# Supplemental Materials

### **Ocupado: Visualizing Location-Based Counts Over Time Across Buildings**

Michael Oppermann, opperman@cs.ubc.ca Tamara Munzner, tmm@cs.ubc.ca

University of British Columbia

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### 1. Data Sources

Organization	Data source	Time period	Device count recordings	Buildings	Floors	Zones	
university campus A	static export	2016-05-15 — 2017-05-19	24.669 million	49	247	730	Many system outages
university campus B	static export	2016-10-28 — 2017-09-13	28.576 million	11	38	181	
university campus A	live stream	2018-04-21 — 2018-12-31 (+ few days in 2019)	62.749 million	25	104	778	
company + synthetic data	live stream	since 2018-02-13	3.628 million	<b>1</b> (+1)	1 (+1)	27 (+6)	This Ocupado instance includes addit synthetic data: 1 building, 1 floor, and zones





### 2. Stakeholders and Demos

Table 1. N. of demos and informal interviews conducted by us and Sensible Building Science (SBS).

Focus domains	1) Custodial services	6
	University 1-A	4
	University 1-B	1
	Company 1	1
	2) Building management	3
	University 1-A	3
	3) Space planning	4
	University 1-A	3
	University 2	1
	4) Classroom management	2
	University 1-A	2
	5) Data quality control	
	SBS	Continuous feedback
Winnowing	Physical security (University 1-A)	1
	Risk management (University 1-A)	1
	Energy management (University 1-B)	3
	Transportation Authority	1

#### Table 2. Demos and informal interviews conducted by SBS without our direct involvement.

#### Potential customers, sponsors, and partners

Universities	9					
Government agencies	6					
Companies	5					
Number of demos per sector	Number of demos per sector					
Innovation program	3					
Technology partner	6					
Facilities planning and management	12					
Energy management	3					



### 2. Stakeholders and Tasks

		Custodial	S
	Tasks	Custodial Head	
T1	Confirm observations that have been made		
T2	Monitor the current/recent utilization rate		
Т3	Communicate space usage and justify decisions		
T4	Validate the data (quality control)		

#### Match



ervices	Duilding		Classroom		
Custodial Manager	Management	Space Planning	Management	Data Quality	





### 2. Stakeholders, Domain Questions, and Tasks

Stakeholder	Domain Questions and Needs	T1	T2	Т3	T4	Match
Custodial Head	Want something informative at start of shift, to prioritize areas					
	Which regions were heavily used recently and are empty now? If space not used, don't have to do things (not room level, more building/floor level)					
	Which regions are normally heavy used but current occupancy is low? (or inverse; current anomaly vs. average)					
Custodial Manager	When should we clean? Have to wait until students leave. Still students sitting there using room and screens. Custodians can't get them cleaned and get complaints in the morning that they're dirty					
	Justify with hard data when there's pushback about resource needs.					
Building Manager	Get a better understanding how space is used. Labs are open early from morning until late at night. We don't know when people are using it and want to know what is going on.					
	What are typical usage patterns of informal learning spaces on the 3rd floor?					
	We want to proof capacity bottlenecks for discussions about new buildings					
	How often are rooms (meetings rooms, project rooms) booked but not used?					
Space Planning	When do people leave buildings in the evening? Which rooms should be kept open for students in the evening or on weekends?					
	Where (on the campus) are most of the people during the day?					
	Interested in whether there are tons of rooms that are supposed to be used, but are not actually in use. Perception that this is happening.	-				
	What is our summer use? We think it is a lot more than people think. Is it going up?					
Classroom Management	Start a flood of consultation around changing the scheduling model. Some of this might be able to inform that. Attrition rates, start times, front/rear loading, actual occupancy vs. registration of the term					
	Do students show up for different classes than they're scheduled for? (e.g. 11 am instead of 8 am class)					
Data Quality Control	Analyze if there are unusual characteristics or gaps					
	Take another look at how accurate the device numbers are (especially for small rooms). What is the minimum size of a zone that can be captured?					
	How are adjacent zones affected by a large number of devices in one room?					
						4



3. Ocupado Architecture & Design



### Notation: Spatial and Temporal Data Granularity

![](_page_7_Figure_1.jpeg)

Examples:ZF-ALL:SI Compare the utilization of all zones on a floor over the past 12 hours.FB-Few:LA Compare the average utilization of floors 1-3 in the CS building.

