Book Chapter

Looking Behind the Screen of Big Data

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CIVAL 6 Able to solve anything from complex fluid flows involving chemical reactions, turbulence and heat transfer, to acoustics, solid mechanics and electromagnetics, OpenFOAM is a common tool used in computer fluid dynamics modelling.

Multi Scale Energy Systems

MUSES 1 Integrating urban planning and energy systems engineering, the City Energy Analyst is an urban energy systems simulation platform used for the design of efficient, low-carbon cities. It allows for the study of the effects, trade-offs and synergies of urban design options and energy infrastructure plans.

Cooling Singapore

CS 1 PSI-BOIL (Parallel SImulator—BOILing) is a computer program that simulates fluid flow, and heat and mass transfer phenomena at various scales.

CS 2 Working at a mesoscale level—an intermediate scale between those of weather systems and of micro climates, the Weather Research and Forecasting model is a weather prediction system design for both atmospheric research and operational forecasting.

Virtual Singapore

VS 1 Semantic labelling incorporates deep learning and artificial intelligence to assign labels to buildings and land cover in high definition 3D urban models.

VS 2 Designed for the Value Lab Screen, Singapore Views is 4D visualisation and presentation tool focusing on urban geographic, spatial, temporal and 3D data complemented by multimedia data such as text, images and videos.

VS 3 The Space Allocation Optimizer is a spatial building programme and layout optimiser that uses land values, floor levels and views for 3D building creation.

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Looking Behind the Screen of Big Data

We set out to examine the digital tool set to see if there was a correlation between the changing accessibility and availability of data (big data) and the development of digital tools at Future Cities Laboratory (FCL). We postulate that these changes in data and the growing coding proficiency amongst our researchers are driving the production of new tools. These are quite different from the tools used in the first phase of the FCL program (FCL 1, 2010–15), which relied in large part on standardised solutions, software packages developed for generic purposes and outside of the context of Singapore.

The focus of FCL 1 was to resolve the control of machines (Value Lab and robotics) and agent-based modelling (Multi-Agent Transport Simulation and the Ethiopia Energy project). At the same time, big data was hardly accessible for Singapore and Southeast Asia. Looking at the digital tools used in the second phase (FCL 2, since 2015), we can see that the main focus is now on analysing urban phenomena and supporting decision making by harnessing big data and writing new code. These tools lead to an increasing number of application cases that draw from contextual data and use tailored digital tools to respond.

To this end, we compiled an inventory of 40 digital tools. Digital tools in this context are defined as protocols or pipelines that capture, organise, structure and transform data into information. Depending on the project, these could be the innovative combination of existing software and plugins, the use of application programming interfaces (APIs) or the development of software. These digital tools were then linked to attributes that emerged from conversations with the researchers and reflected to the best extent the range of applicable features. The attributes were: sensing, analysing, enabling, modelling, optimising, simulating, evaluating, generating, visualising and communicating. The 40 digital tools reflect the complexity of the research. Understood as processes rather than products, these tools offer many possibilities for transformation and transposition to other interdisciplinary projects.

The approach used to analyse the digital tool set was similar to that used in the analysis of the physical tools. We used bipartite modularity to identify clusters. This resulted in the identification of four clear clusters that match the physical tool clusters: analytical, supportive, transformative and representational. (See the chapter ‘Taxonometric insights: Emerging tool clusters and research links’.)

The resulting clusters exhibit strong primary links as described by a high bipartite modularity value, underlining the well-defined structure of the clusters. Because these clusters are not silos, they also exhibit particular secondary links across clusters. The *visualising* attribute of the *representational* cluster in the digital tool set, for instance, is linked to almost all the tools due to the prevalence of visual communication in digital tools. (See the chapter ‘Taxonometric insights: Emerging tool clusters and research links’.) It has been grouped by the algorithm together with *communicating*, a node that is almost exclusively linked to tools in that cluster. Yet, not surprisingly, visualising is a key concept of communicating, and thus these tools are grouped together.

The *modelling* attribute of the *transformative* cluster is also linked to almost all the tools, which supports the argument that models and modelling are central to the use of big data. The *simulating* attribute of the *transformative* cluster is linked to both the *analytical* and *representational* clusters, highlighting a ‘bridge’ function between analysis and visualisation that is necessary to explicate complex processes.

The *sensing* and *enabling* attributes of the *supportive* cluster, in contrast, show fewer backlinks to other clusters, which we interpret as a move towards cross-platform and hardware-independent

digital tools at FCL. The *optimising* attribute of the *analytical* cluster shows few backlinks to tools in other clusters which could derive from the early stage of technologies found in the *analytical* cluster such as genetic algorithms, machine learning and artificial intelligence deployed here.

The cluster graph shown in the chapter 'Taxonometric insights: Emerging tool clusters and research links' supports our statement that the new quality and availability of and access to data on one side and the growing coding proficiency on the other have led to the emergence of transdisciplinary digital tools at FCL.

