Multivariate visualisation of data and introduction to Immersive Analytics

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Infovis Guest Lecture – 13/09/18

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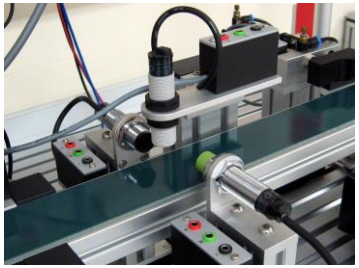
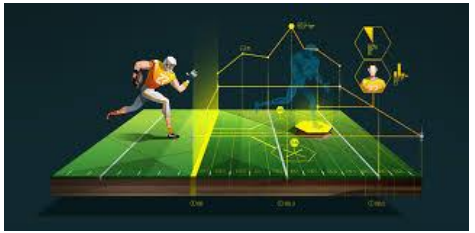
Overview

- Multivariate data
- Advanced MV techniques
- Introduction to immersive analytics
- Examples
  - ImAxes
  - Fader Axes
- Conclusion

Motivation

- Multivariate, multidimensional are ubiquitous
  - Sensor data
  - User data
  - Tracking data in sports
  - Business/ stock exchange





- Understand complex processes/phenomenon
- Support decision making

X	Y	OBJECTID	ACCIDENT	ABS_CODE	ACCIDENT	ACCIDENT	ACCIDENT	ALCOHOLT	ACCIDENT	DAY_OF_W	DCA_CODE	HIT_RUN_F	LIGHT_CO	POLICE_A	ROAD_GE	SEVERITY	SPEED_ZO	RUN_OFF	NODE_ID	LONGITUE	LATITUDE	NODE_TYP	LGA_NAM	REGION_NAME	VICGRID_	VICGRID_	TOTAL_PE	INJ_OR_F	FATALITY	SERIOUSIN	OTHERINJ	NONINJUF	MALES	F
145.1157	-38.0517	1001	T2010003(	ABS to rec	Finished	########	12.30.00	No	Collision w	Saturday	LEFT REAR	No	Day	Yes	T intersect	Serious injury accider	60	No	893	145.1157	-38.0517	Intersectio	KINGSTON	METROPOLITAN SOUTH	2510152	2383278	3	2	0	1	1	1	2	
145.437	-37.5288	1002	T2010003(	ABS to rec	Finished	########	10.20.00	No	No collisio	Saturday	OUT OF C(	No	Day	Yes	T intersect	Serious injury accider	100	No	60668	145.437	-37.5288	Intersectio	MURRIND	NORTH EASTERN REGIO	2538622	2441234	1	1	0	1	0	0	0	
143.9754	-38.542	1003	T2010003(	ABS to rec	Finished	########	13.02.00	No	Struck Ped	Saturday	FAR SIDE,	No	Day	Yes	Not at inte	Other injury accident	50	No	235067	143.9754	-38.542	Non-Inter	SURF COA	SOUTH WESTERN REGIC	2410657	2328377	2	2	0	0	2	0	1	
145.0042	-37.737	1004	T2010003(	ABS to rec	Finished	########	11.50.00	No	Collision w	Saturday	RIGHT NE/	No	Day	Yes	T intersect	Serious injury accider	40	No	1096	145.0042	-37.737	Intersectio	DAREBIN	METROPOLITAN NORTH	2500368	2418218	3	1	0	1	0	2	3	
144.9329	-37.624	1005	T2010003(	ABS to rec	Finished	########	11.20.00	No	Struck anii	Saturday	STRUCK AI	No	Day	Yes	T intersect	Serious injury accider	70	No	57208	144.9329	-37.624	Intersectio	HUME	METROPOLITAN NORTH	2494080	2430756	4	2	0	1	1	2	1	
145.9073	-38.4205	1006	T2010003(	ABS to rec	Finished	########	11.40.00	No	Vehicle ov	Saturday	OFF CARR	No	Day	Yes	Not at inte	Serious injury accider	100	Yes	235107	145.9073	-38.4205	Non-Inter	SOUTH GI	EASTERN REGION	2579242	2341963	1	1	0	1	0	0	1	
145.1101	-37.8827	1007	T2010003(	ABS to rec	Finished	########	11.00.00	No	Collision w	Saturday	REAR END	No	Day	Yes	Cross inte	Other injury accident	70	No	29662	145.1101	-37.8827	Intersectio	MONASH	METROPOLITAN SOUTH	2509688	2402043	5	2	0	0	2	3	1	
145.0923	-37.6952	1008	T2010003(	ABS to rec	Finished	########	12.10.00	No	Collision w	Friday	RIGHT THI	No	Day	Yes	T intersect	Other injury accident	80	No	222100	145.0923	-37.6952	Intersectio	BANYULE	METROPOLITAN NORTH	2508140	2422848	3	1	0	0	1	2	1	
