction

CARTOGRAPHY³

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Characterizing movement visualization

How and what conditions? Geographic representation pyramid **Context parameters** Attributes **Movement parameters** Kraak (2014), Mennis, Peuquet, and Qian (2000) Mr. in State of the state of th What behavior? 150 —> 40 (from 2010-2020) MIN SOLOW SO

How often?

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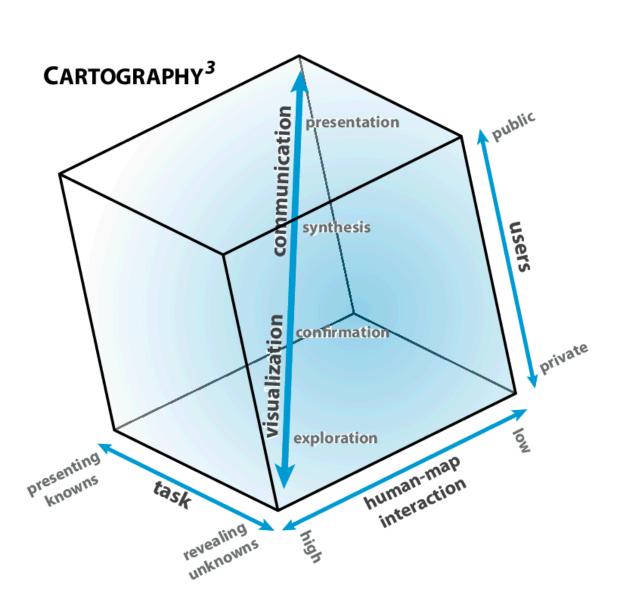
What? What changes in How many flows? flows and density? Linear Lagrangian What path or extent? Time Location **Eulerian** Cyclic Where in space and time? When? Where? How long? What path?

Discrete

Aggregate

@Noi noiev.com

Characterizing movement visualization



MacEachren et al., (2004), Roth (2013)

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	Category	#	Elements	Element type (encoding)						
VISUAL ELEMENTS	Visualization perspectives	$\frac{1}{2}$	Lagrangian Eulerian	binary $(0/1)$ binary $(0/1)$						
	Movement components	3 4 5 6 7 8	Discrete Aggregate Location Time Movement parameters Context parameters	binary $(0/1)$ binary $(0/1)$ binary $(0/1)$ binary $(0/1)$ binary $(0/1)$ binary $(0/1)$						
	Movement data Representation forms	9 10	Vector Raster	binary $(0/1)$ binary $(0/1)$						
	Cartographic features	11 12 13 14	2D 3D Dynamic Static	binary $(0/1)$ binary $(0/1)$ binary $(0/1)$ binary $(0/1)$						
FUNCTIONAL	Dimensions of Cube ³	13 15 16 17 18	Specialized users Public/novice user Interaction Knowledge construction Information presentation	binary $(0/1)$ binary $(0/1)$ ordinal (low/med/high) binary $(0/1)$ binary $(0/1)$						
ELEMENTS	Advanced Exploratory Functions	19 20	Multiple coordinated views Dynamic querying	binary $(0/1)$ binary $(0/1)$						
	Design Flexibility	21	Flexibility	ordinal (low/med/high)						



Characterizing movement visualization

Clustering and Community detection analysis.

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	VISUAL ELEMENTS													FUNCTIONAL									
Citation	Cluster	Vector	Raster	Lagrangian	Eulerian	Discrete	Aggregate	2D	3D	Static	Dynamic	Location	Time	Movement Parameters	Context Parameters	Multiple Coordinated Views	Dynamic Querying	Specialized user	Noice/general user	Knowledge Construction	Information presentation	Flexibility	Human-map Interaction
Andrienko, G., Andrienko, Fuchs, et al. (2017)	1			_		_			()		_			_	_		_				_	M	H
Anwar et al. (2014)	1																					М	М
Beecham & Wood (2013)	1																					М	L
Chen et al. (2015)	1																					М	Н
Ding et al. (2015)	1																					М	Н
Gong et al. (2018)	1																					М	М
Krueger et al. (2016)	1																					М	Н
Liu et al. (2017)	1																					М	М
Lu et al. (2015)	1																					М	М
Pu et al. (2013)	1																					М	Н
Sun et al. (2014)	1																					М	Н
Von Landesberger et al. (2016)	1																					М	Н
Zeng et al. (2013)	1																					L	Н
Boyandin et al. (2011)	2								_													L	M
Demsar et al. (2014)	2			\Box																		L	M
Graser et al. (2020)	2																					L	L_
Guo & Zhu (2014)	2								lacksquare		\perp											L	M
Hyougo et al. (2014)	2												\vdash			\sqcup						L	<u> </u>
Klein et al. (2014)	2						_		_													L	M
Lyu et al. (2020)	2										_		_			\square	-					느	M
Mungthanya et al. (2019)	2					_					_		_				-					느	<u> </u>
Scheepens et al. (2011)	2								_		<u> </u>					\vdash	-					느	H
Tao et al. (2014)	2								\vdash							$\vdash \vdash \vdash$						누	L N #
van den Berg et al. (2018)	2															$\vdash \vdash \vdash$	-					L I	M
Ventura & McGuffin (2016)	2						_				_											М	<u> </u>
Vrotsou et al. (2017) Wood et al. (2010)	2										-		_			\vdash						<u> </u>	
Yang et al. (2017)	2			$\vdash\vdash$		_			\vdash		<u> </u>		-									<u> </u>	M
Yu et al. (2015)	2					_					\vdash											-	M
Buschmann et al. (2014)	3																					М	M
Fukaya & Misue (2018)	3						\vdash									$\vdash\vdash\vdash$						H	H
Gomes et al. (2017)	3						\vdash			\vdash						$\vdash\vdash\vdash$						М	H
Hoeber & Hasan (2018)	3						\vdash									$\vdash\vdash\vdash$						M	H
Itoh et al. (2016)	3																					M	H
Li et al. (2020)	3																					М	H
Lock et al. (2020)	3																					М	H
Ni et al. (2017)	3															$\vdash \vdash \vdash$						М	H
Tominski et al. (2012)	3																					М	H
Xavier & Dodge (2014)	3																					Н	H
Zhang et al. (2014)	3																					М	Н