Region ← {Zone, Floor, Building} Context ← {Floor, Building, Campus} Cardinality ← {One, Few, All } Regions

Period ← { Short-Term, Long-Term }
Rollup ← { Aggregate, Individual } Counts

![](_page_7_Picture_5.jpeg)

### Visualization Components: Region Selectors

![](_page_8_Figure_1.jpeg)

Interfaces	Data Granularity
Campus Explorer	(all combinations if they are within the <i>scale</i> limit)
Building Long-Term	[ZF,ZB,FB]-*
Sandbox	BC-*

![](_page_8_Picture_3.jpeg)

## Visualization Components: Region Subset Views

![](_page_9_Figure_1.jpeg)

Comparisons	Interfaces	Data Granularity
epeating patterns, rends, outliers c <i>ontiguous)</i>	<ul> <li>Sandbox</li> <li>Campus Explorer</li> <li>Building Long-Term</li> </ul>	*:LI ≤ 30 regions
epeating patterns, rends, outliers non-contiguous)	• Campus Explorer	*:LA ≤ 30 regions
ypical profiles	<ul> <li>Campus Explorer</li> <li>Building Long-Term</li> </ul>	*:LA ≤ 30 regions
vithin-session batterns, outliers	<ul> <li>Sandbox</li> <li>Campus Explorer</li> <li>Region Compare</li> </ul>	*:LI ≤ 30 regions
vithin local spatial neighborhood	<ul> <li>Building Recent</li> </ul>	[ZF,ZB]-*:S* ≤ 10 floors
across distributed egions	• Campus Explorer	[ZF,ZB,ZC]-*:S*

### Visualization Components: Region Detail Views

### Visual encoding

![](_page_10_Figure_2.jpeg)

![](_page_10_Figure_3.jpeg)

### **B** Floor plan

![](_page_10_Figure_5.jpeg)

### C Confidence-band line chart

![](_page_10_Figure_7.jpeg)

Interfaces	Data Granularity
<ul> <li>Sandbox</li> <li>Campus Explorer</li> <li>Building Long-Term</li> <li>Building Recent</li> </ul>	*-One:L*
<ul> <li>Sandbox</li> <li>Campus Explorer</li> <li>Building Long-Term</li> <li>Building Recent</li> </ul>	ZF-*
<ul> <li>Campus Explorer</li> <li>Building Long-Term</li> <li>Building Recent</li> </ul>	*-[One,Few]:LA

## **Ocupado Evolution**

![](_page_11_Figure_1.jpeg)

Time

### Interfaces: Spatial and Temporal Data Granularity

			One region		Few regions				All regions					
Interface	Region	Context	Short-Term Individual	Short-Term Aggregated	Long-Term Individual	Long-Term Aggregated	Short-Term Individual	Short-Term Aggregated	Long-Term Individual	Long-Term Aggregated	Short-Term Individual	Short-Term Aggregated	Long-Term Individual	Lo Ag
Sandbox	Zone	Floor			ZF-One:LI	ZF-One:LA			ZF-Few:LI	ZF-Few:LA			ZF-All:LI	Z
	Zone	Building				ZB-One:LA				ZB-Few:LA				Z
	Floor	Building				FB-One:LA				FB-Few:LA				F
	Building	Campus			BC-One:LI	BC-One:LA			BC-Few:LI	BC-Few:LA			BC-All:LI	В
Campus Explorer	Zone	Floor	ZF-One:SI	ZF-One:SA	ZF-One:LI	ZF-One:LA	ZF-Few:SI	ZF-Few:SA	ZF-Few:LI	ZF-Few:LA	ZF-All:SI	ZF-All:SA	ZF-All:LI	Z
	Zone	Building	ZB-One:SI	ZB-One:SA	ZB-One:LI	ZB-One:LA	ZB-Few:SI	ZB-Few:SA	ZB-Few:LI	ZB-Few:LA	ZB-All:SI	ZB-All:SA	ZB-All:LI	Z
	Floor	Building	FB-One:SI	FB-One:SA	FB-One:LI	FB-One:LA	FB-Few:SI	FB-Few:SA	FB-Few:LI	FB-Few:LA	FB-All:SI	FB-All:SA	FB-All:LI	F
	Zone	Campus	ZC-One:SI	ZC-One:SA	ZC-One:LI	ZC-One:LA	ZC-Few:SI	ZC-Few:SA	ZC-Few:LI	ZC-Few:LA	ZC-All:SI	ZC-All:SA		Z
	Floor	Campus	FC-One:SI	FC-One:SA	FC-One:LI	FC-One:LA	FC-Few:SI	FC-Few:SA	FC-Few:LI	FC-Few:LA	FC-All:SI	FC-All:SA		F
	Building	Campus	BC-One:SI	BC-One:SA	BC-One:LI	BC-One:LA	BC-Few:SI	<b>BC-Few:SA</b>	<b>BC-Few:LI</b>	BC-Few:LA	BC-All:SI	BC-All:SA	BC-All:LI	В
<b>Building Long-Term</b>	Zone	Floor			ZF-One:LI	ZF-One:LA			ZB-Few:LI	ZB-Few:LA			ZB-All:LI	Z
	Zone	Building			ZB-One:LI	ZB-One:LA			FB-Few:LI	FB-Few:LA			FB-All:LI	F
	Floor	Building			FB-One:LI	FB-One:LA				FB-Few:LA				F
Building Recent	Zone	Floor	ZF-One:SI	ZF-One:SA			ZF-Few:SI	ZF-Few:SA			ZF-All:SI	ZF-All:SA		
	Zone	Building	ZB-One:SI	ZB-One:SA			ZB-Few:SI	ZB-Few:SA			ZB-All:SI	ZB-All:SA		
	Floor	Building	FB-One:SI	FB-One:SA	FB-One:LI	FB-One:LA	FB-Few:SI	FB-Few:SA		FB-Few:LA	FB-All:SI	FB-All:SA		F
Region Compare	Zone	Floor			ZF-One:LI	ZF-One:LA			ZF-Few:LI	ZF-Few:LA				
	Zone	Building			ZB-One:LI	ZB-One:LA			ZB-Few:LI	ZB-Few:LA				
	Floor	Building			FB-One:LI	FB-One:LA			FB-Few:LI	FB-Few:LA				
	Zone	Campus			ZC-One:LI	ZC-One:LA			ZC-Few:LI	ZC-Few:LA				
	Floor	Campus			FC-One:LI	FC-One:LA			FC-Few:LI	FC-Few:LA				
	Building	Campus			BC-One:LI	BC-One:LA			<b>BC-Few:LI</b>	BC-Few:LA				