145.6898	-36.3275	1009	T2010003(	ABS to rec	Finished	########	14.40.00	Yes	Collision w	Saturday	LANE SIDE	No	Day	Yes	Cross inte	Serious injury accider	60	No	17605	145.6898	-36.3275	Intersectio	SHEPPART	NORTH EASTERN REGIO	2561933	2574396	3	2	0	1	1	1	3	
145.0891	-37.9248	1010	T2010003(	ABS to rec	Finished	########	13.50.00	No	Collision w	Friday	RIGHT RE/	No	Day	No	T intersect	Other injury accident	60	No	29682	145.0891	-37.9249	Intersectio	KINGSTON	METROPOLITAN SOUTH	2507837	2397362	2	2	0	0	2	0	1	
144.773	-37.783	1011	T2010003(	ABS to rec	Finished	########	14.56.00	Yes	Collision w	Saturday	REAR END	No	Day	Yes	Cross inte	Other injury accident	70	No	57065	144.773	-37.783	Intersectio	BRIMBANI	METROPOLITAN NORTH	2480006	2413088	5	1	0	0	1	4	1	
145.2382	-37.8983	1012	T2010003(	ABS to rec	Finished	########	07.58.00	Yes	Collision w	Saturday	REAR END	No	Day	No	Not at inte	Other injury accident	80	No	235109	145.2382	-37.8983	Non-Inter	KNOX	METROPOLITAN SOUTH	2520946	2400285	2	1	0	0	1	1	0	
142.3343	-37.3975	1013	T2010003(	ABS to rec	Finished	########	14.05.00	Yes	Struck anii	Saturday	STRUCK AI	No	Day	Yes	Not at inte	Serious injury accider	100	No	235203	142.3343	-37.3975	Non-Inter	SOUTHERI	SOUTH WESTERN REGIC	2264020	2452591	1	1	0	1	0	0	1	
144.2361	-36.9559	1014	T2010003(	ABS to rec	Finished	########	13.30.00	No	Collision w	Saturday	CROSS TR/	No	Day	Yes	Cross inte	Fatal accident	100	No	279270	144.2361	-36.9559	Intersectio	MOUNT A	NORTHERN REGION	2431972	2504617	4	4	1	2	1	0	1	
145.1624	-37.8991	1015	T2010003(	ABS to rec	Finished	########	15.30.00	Yes	Collision w	Saturday	REAR END	No	Day	Yes	Not at inte	Other injury accident	80	No	235087	145.1624	-37.8991	Non-Inter	MONASH	METROPOLITAN SOUTH	2514281	2400212	11	2	0	0	2	9	5	
145.9805	-36.7529	1016	T2010003(	ABS to rec	Finished	########	16.15.00	Yes	collision w	Saturday	OTHER AC	No	Day	Yes	Not at inte	Serious injury accider	100	No	235149	145.9805	-36.7529	Non-Inter	BENALLA	NORTH EASTERN REGIO	2587540	2526969	1	1	0	1	0	0	1	
147.007	-36.1414	1017	T2010003(	ABS to rec	Finished	########	16.00.00	Yes	Collision w	Saturday	RIGHT OFI	No	Day	Yes	Cross inte	Other injury accident	80	Yes	49355	147.007	-36.1415	Intersectio	WODONG	NORTH EASTERN REGIO	2680616	2593359	2	1	0	0	1	1	1	
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145.2109	-37.8609	1019	T2010003(	ABS to rec	Finished	########	17.15.00	No	Collision w	Saturday	RIGHT THI	No	Dusk/Daw	Yes	Multiple ir	Other injury accident	80	No	221880	145.2109	-37.8609	Non-Inter	KNOX	METROPOLITAN SOUTH	2518557	2404441	4	2	0	0	2	2	4	
145.1878	-38.1014	1020	T2010003(	ABS to rec	Finished	########	18.05.00	Yes	Collision w	Saturday	RIGHT THI	No	Dark Stree	Yes	T intersect	Other injury accident	70	No	29445	145.1878	-38.1014	Intersectio	FRANKSTC	METROPOLITAN SOUTH	2516472	2377757	3	2	0	0	2	1	2	
145.0767	-37.8951	1021	T2010003(	ABS to rec	Finished	########	16.30.00	Yes	Collision w	Saturday	RIGHT FAI	No	Day	Yes	T intersect	Serious injury accider	50	No	41503	145.0767	-37.8951	Intersectio	GLEN EIRA	METROPOLITAN SOUTH	2506743	2400666	5	2	0	2	0	3	3	