Categories of movement visualization

Cluster 1: Interactive Visual Analytics of Aggregate Movement

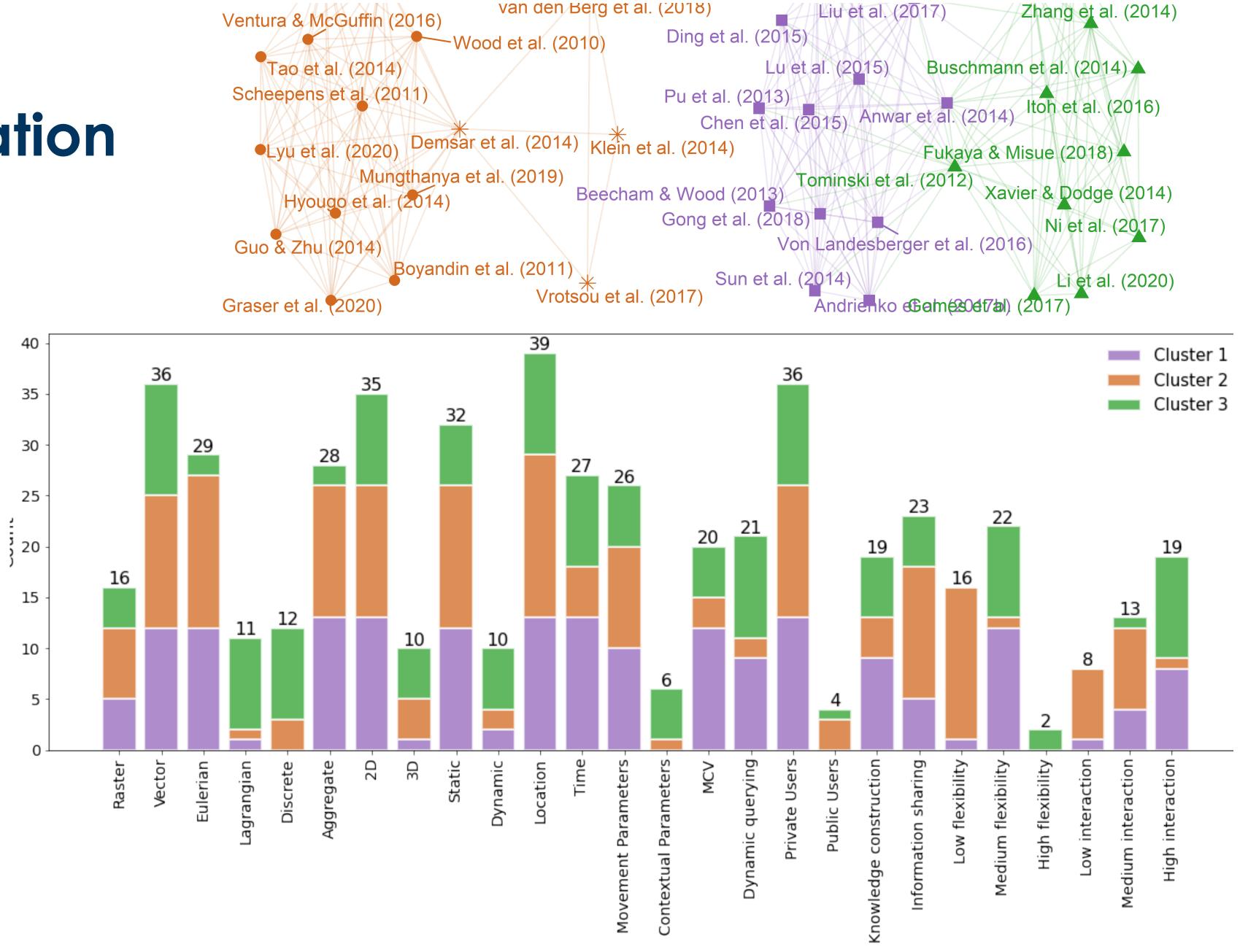
Cluster 2:
Communicative Visualization Methods to
Map Aggregate Movement