The change in the quality of data used by our researchers is evident from the tool inventory list. We see a shift from closed, small, researcher-generated datasets towards open, large, public-generated datasets. Social media data is used by the Big Data-Informed Urban Design and Governance project, data spark data by the Engaging Mobility project and mobile phone data by the Urban Complexity project. Sensor data gathered by SENSg is used by the Big Data-Informed Urban Design and Governance and Engaging Mobility projects, other sensor data by the Cyber Civil Infrastructure project and the aggregation of open international datasets with remote sensing by the Urban-Rural Systems project.

The growing coding proficiency can be seen in the same inventory list by looking at the software platforms used to run the digital tools. The parametric design software Grasshopper is used in the Education Research Programme, the Waterfront Tanjong Pagar Project and the Big Data-Informed Urban Design and Governance group. The gaming engine Unity powers the UR-Scape platform in the Urban-Rural Systems project, and the virtual reality environments of the Engaging Mobility platform, the Cognition, Perception and Behaviour in Urban Environments project and the Singapore Views software by Collaborative Interactive Visualisation and Analysis Laboratory (CIVAL).

The parametric urban design package CityEngine drives the Advanced Studies in Urban Design course by the Education Research Programme. Space Syntax and R, the statistical software environment, are used across many projects. Projects such as Ecosystem Services in Urban Landscapes use APIsand tap into the vast datasets of Google Street View to generate tree shade maps for the streets of Singapore. The Big Data-Informed Urban Design and Governance group collects data from social media channels like Twitter and Instagram to create heat maps of spatial use across Singapore. By exploring the digital tool taxonomy, we can further observe the following trends:

Tool Eco-Systems

We have a diversity of tools that cover four different clusters with specific primary and secondary backlinks to other clusters. It is likely that these backlinks will further evolve into specific clusters, as described by the *optimising* attribute, which encompasses machine learning and artificial intelligence. Together these tools and clusters form an eco-system that operates across scales and disciplines.

User-Friendly and Interactive Interfaces

As seen in tools such as the UR-Scape platform, user-friendly and interactive interfaces are critical to carrying out analytical research work, transforming findings into communicable outcomes and supporting decision making. This also shows that digital tools production at FCL matches the hard skills of research and the soft skills of communication, combining both programming-intensive aspects and communication and visualisation aspects.

Harness Big Data

Digital tools tap into diverse, complex and large datasets (big data). Social media data, unstructured data found in images, are being used more and more by FCL researchers, as seen in the alternative mapping of art places in Singapore by the Big Data-Informed Urban Design and Governance group and the Ecosystem Services in Urban Landscapes project.

Tailored Digital Tools

Digital tools are developed in-house, either as a creative combination of existing software (pipelines) and protocols or as customised codes to perform specific tasks related to specific research questions. These protocols, or ways of doing, are transferable to other projects within FCL and beyond. Projects using virtual reality, for instance, both display the possibilities of the technologies and create new avenues for live data collection, such as in the Bike to the Future project by the Engaging Mobility group, and studies on cognition and perception.

Context Specificity

Digital tools address specific issues related to Singapore and the larger Southeast Asian context, which is characterised by highly heterogeneous data gradients. This allows FCL to engage on a totally different level with regional stakeholders and positions the research globally, from the Waterfront Tanjong Pagar to the Bandung Smart Systems project and beyond.

Data Transparency

The changing attitude towards tools and data at FCL coincides with Singapore and Southeast Asia's efforts towards data transparency and accessibility. The Urban Redevelopment Authority (URA) grants interested researchers access to its large urban data collection in a Digital Planning Lab at their premises. Through the Bandung Smart Systems project, many agencies have been onboarded to provide data for the UR-Scape platform in Indonesia. There is also growing interest in the data-informed expertise of FCL's researchers, as shown by the growing number of projects funded by third parties, such as the World Bank, the Asian Development Bank and the Rockefeller Foundation.

As FCL develops further case studies in Singapore and Southeast Asia to validate models, simulation and evaluation methods, new questions and opportunities will arise. By examining the cross-section of digital tools at FCL, we see a dynamic instrumentarium that has emerged in response to the changing quality and quantity of data and the greater coding literacy amongst researchers. From the specific case of FCL, we postulate a global shift from standardised to customised data and tool solutions for urban design and planning. As this taxonomy has been developed, new technologies have disrupted the scientific community. Working groups have formed that discuss the potential of future technologies in the city. This is a significant step towards the transformative aspirations of FCL, and new challenges await FCL researchers in their use of Data:

- The rise of AI and machine learning techniques will lead to the automation of different tasks, speed up analytical and generative processes, and empower designers and decision makers.
- Considered as disruptive, blockchain technology goes hand in hand with more distributed and decentralised decisions, transparency and accountability.
- Finally, impacts on urban governance will transform planning processes. As projects and tools developed by FCL gain traction through their real-life applications and case studies, we aim at reflecting on the conditions that need to be in place to ensure their long-term usefulness. Those conditions stem from urban governance structures as well as maturity in the use of digital tools to transform cities.