145.2385	-37.8629	1022	T2010003(	ABS to rec	Finished	########	23.00.00	Yes	Collision w	Saturday	REAR END	No	Dark Stree	Yes	Not at inte	Other injury accident	80	No	236199	145.2385	-37.8629	Non-Inter	KNOX	METROPOLITAN SOUTH	2520982	2404220	3	1	0	0	1	2	3	
145.2916	-37.8629	1023	T2010003(	ABS to rec	Finished	########	08.00.00	Yes	Collision w	Sunday	OFF END (	Yes	Day	No	T intersect	Other injury accident	60	No	35534	145.2916	-37.8629	Intersectio	KNOX	METROPOLITAN SOUTH	2525659	2404204	1	1	0	0	1	0	0	
144.9586	-37.6917	1024	T2010003(	ABS to rec	Finished	########	23.00.00	Yes	Collision w	Saturday	RIGHT/LEI	No	Dark Stree	Yes	Multiple ir	Other injury accident	60	No	222013	144.9586	-37.6917	Intersectio	HUME	METROPOLITAN NORTH	2496347	2423239	9	2	0	0	2	7	5	
145.7138	-35.9699	1025	T2010003(	ABS to rec	Finished	########	23.00.00	Yes	Collision w	Saturday	CROSS TR/	No	Dark No st	Yes	Cross inte	Other injury accident	100	No	235093	145.7138	-35.9699	Intersectio	MOIRA	NORTH EASTERN REGIO	2564379	2614057	4	2	0	0	2	2	2	
145.0743	-37.8023	1026	T2010003(	ABS to rec	Finished	########	02.50.00	Yes	Collision w	Sunday	VEHICLE C	No	Dark Stree	Yes	Not at inte	Other injury accident	60	No	235094	145.0743	-37.8023	Non-Inter	BOROONC	METROPOLITAN SOUTH	2506544	2410961	1	1	0	0	1	0	1	
144.9818	-37.8062	1027	T2010003(	ABS to rec	Finished	########	23.25.00	Yes	Struck Ped	Friday	PED NEAR	No	Dark Stree	Yes	Cross inte	Serious injury accider	40	No	36545	144.9818	-37.8062	Intersectio	YARRA	METROPOLITAN NORTH	2498398	2410530	5	1	0	1	0	4	3	
145.145	-37.6907	1028	T2010003(	ABS to rec	Finished	########	02.25.00	Yes	Collision w	Sunday	OFF RIGHT	No	Dark No st	Yes	Not at inte	Fatal accident	70	Yes	235025	145.145	-37.6907	Non-Inter	NILLUMBI	METROPOLITAN NORTH	2512788	2423348	1	1	1	0	0	0	1	
144.9916	-37.8096	1029	T2010003(	ABS to rec	Finished	########	01.24.00	Yes	Struck Ped	Sunday	PED NEAR	No	Dark Stree	Yes	Not at inte	Other injury accident	40	No	235692	144.9916	-37.8096	Non-Inter	YARRA	METROPOLITAN NORTH	2499260	2410155	2	1	0	0	1	1	2	
145.2272	-37.8129	1030	T2010003(	ABS to rec	Finished	########	06.00.00	Yes	Struck Ped	Sunday	ANY MANI	Yes	Dark Stree	No	Not at inte	Other injury accident	50	No	235693	145.2272	-37.8129	Non-Inter	MAROONI	METROPOLITAN SOUTH	2520003	2409765	2	1	0	0	1	1	2	
145.2375	-37.811	1031	T2010003(	ABS to rec	Finished	########	22.37.00	Yes	Collision w	Saturday	CROSS TR/	No	Dark Stree	Yes	Cross inte	Other injury accident	80	No	84	145.2375	-37.811	Intersectio	MAROONI	METROPOLITAN SOUTH	2520912	2409974	4	1	0	0	1	3	3	
145.2549	-38.0796	1032	T2010003(	ABS to rec	Finished	########	19.15.00	Yes	Collision w	Wednesda	REAR END	No	Dark Stree	No	Not at inte	Other injury accident	80	No	236411	145.2549	-38.0796	Non-Inter	CASEY	METROPOLITAN SOUTH	2522365	2380160	4	1	0	0	1	3	2	
145.1807	-37.8686	1033	T2010003(	ABS to rec	Finished	########	10.45.00	No	Collision w	Saturday	U TURN	No	Day	Yes	Not at inte	Other injury accident	50	No	235095	145.1807	-37.8686	Non-Inter	MONASH	METROPOLITAN SOUTH	2515901	2403595	4	3	0	0	3	1	4	