![](_page_12_Figure_2.jpeg)

## Architectural Overview of All Ocupado Applications

![](_page_13_Figure_1.jpeg)

![](_page_13_Picture_2.jpeg)

### **Ocupado Interfaces and Tasks**

	Tasks	Campus Explorer	Building Long-Term	Building Recent	Region Comp
T1	Confirm observations that have been made				
T2	Monitor the current/recent utilization rate				
Т3	Communicate space usage and justify decisions				
T4	Validate the data (quality control)				

#### Match

![](_page_14_Figure_3.jpeg)

![](_page_14_Picture_4.jpeg)

4. Ocupado Interfaces

![](_page_15_Picture_2.jpeg)

### 4.1 Prototyping Sandbox

![](_page_16_Picture_2.jpeg)

## **Prototyping Sandbox: View Coordination & Layout**

![](_page_17_Figure_1.jpeg)

![](_page_17_Figure_2.jpeg)

#### Compact summary:

![](_page_17_Figure_4.jpeg)

![](_page_17_Picture_7.jpeg)

![](_page_18_Figure_0.jpeg)

**Sandbox overview.** Side-by-side views provide a high-level overview: (a) Campus map with geographical locations of all buildings. (b) Temporal overview uses sparklines to show aggregated device counts over the course of one year. Y-scales are normalized to the maximum device count per building to reveal patterns despite varying occupancy rates between buildings. The first dataset was characterized by a large number of outages and short recording periods for some of the buildings. Grey stripes explicitly indicate missing data. BC-AII:LI

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![](_page_18_Picture_3.jpeg)

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	Henry Angus
	Library PARC

![](_page_18_Picture_5.jpeg)

**OCUPADO** sandbox 124 🔵 Independent scales 🛛 💿 Global scale June July August Wesbrook CA Chancellor Blvd August June July Green College mu\_m 22 0 Museum of Anthropology at UBC each Man man mr. m\_m\_m\_m\_m\_m Wreck Beach (Clothing Optional) . Doug Thur Sport

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Totem Field Research Station

Sandbox overview. Users can choose absolute y-scales to compare device counts of different buildings. BC-AII:LI

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![](_page_19_Picture_5.jpeg)

![](_page_19_Picture_6.jpeg)

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	Brimacombe
	Chem Bio Eng
	Beaty Biodiver
	Biological Sci
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	Buchanan A, B,
	TEF3
	Henry Angus
	Library PARC

![](_page_19_Picture_8.jpeg)

![](_page_20_Figure_0.jpeg)

Sandbox overview. We experimented with an interactive heatmap as an alternative visual encoding for the overview visualization. Users can choose between different daily metrics that define the color of each cell: average, minimum, maximum, and stddev. This screenshot shows independent scales, normalized to the maximum value of each building. BC-AII:LA

Search buildings

![](_page_20_Figure_4.jpeg)

![](_page_20_Picture_5.jpeg)

![](_page_21_Figure_0.jpeg)

Sandbox overview. Heatmap with absolute scales to facilitate cross-building comparisons. BC-All:LA

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![](_page_21_Picture_4.jpeg)

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**Comparison between sparklines and heatmaps.** We tried interactive heatmaps but ruled them out quickly: the higher precision of the positional vs. the color channel for visual encoding was indeed crucial in this case, as discussed with Pathline [Meyer, 2010] and studied by Lam et al. [Lam, 2007]. BC-All:L\*

![](_page_22_Figure_2.jpeg)

![](_page_22_Figure_4.jpeg)

![](_page_23_Picture_0.jpeg)

Sandbox overview. Smaller university campus. BC-All:LI

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sing values							
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![](_page_23_Picture_4.jpeg)

![](_page_23_Figure_5.jpeg)

![](_page_23_Picture_6.jpeg)

![](_page_24_Figure_0.jpeg)