Cluster 3: Exploratory & Dynamic Visualization of Trajectories

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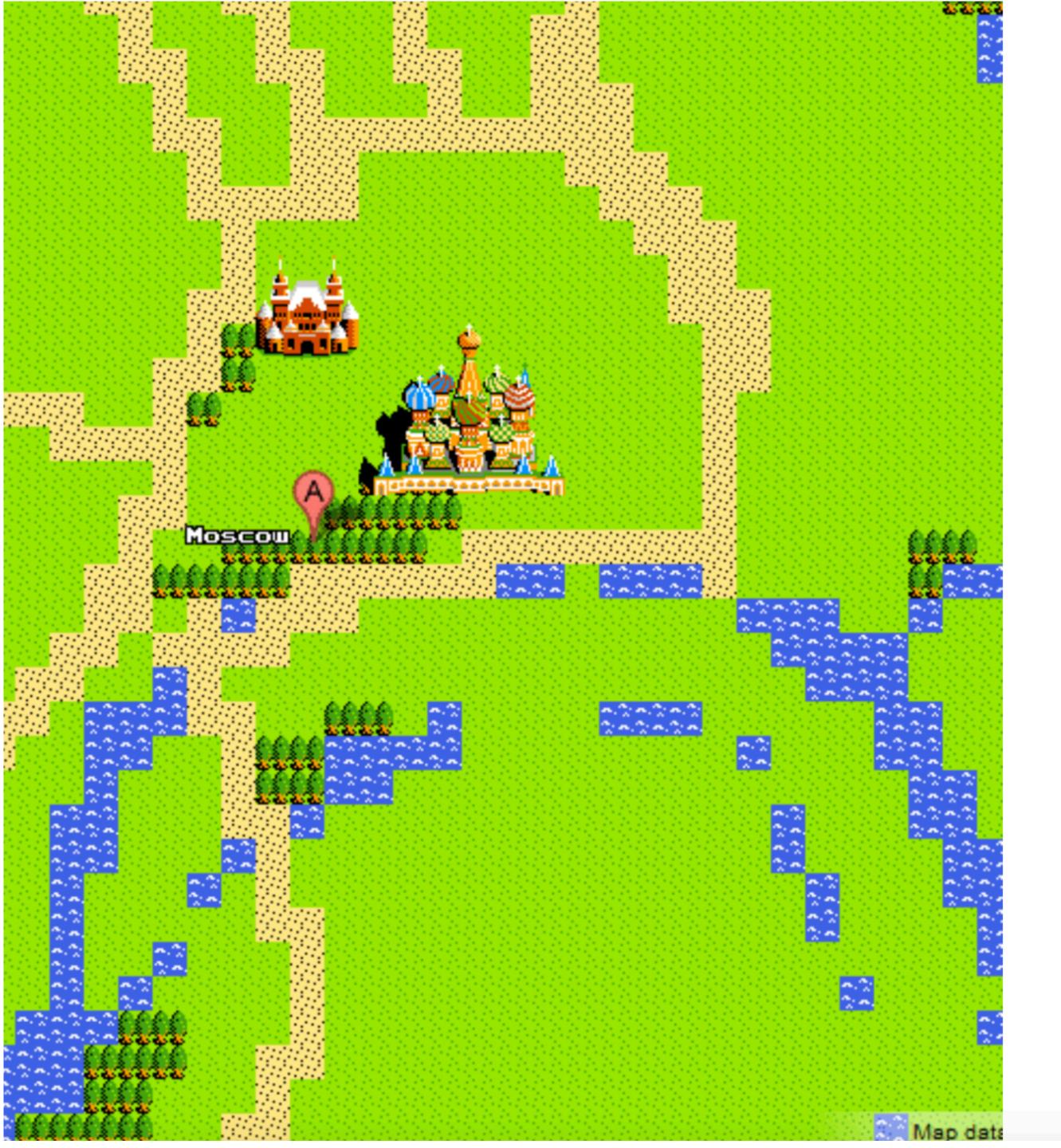




Trends and Gaps in Movement Visualization

- Human-centered visualization tools
 - Combination of visual analytics tools and exploratory tools that is flexible enough to switch between representations (and data models)
- Mapping Context (weather, behavior, interactions)
 - Mapping movement vs contextualizing movement (the latter are rare)
- Bridging the interdisciplinary gap in tools
- Cognitive evaluation and usability studies





I would like to thank my advisor and co-author Somayeh Dodge, as well as MoveLAB at UCSB.

Beers Questions?



Evgeny Noi



" If geography is a prose, maps are iconography. (Lennar Meri)

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Appendix