144.3065	-36.7293	1034	T2010003(	ABS to rec	Finished	########	09.55.00	Yes	Collision w	Sunday	RIGHT THI	No	Day	Yes	Not at inte	Other injury accident	60	No	235694	144.3065	-36.7293	Non-Inter	BENDIGO	NORTHERN REGION	2438064	2529808	3	1	0	0	1	2	1	
144.791	-37.7864	1035	T2010003(	ABS to rec	Finished	########	09.20.00	Yes	Collision w	Sunday	LEFT OFF (	No	Day	Yes	Cross inte	Other injury accident	60	Yes	38501	144.791	-37.7864	Intersectio	BRIMBANI	METROPOLITAN NORTH	2481594	2412717	1	1	0	0	1	0	0	
145.1942	-38.3535	1036	T2010003(	ABS to rec	Finished	########	09.14.00	No	Collision w	Saturday	U TURN	No	Day	No	Not at inte	Other injury accident	70	No	235152	145.1942	-38.3535	Non-Inter	MORNING	METROPOLITAN SOUTH	2516975	2349766	2	1	0	0	1	1	1	
145.1554	-37.873	1037	T2010003(	ABS to rec	Finished	########	11.50.00	No	Struck Ped	Sunday	PED NEAR	No	Day	Yes	Not at inte	Other injury accident	70	No	125116	145.1554	-37.873	Non-Inter	MONASH	METROPOLITAN SOUTH	2513669	2403106	2	1	0	0	1	1	0	
145.1147	-37.5146	1038	T2010003(	ABS to rec	Finished	########	16.40.00	Yes	Collision w	Friday	CROSS TR/	No	Dusk/Daw	Yes	Cross inte	Other injury accident	60	No	49067	145.1147	-37.5146	Intersectio	WHITTLES	METROPOLITAN NORTH	2510140	2442890	3	2	0	0	2	1	2	
145.148	-37.8522	1039	T2010003(	ABS to rec	Finished	########	19.00.00	Yes	Collision w	Saturday	U TURN	No	Dark Stree	Yes	Not at inte	Other injury accident	70	No	235153	145.148	-37.8522	Non-Inter	WHITEHO	METROPOLITAN SOUTH	2513027	2405415	3	1	0	1	0	2	1	
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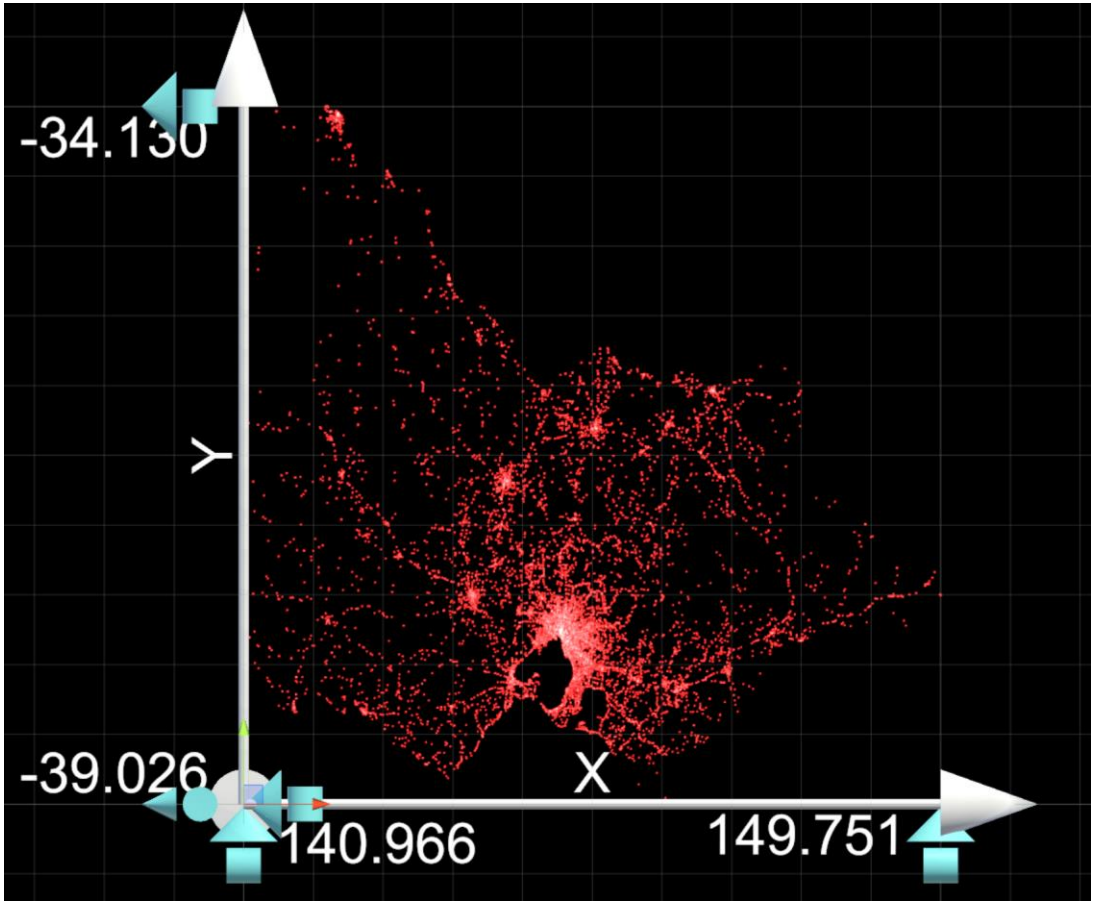
145.4499	-37.9258	1041	T2010003(	ABS to rec	Finished	########	15.28.00	No	Collision w	Sunday	HEAD ON	No	Day	Yes	T intersect	Other injury accident	60	No	43843	145.4499	-37.9258	Intersectio	CARDINIA	METROPOLITAN SOUTH	2539558	2397168	2	1	0	0	1	1	1	
144.7869	-37.6987	1042	T2010003(	ABS to rec	Finished	########	15.50.00	No	Collision w	Sunday	REAR END	No	Day	Yes	Not at inte	Other injury accident	80	No	235154	144.7869	-37.6987	Non-Inter	BRIMBANI	METROPOLITAN NORTH	2481211	2422445	5	2	0	0	2	3	3	
144.9699	-37.8101	1043	T2010003(	ABS to rec	Finished	########	04.35.00	Yes	Collision w	Sunday	RIGHT TUI	No	Dark Stree	Yes	Not at inte	Other injury accident	60	No	75309	144.9699	-37.8101	Non-Inter	MELBOUR	METROPOLITAN NORTH	2497347	2410105	7	1	0	0	1	6	5	
145.1253	-37.7901	1044	T2010003(	ABS to rec	Finished	########	15.35.00	No	Collision w	Sunday	LEFT TURN	No	Day	Yes	T intersect	Other injury accident	60	No	39303	145.1253	-37.7901	Intersectio	MANNING	METROPOLITAN NORTH	2511038	2412315	3	1	0	0	1	2	0	
144.9215	-37.5968	1045	T2010003(	ABS to rec	Finished	########	14.30.00	No	Collision w	Sunday	VEHICLE S	No	Day	Yes	Not at inte	Other injury accident	60	No	234464	144.9215	-37.5968	Non-Inter	HUME	METROPOLITAN NORTH	2493069	2433771	4	1	0	0	1	3	3	
145.0175	-37.8551	1046	T2010003(	ABS to rec	Finished	########	14.05.00	No	Collision w	Sunday	REAR END	No	Day	Yes	Cross inte	Other injury accident	60	No	46227	145.0175	-37.8551	Intersectio	STONNIN(	METROPOLITAN SOUTH	2501542	2405107	3	1	0	0	1	2	1	