Sandbox, building details. The building detail view contains: (a) geo map that shows the location of the building; (b) list of floors that can be used to navigate; (c) average day profiles for different temporal resolutions. The y-axis shows normalized device counts (%) and the x-axis the hours of the day. Users can, for example, analyze the typical daily utilization on weekdays or during the summer term. A click on one of the small multiples opens the results for the selected time period in the main view. We can change the spatial aggregation from building to floor or zone (see next) page). B-One:LA

![](_page_24_Figure_3.jpeg)

![](_page_24_Picture_4.jpeg)

![](_page_25_Figure_0.jpeg)

![](_page_25_Figure_1.jpeg)

![](_page_25_Picture_4.jpeg)

![](_page_26_Figure_0.jpeg)

Sandbox, floor details. (a) interactive floor plan for spatial context and to navigate to specific zones; (b) superimposed average day profiles for all zones on this floor. ZF-All:LA

![](_page_26_Figure_2.jpeg)

![](_page_26_Picture_3.jpeg)

![](_page_27_Figure_0.jpeg)

Sandbox, floor details. Zone detail view includes a zoomable binned timeline to show the absolute device count over time. ZF-One:LI

OCUPADO

![](_page_27_Picture_2.jpeg)

Second Floor \$ / Building Zone 11 Q Search buildings

![](_page_27_Picture_5.jpeg)

![](_page_28_Figure_0.jpeg)

Clustering interface. The goal of this endeavour was to identify regions on a campus that are usually very quiet or only busy in the morning based on a clustering approach. During an early project stage, we thought about embedding extensive clustering and prediction models into Ocupado. This interface was intended as an internal tool for us and our collaborator to inspect clustering results that we generated offline because of the large volume of data (input for clustering: 1 row = 1 "region" day). For the example shown above, we generated 5 clusters and the user can choose between absolute device counts or normalized counts based on the maximum of each region. (a) Multi-series line chart shows the average of each cluster. We can see that most of the days are in the blue cluster. The absolute device count during these days was very low. (b) Stacked bar charts for different regional levels. Each row corresponds to a building, floor or zone. The width of a bar denotes the number of days a region is in one of the 5 clusters. Selection windows can be dragged across the the stacked bar charts to filter regions. (c) The timeline displays the temporal distribution of each cluster as bars. (d) The heatmap displays the locations (building, floor) of the selected zones. We abandoned this approach completely because of its lack of semantic meaning for our focus domain. Similar to the average day profiles, we lose a lot of nuances by clustering that are needed to answer common stakeholder questions. The workflow may be of interest for other use cases.

![](_page_28_Figure_2.jpeg)

![](_page_28_Picture_3.jpeg)

OCUPADO sandbox

![](_page_29_Figure_1.jpeg)

Clustering interface with data from a smaller campus. We selected normalized device counts and filtered the regions with selection windows that are displayed as black-bordered rectangles on top of stacked bar charts.

![](_page_29_Figure_4.jpeg)

	# Floors	# Zones	В	1	2	3
EME	5/5	<b>21</b> / 32				
ART	3/4	16 / 23				
LIB	1/4	3/15				

![](_page_29_Figure_7.jpeg)

![](_page_30_Figure_0.jpeg)

Clustering interface with data from a smaller campus. Static visualization that shows individual cluster items (= individual days).

![](_page_30_Figure_2.jpeg)

![](_page_30_Picture_3.jpeg)

![](_page_31_Figure_0.jpeg)

![](_page_31_Figure_1.jpeg)

**Campus map small multiples.** We examined the use of geographical maps to show the distribution of devices on a university campus. The maps are created with the open-source library leaflet.js that uses kernel density estimation to generate the heatmap overlays. This prototype was rejected because it shows location-based counts averaged over a long time period and only from a bird's eye view. This view was not directly relevant to our stakeholders because their analysis questions are at a much lower data granularity level. BC-All:\*A

![](_page_31_Picture_3.jpeg)

### 4.2 Campus Explorer Interface

![](_page_32_Picture_1.jpeg)

### **Campus Explorer: View Coordination & Layout**

![](_page_33_Figure_1.jpeg)

![](_page_33_Figure_2.jpeg)

![](_page_33_Picture_3.jpeg)

![](_page_33_Picture_4.jpeg)

![](_page_34_Figure_0.jpeg)

**Campus explorer.** (a) Control panel for filter and display settings; (b) Region selector shown as quantitative and categorical data stripes to provide a high-level overview ZC-AII:\*A; (c) Region subset view provides mid-level details for selected regions ZC-Few:LI. Users can choose between different visual encodings for the region subset view. Clicking on one region opens a modal window with low-level details.

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![](_page_34_Figure_4.jpeg)

![](_page_34_Picture_5.jpeg)

![](_page_35_Picture_0.jpeg)

![](_page_35_Figure_1.jpeg)

Campus explorer, control panel. Users can choose between different visual encoding idioms for the region subset view.

![](_page_35_Picture_4.jpeg)




Campus explorer, control panel. Regions can be filtered by building or space type.





