141.2898	-37.9258	1047	T2010003(	ABS to rec	Finished	########	12.30.00	No	Collision w	Sunday	OFF LEFT (	No	Day	Yes	Not at inte	Other injury accident	100	Yes	235229	141.2898	-37.9258	Non-Inter	GLENELG	SOUTH WESTERN REGIC	2173885	2390903	4	2	0	0	2	2	2	
145.12	-37.9239	1048	T2010003(	ABS to rec	Finished	########	19.00.00	Yes	Struck Ped	Sunday	FAR SIDE,	No	Dark Stree	No	Cross inte	Other injury accident	60	No	42404	145.12	-37.9239	Intersectio	MONASH	METROPOLITAN SOUTH	2510549	2397468	3	1	0	0	1	2	2	
145.0234	-37.8133	1049	T2010003(	ABS to rec	Finished	########	16.30.00	Yes	Collision w	Sunday	U TURN	No	Day	No	Not at inte	Other injury accident	60	No	85996	145.0234	-37.8133	Non-Inter	BOROONC	METROPOLITAN SOUTH	2502058	2409749	3	2	0	0	2	1	1	
144.7601	-37.8705	1050	T2010003(	ABS to rec	Finished	########	21.05.00	Yes	Collision w	Sunday	LANE CHA	Yes	Dark Stree	No	Cross inte	Other injury accident	60	No	10586	144.7601	-37.8705	Intersectio	HOBSONS	METROPOLITAN NORTH	2478890	2403370	2	1	0	0	1	1	0	
145.0336	-37.9335	1051	T2010003(	ABS to rec	Finished	########	21.40.00	Yes	Collision w	Sunday	RIGHT OFI	No	Dark Stree	Yes	Not at inte	Serious injury accider	40	Yes	235722	145.0336	-37.9335	Non-Inter	BAYSIDE	METROPOLITAN SOUTH	2502952	2396401	2	1	0	1	0	1	2	
143.8105	-37.5698	1052	T2010003(	ABS to rec	Finished	########	06.00.00	Yes	Collision w	Monday	CROSS TR/	No	Dark Stree	Yes	Cross inte	Other injury accident	60	No	52938	143.8105	-37.5698	Intersectio	BALLARAT	WESTERN REGION	2394926	2436110	2	1	0	0	1	1	1	
145.2983	-37.8007	1053	T2010003(	ABS to rec	Finished	########	22.40.00	Yes	Struck Ped	Saturday	ANY MANI	Yes	Dark Stree	Yes	Not at inte	Other injury accident	60	No	242605	145.2983	-37.8007	Non-Inter	MAROONI	METROPOLITAN SOUTH	2526273	2411105	4	1	0	1	0	3	2	
145.0434	-37.7786	1054	T2010003(	ABS to rec	Finished	########	06.15.00	No	Collision w	Friday	VEHICLE C	No	Dark Stree	No	Not at inte	Other injury accident	60	No	235100	145.0434	-37.7786	Non-Inter	BANYULE	METROPOLITAN NORTH	2503820	2413593	1	1	0	0	1	0	1	
145.311	-38.0607	1055	T2010003(	ABS to rec	Finished	########	07.59.00	No	Collision w	Monday	LEFT NEAF	No	Day	Yes	T intersect	Other injury accident	50	No	46881	145.311	-38.0607	Intersectio	CASEY	METROPOLITAN SOUTH	2527295	2382246	2	1	0	0	1	1	1	
144.9423	-37.8316	1056	T2010003(	ABS to rec	Finished	########	08.33.00	No	Collision w	Monday	REAR END	No	Day	Yes	T intersect	Other injury accident	60	No	37412	144.9423	-37.8316	Intersectio	PORT PHIL	METROPOLITAN SOUTH	2494920	2407710	3	1	0	0	1	2	2	
144.979	-37.8374	1057	T2010003(	ABS to rec	Finished	########	08.39.00	No	Collision w	Monday	U TURN	No	Day	Yes	T intersect	Other injury accident	60	No	66765	144.979	-37.8374	Intersectio	MELBOUR	METROPOLITAN NORTH	2498155	2407075	2	1	0	0	1	1	1	
145.1447	-37.9909	1058	T2010003(	ABS to rec	Finished	########	05.45.00	Yes	Struck Ped	Monday	PED NEAR	No	Dark Stree	No	Cross inte	Serious injury accider	80	No	70726	145.1447	-37.9909	Intersectio	DANDENO	METROPOLITAN SOUTH	2512711	2390030	2	1	0	1	0	1	2	

visual analytics / infovis



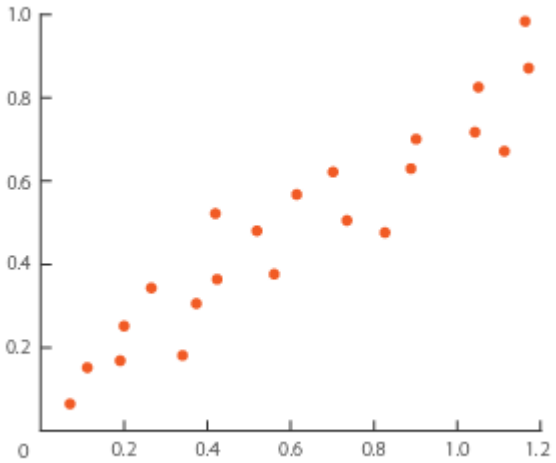
How do we visualize Multidimensional data?

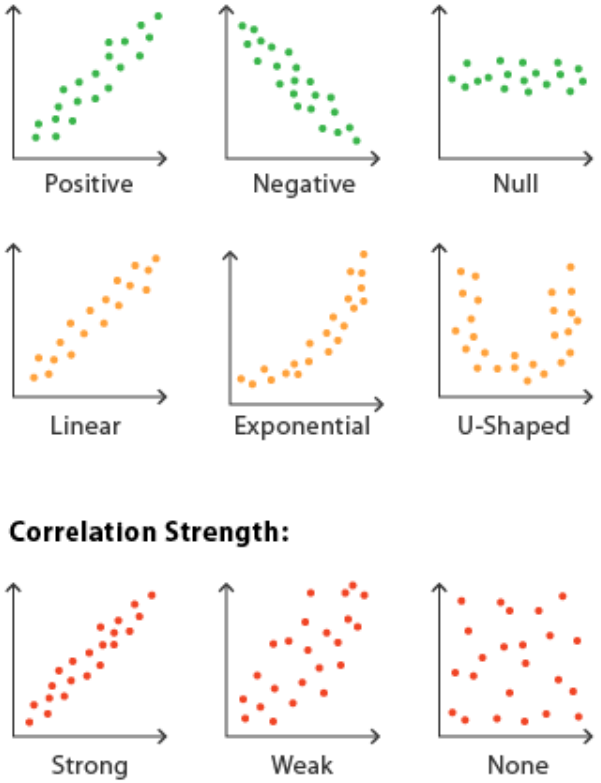
How do we visualize Multidimensional data?