**Campus explorer, control panel.** Activity patterns provide one-click shortcuts to complex combinations of actions. They can control spatial and temporal filter criteria, the visual encoding of the region subset view, and the selection window in the region overview.







**Campus explorer, control panel.** We integrated a small widget that shows a textual summary of all active filters because custom selections would not be immediately visible due to the many different options that are hidden in dropdown menus.









DISPLAY	REGION	Ø SPA	ACE TYPE	🛱 ти	ME SPAN	💭 Ы	SCRETE TIM
31 results ( 7 selected) Sp	atial aggregation: Zone	∽ Sort b	y: Avg. activity	· ~ /	Data gaps	✓ Divider	Scale: In
Live activity Avg. activity	45 1 749	ි Sess	ions Juxtapo	osed			
		ī —			July		
		KOER 101					
		KOER 361					
		KOER g641-					
		KOER 201					
		KOER 341					
		KOER g580-					
		KOER g480-					

Campus explorer, region subset view. Box-plot-bars for discrete time intervals, such as Mondays between 2-8pm. ZB-Few:LA



### Campus

ME SESSIONS	ACTIVITY PATTERNS	FILTER CRITE
ndependent $\sim$	Last 24h	between 14:00-20:0 range 05/31/201
		range oor or zon











Campus explorer, region subset view. Discrete time intervals visualized as superimposed line charts. A region gets automatically highlighted in both views when we hover over it. ZC-Few:LI





8:00		19:00	
	-		
	-		
	-		
			-





Campus explorer, region subset view. Many discrete time sessions, such as all weekdays during a long recording period, are displayed as superimposed line charts. Different temporal filter options help users in narrowing down the search space. ZB-Few:LI









### Campus

Q Search buildings

OCUPADO





Campus explorer, region subset view. Absolute scales ensure consistent axes and enable direct comparisons of device counts between regions. Users can globally choose between independent and absolute y-scales that are applied to all temporal visualizations (sparklines, box-plot-bars, superimposed line charts). ZC-Few:LA

### Campus

**OCUPADO** 



Search buildings

	21:00	
		-
(10)		<u>01</u>





Campus explorer, region subset view. The spatial heatmap provides a campus-level view on device counts. Each row in the grid represents a building and each column indicates a floor. A cell is composed of one or more subcells, one for each zone, where its size and color depends on the number of devices. We decided to encode the same variable with two channels (size and color) to increase saliency. Users can hover over subcells to see more details or click on it to open the floor plan. This visualization approach provides a way to locate regions with certain characteristics and to investigate spatial relationships. ZC-AII:\*







Campus explorer, region detail view. (a) Zoomable binned time series chart with confidence bands (ZF-One:LI). (b) Interactive floor plan to provide a spatial context and to navigate between close regions. (c) Typical day profiles show aggregated device counts (ZF-One:LA).

Avera	age day							
	03:00	09:00	15:00	21:00	03:00	09:00	15:00	21
	Weekday				Weekend day			
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200								
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Campus explorer, region detail view. Example for another zone. ZF-One:L\*

	03:00	09:00	15:00	21:00	03:00	09:00	15:00	21:
:50 -	Weekday				Weekend day			
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## **OCUPADO**

Campus



Campus explorer, region detail view. The detail view of a building is divided into two tabs: the first tab shows all floor plans ([ZB,FB]-AII) and the second tab contains a binned time series chart and typical day profiles, similar to floor or zone detail views.

Search buildings

Classroom Non-assigned

Level 1







_

**OCUPADO** campus explorer



Campus explorer, region subset view. Regions are filtered by building (DMP) and displayed as sparklines (ZB-AII:LI).

Campus

	SCRETE TIME	SESSIONS	ନ୍ୟ <b>AC</b>	ΤΙVITY ΡΑΤΤΕ	RNS		FILTER CRITE
ale: Indep	endent $\checkmark$	Group build	ings 🗌 L	ast 24h			Regions i
August	September	October	November	December	2"19	Febru	ary March
		_M					Minham
M	M	Mr.l					M
		_Mmmmmm				M. M.M	Malma
_m_mh_	.mh_mm_MML	_MM_MM				MMMM	Mahmen
				MM_MM_M	_Mp_MM_A	http://www.m	M
		_MMM	MMMM			MMMM	Mursh-in
_m_m	_m_mh_mh_	_mh_Mm_mm_m				MMM	m_m_m
					- <b>A .</b>		
July	August	Sept	ember	October	Nov	rember	December







OCUPADO campus explorer



**Campus explorer, region selector.** The width of the data stripes (ZC-AII:\*A) is adjustable and users can enable or disable variables.