- Scatterplots
- Scatterplot matrices
- Parallel coordinates plots

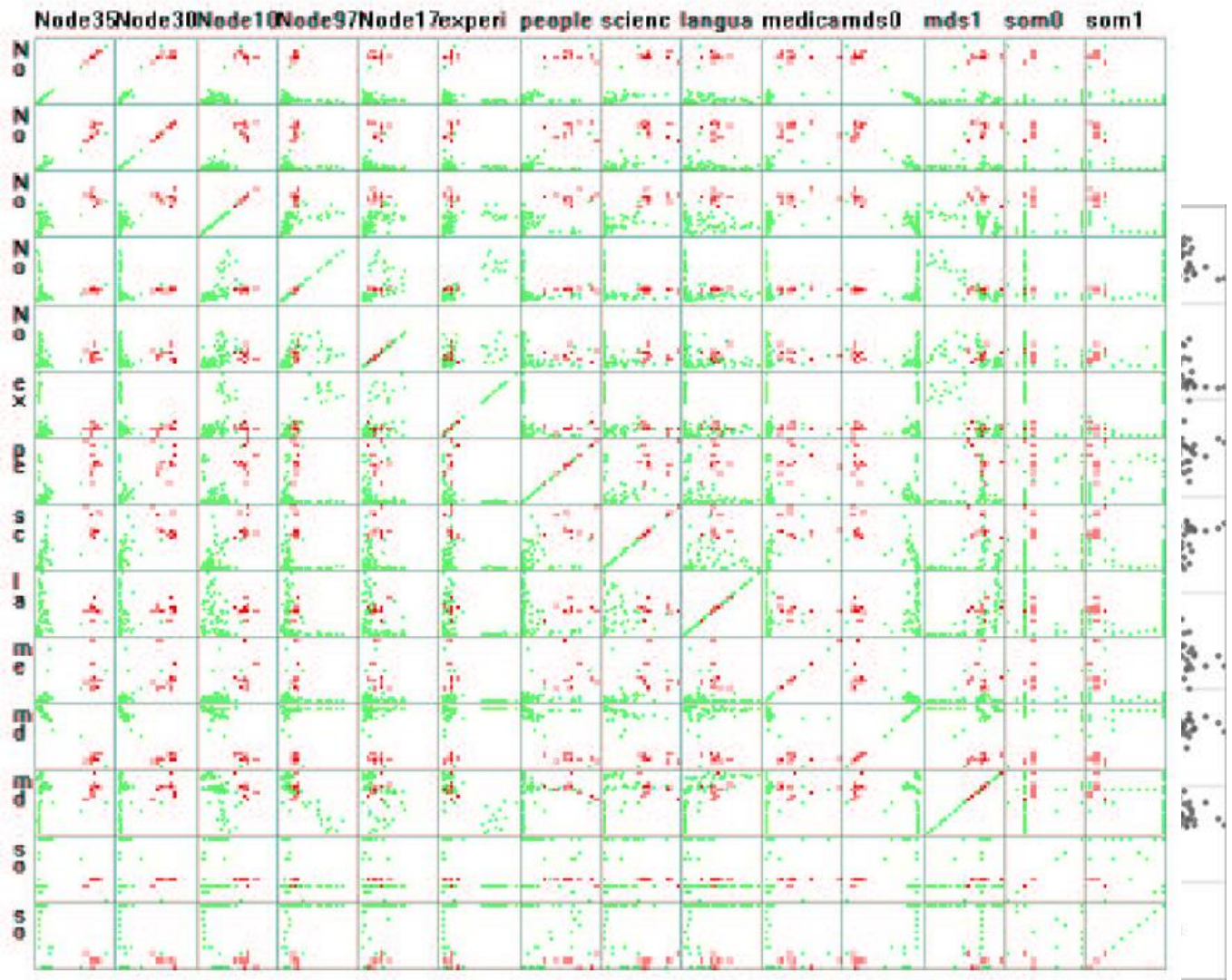
- When dimensions are **very large we need** dimension reduction techniques
  - PCA
  - T-sne

Scatterplots



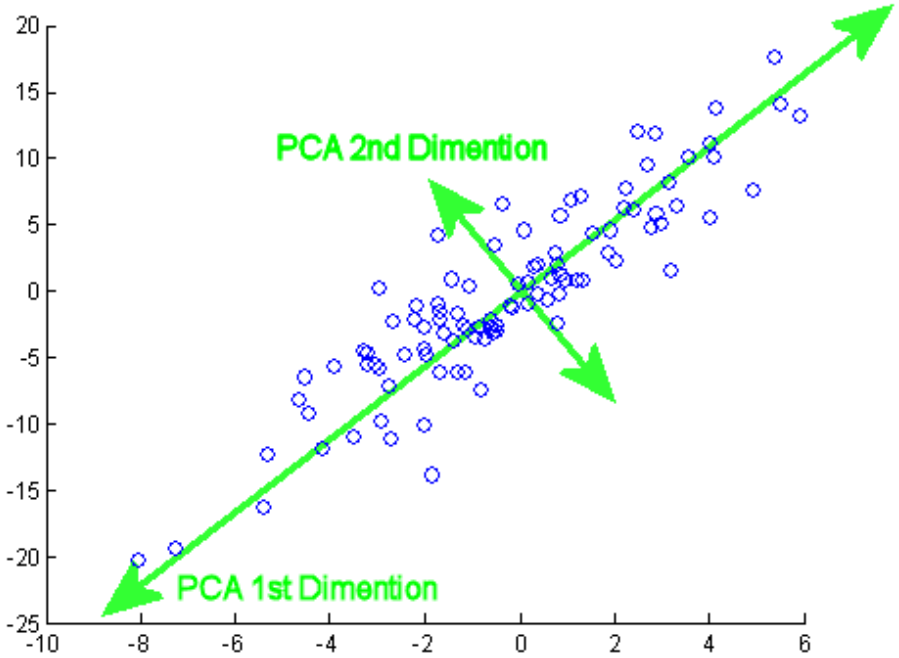


Scatt


Node35
Node30
Node10
Node97
Node17
experi
people
scienc
langua
medica
mds0
mds1
som0
som1