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## 4.3 Building Long-Term Interface

# **Building Long-Term Interface: View Coordination & Layout**



## Compact summary:









### Building X



**OCUPADO** building long term



Building Long-Term Interface. Selected zones are shown as typical day profiles. ZB-Few:LA

### Building X



avg.	activity	
	min/max	







Building Long-Term Interface. Typical day profiles for many zones, automatically sized to fit onscreen. ZF-All:LA

		Scale: independent	absolute View: time	elines average day Sort:	unroll alphabetica
				average mid	dle 50% of distributior
- 200	F2 - 2204	- 200 F2 - 2201	- 200 <b>F2 - 2402</b>	- 200 F2 - 2401	- 200 F2 ·
- 150		- 150	- 150	- 150	- 150
- 100		- 100	- 100	- 100	- 100
- 50		- 50	- 50	- 50	- 50
	and the second	والمراجع	يرون مرود مرود مرود مرود مرود مرود مرود مرود	1 ambas and 1 a	the second s
- 200	F2 - 2239	- 200 F2 - 2232	- 200 <b>F2 - 2233</b>	- 200 F2 - 2231	- 200 F2 - g2
- 150		- 150	- 150	- 150	- 150
- 100		- 100	- 100	- 100	- 100
- 50		- 50	- 50	- 50	- 50
- 200	F2 - 2965	-200 F2 - 2964	- 200 <b>F2 - 2942</b>	- 200 F2 - 2916	- 200 <b>F2</b>
- 150		- 150	- 150	- 150	- 150
- 100		- 100	- 100	- 100	- 100
- 50		- 50	- 50	- 50	- 50
F2 - (	2600-2653 2700-2721	F2 - g2002-2005			
- 200		- 200			
- 150		- 150			
- 100		- 100			
- 50	1 Laborately	- 50			
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# **Linearized Floor-Plan Ordering for Regions**

We use a shortest path algorithm to create a linearized order for the perzones displays of sparklines or line charts in the region subset view of the Building Long-term interface, based on spatial contiguity within the floor plans.

- In the outer loop, traverse each floor in order from top to bottom floor.  $\bullet$
- Within each floor, the start position is at the top left corner (x=0; y=0).  $\bullet$
- Compute the bounding box for all shapes/zones.
- Calculate the distance to the nearest bounding box centroid (nearest zone). Save the zone ID that is assigned to a shape in an ordered list and label the shape as visited. Repeat this step until all shapes are visited.

## **Examples:**









## 4.4 Building Recent Interface

## **Building Recent Interface: View Coordination & Layout**



Compact summary:























Building Recent Interface. Floor plans are arranged in a grid layout to fit on screen and live device counts are displayed as superimposed circle symbols ([ZF,ZB]-AII:S\*). The left sidebar shows the aggregated per-floor usage for a typical day compared to the current device count (FB-AII:LA).









Building Recent Interface. Users can switch between histograms and line charts in the left sidebar. This screenshot shows per-floor aggregate trend charts with device counts over past 12 hours (FB-AII:SI) and prediction for the next 3 hours (red dashed line).









Building Recent Interface. The underlying variable for the glyphs can be changed in the control panel. For example, analysts can choose to show the maximum device count during the last 12 hours instead of the live device count. Average device count is the third option. [ZF,ZB]-All:SA











Building Recent Interface. The range slider in the top right corner can be used to select a shorter time window; for example, to select the average device count between 8am - 12pm today. [ZF,ZB]-AII:SA









Building Recent Interface. Example for another building with aggregated per-floor usage in the left column (FB-AII:LA) and live device counts superimposed on floor plans in the right column (ZB-AII:SI).





## **OCUPADO** custodial services





12:00

06:00

18:00

Building Recent Interface. Example for another building with per-floor trend charts in the left column (FB-AII:SI) and live device counts in the right column (ZB-AII:SI).

Transa 0940

3

12

17

25

3















Building Recent Interface. Example for another building (left column: FB-AII:LA ; right column: ZB-AII:SI ).

-



## 4.5 Region Comparison Interface

## **Region Comparison Interface: View Coordination & Layout**

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## Compact summary:





# **Region Comparison Interface**

This interface allows users to compare a small subset of regions or time periods. A recurring task (T6), for instance, to analyze the impact of space upgrades, to compare summer vs. winter use, or to help assess the custodial workload of different floors.

The *Campus Explorer* and the *Building Long-Term Interface* support this task only to a limited extent. In these tools, we use juxtaposition to provide overviews of many regions but this faceting approach can hinder direct local comparison [Javed, 2010]. In the *Region Comparison Interface*, we display data from multiple regions in the same space, superimposed.



70





Region Compare Interface. The visual query builder is the key component that aids comparisons along two dimensions: space and time. For each query, users can select a building, floor or zone and a specific time period. FB-Few







Region Compare Interface. The results are displayed in multiple views: (a) Interactive zoomable line chart to show the raw device counts over time (ZB-Few:LI); (b) boxplots to summarize the distribution of counts (ZB-Few:LA); (c) trend charts to facilitate a high-level comparison (ZB-Few:LA); and (d) line charts with aggregated counts to illustrate the average daily and weekly utilization (ZB-Few:LA). We allow a maximum of five time series or regions to avoid visual clutter. Queries can be added and removed dynamically and all views are updated accordingly.






5. Analysis Scenarios

73

### 5.1 Analysis Scenario: Compare Usage Patterns



# **Compare Usage Patterns**

The motivating question for this analysis scenario is: How do renovations or space improvements affect the usage pattern of a region?

A building manager and a senior planner for informal learning spaces posed this question several times. It is an important but infrequent task that requires a

substantial amount of recorded data before and after conducting the upgrades.

We describe this analysis based on winter vs. summer usage because of insufficient available data that can be linked to current renovations.





				Select a reg
Regi		Dat	te range	
	)FSC		📋 02/13/2018 –	03/31/2019
	Forest Sciences - 353		Select a floor	
	Earth Sciences Building - 225 Food Nutrition Health - 449			
	Forest Sciences - 353			
	Friedman - 523-2 Geography - 401 Hebb - 656 Hugh Dempster Pavilion - 163 ICICS Addition - 166 ICICS CS - 165			

Region Comparison Interface. Analysts select the Forest Sciences building.







Region	Date range	
S FSC	📋 05/31/2018	- 03/31/2019
	Day Week Last 30 days	Month Quarter Yea
	Last Year All Time	
	Custom Range 06/01/2018	08/31/2018
	Арр	oly date filter

Region Comparison Interface. Select date range (Jun-Aug) and submit the query.











Region Comparison Interface. The result of the query, the device count over time and the typical daily and weekly activity, is displayed directly below. The building remains selected and the analysts pick Sep-Dec for the second query.





**Region Comparison Interface.** The two time series are now displayed in all views and enable direct comparisons. The maximum device count during the fall is around 1400 and in the summer not substantially lower. The analysts can observe generally very similar patterns and a major decline on Dec 20th, after the term officially ended. BC-One:L<sup>\*</sup>







Region Comparison Interface. To investigate a specific classroom in the building, the analysts remove the two active queries and select the main floor in the query builder. An interactive floor plan is displayed that lets them pick a specific zone. The analysts send a second query by just changing the time frame to compare summer vs. winter usage. ZB-One:L\*







**Region Comparison Interface.** The two time series for summer and winter terms are visualized in multiple views. The room was used in the summer but the timeline also reveals two week-long gaps. The average activity on weekends is slightly higher during the summer than in the winter which is caused by a few outliers. ZB-One:L\*



### 5.2 Analysis Scenario: Campus-Wide Situational Awareness





Campus Explorer. The analysts select the Campus, live overview activity pattern from the control panel. (Activity patterns provide single-click shortcuts for complex combinations of actions to simplify the sometimes-overwhelming interface)

Search buildings  $\bigcirc$ 

	오 ACTIVITY PATTERNS			
e, daily Campus, live overview	UBC-CS, busy last 12, quiet now			
		9	February	March
shift,				
Add preset		m	MMMMM	
				Mintherm
M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M.	Mar	n,		
h_m_m_h_Mk_m_m_m_m_				
m_m_m_m_m_m_m_m_m		n.MMh.MMh.		
man MM MM MM MM		MMMMMM		
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Campus Explorer. The interface automatically sorts zones based on live activity in descending order, selects the top 70, and visualizes them in a spatial heatmap (ZC-Few:SI). The analysts are running this query on the weekend, and are unsurprised to see high activity in NEST, a student union building. However, the high device counts in *DMP* are surprising in a building primarily used for lectures.





DISPLAY	REGION	SPACE TYPE	🛗 TIME SPAN	
8 results (70 selected) Sr Live activity 1 115	REGION         Buildings       AI         AERL - 316         AIIard Hall - Law         Allard Hall - Law         AMS Student Nee         Buchanan A B C         Buchanan D E -         Chemistry - 132         Chemistry - 132         Chemistry Physi         Earth Ocean Sci         Earth Ocean Sci         Earth Sciences         Food Nutrition H         Forest Sciences         Friedman - 523-         Geography - 40         Hebb - 656         Hugh Dempster         ICICS CS 165         IRC - 473         Irving K. Barber         Klinck - 308         Koerner _ Sedge         NCE - 081-2         Pharmaceutical         Scarfe Classrood         Scarfe Library -         Scarfe Classrood         Scarfe Office Bid         Woodward Libra	None None A 482 est - 795 121-1 121-2 121-3 122-1 122-2 cs - 447 Main - 402 South - 403 Building - 225 Health - 449 - 353 - 353 - 2 1 Pavilion - 163 166 - 516 wick Lib - 515 Sciences - 527 m Block - 240-1 Block - 232-A 234 ock - 240-1 01 g - 790 ry - 536	Area	DISCRETE TIME SESSIONS

**Campus Explorer.** In the control panel, the analysts filter on DMP to exclude all other buildings.

Campus







Campus Explorer. The analysts use the control panel to change the view to superimposed line charts. Since each line denotes one day, clear patterns are not discernible due to the long (8-month) recording period. They select only weekends with the discrete time sessions menu. ZB-Few:LI









Campus Explorer. The analysts see five outlier days stand out from the other near-zero lines; they have learned that occasional after-hours use does occur. ZB-Few:LI

	오 ACTIVITY PATTERNS	FILTER CRITERIA (reset) Regions in DMP on weekends
Last 24h		Regions in DMP on weekends

3:00 06:00 09:00 12:00 15:00 18:00 21:00	03:00 06:00 09:00 12:00 15:00 18:00 21:00	03:00 06:00 09:00 12:00 15:00 18:00 21:00
DMP - 110	DMP - 301	DMP - 101
	- 300	- 300
	- 200	- 200
DMP - 300	DMP - 100	DMP - 200
	- 300	- 300
	- 200	- 200





## 5.3 Analysis Scenario: Data Quality Control



<b>OCUPADO</b> campus explorer		Campus       Campus       Sarch buildings         Zone ·       Sort by: Avg. activity ·       Scale: Global ·       Average by: Day ·       Last 2.4h         Image: Second Average by: Day ·       Cast 0       1500 2100 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2100 0000 1500 2000 0000 1500 2000 0000 1500 2000 0000 1500 2000 0000 0				
DISPLAY	REGION	SPACE TYPE	📋 TIME SPAN		SIONS R ACTIVITY PATTERNS	
778 results (153 selected)	Spatial aggregation: <b>Zon</b>	he $\checkmark$ Sort by: Avg. activ	ity $\checkmark$ Scale: Global $\sim$	Average by: Day V	Last 24h	
Live activity Avg. action 134	tivity Max. activity	Sessions Averag	ed			
		03:00 09:00	15:00 21:00	03:00 09:00 15:00	21:00 03:00 09:00 15:00	21:00 03:00 09:00 15:00 21:00
		ICCS/X - X530	LS	sk - 107	ICCS/X - X535	ICCS/X - X635
		BUCHABC - B312	IC	CS/X - X550	FSC - 3231	FSC - 4310
		FSC - g4234_4236	FS	SC - g4322-4324	FSC - g4230_4232	HEBB - g30-32

Campus Explorer. The data stripes can be used to rank zones based on average device count in order to locate constantly empty regions (ZC-All:LA).

15:00	21:00	03:00	09:00	15:00	21:00	03:00	09:00	15:00	21:00
		ICCS/X - X53	35			ICCS/X - X6	35		
		FSC - 3231				FSC - 4310			
		FSC - a4230	4232			HEBB - q30	-32		
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			15:00       21:00       03:00         ICCS/X - X53       ICCS/X - X53         FSC - 3231       FSC - 3231         FSC - 3231       FSC - 3230	15:00       21:00       03:00       09:00         ICCS/X - X535       ICCS/X - X535         FSC - 3231       FSC - 3231         FSC - g4230_4232       FSC - g4230_4232	15:00     21:00     03:00     09:00     15:00       ICCS/X - X535     ICCS/X - X535     ICCS/X - X535     ICCS/X - X535	15:00       21:00       03:00       09:00       15:00       21:00         ICCS/X - X535         FSC - 3231       FSC - 3231       ICCS/X - X535       ICCS/X - X535       ICCS/X - X535       ICCS/X - X535         FSC - 3231       FSC - 3231       ICCS/X - X535       ICCS/X - X535       ICCS/X - X535       ICCS/X - X535         FSC - 94230_4232       FSC - 94230_4232       ICCS/X - X535       ICCS/X - X535       ICCS/X - X535	1500       2100       0300       0900       1500       2100       0300         ICCS/X - X535       ICCS/X - X635         FSC - 3231       FSC - 3231       FSC - 4310       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         FSC - 3231       FSC - 3231       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X64       ICCS/X - X635       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64         ICCS/X - X64       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64         ICCS/X - X64       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64         ICCS/X - X64       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64         ICCS/X - X64       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64         ICCS/X - X64       ICCS/X - X64       ICCS/X - X64       ICCS/X - X64 <t< td=""><td>1500       2100       0300       0900       1500       2100       0300       0900         ICCS/X - X535       ICCS/X - X635         FSC - 3231       FSC - 3231       FSC - 4310       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         FSC - 3231       FSC - 3231       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       <t< td=""><td>15:00       21:00       03:00       09:00       15:00       03:00       09:00       15:00         ICCS/X - X535       ICCS/X - X535       ICCS/X - X635       I</td></t<></td></t<>	1500       2100       0300       0900       1500       2100       0300       0900         ICCS/X - X535       ICCS/X - X635         FSC - 3231       FSC - 3231       FSC - 4310       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         FSC - 3231       FSC - 3231       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635       ICCS/X - X635         ICCS/X - X635       ICCS/X - X635       ICCS/X - X635 <t< td=""><td>15:00       21:00       03:00       09:00       15:00       03:00       09:00       15:00         ICCS/X - X535       ICCS/X - X535       ICCS/X - X635       I</td></t<>	15:00       21:00       03:00       09:00       15:00       03:00       09:00       15:00         ICCS/X - X535       ICCS/X - X535       ICCS/X - X635       I