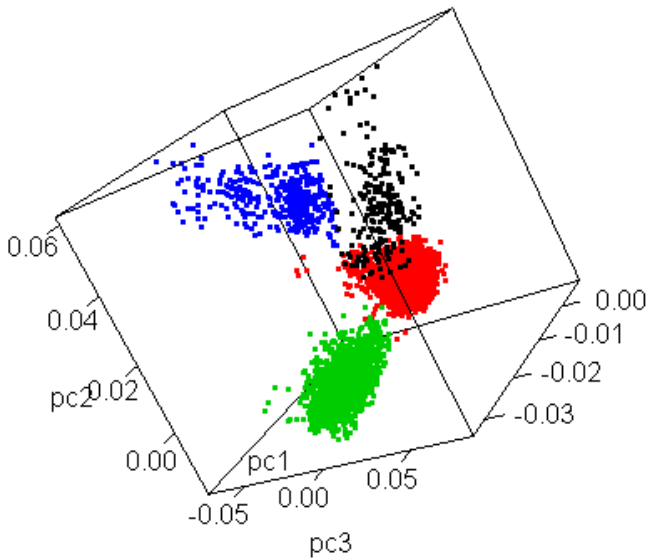
Dimension reduction

- Useful when number of dimensions is very large
- Find/extract vectors/features that explain most of the variance in the data

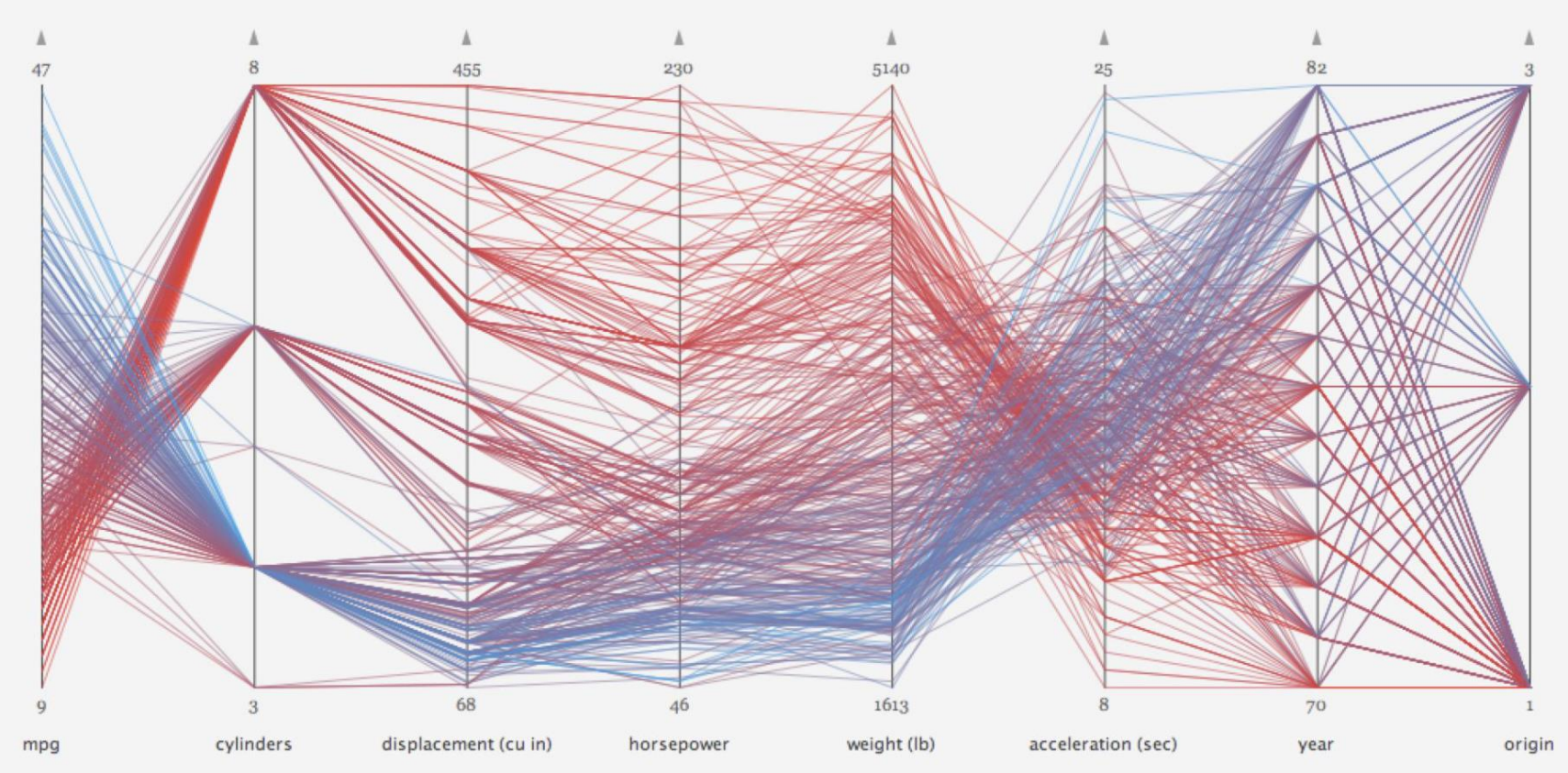


Dimension reduction and 3D Scatterplots

- Linear methods, e.g. Principal Component Analysis (PCA)



Parallel Coordinates



Reading Parallel Coordinates plots: patterns

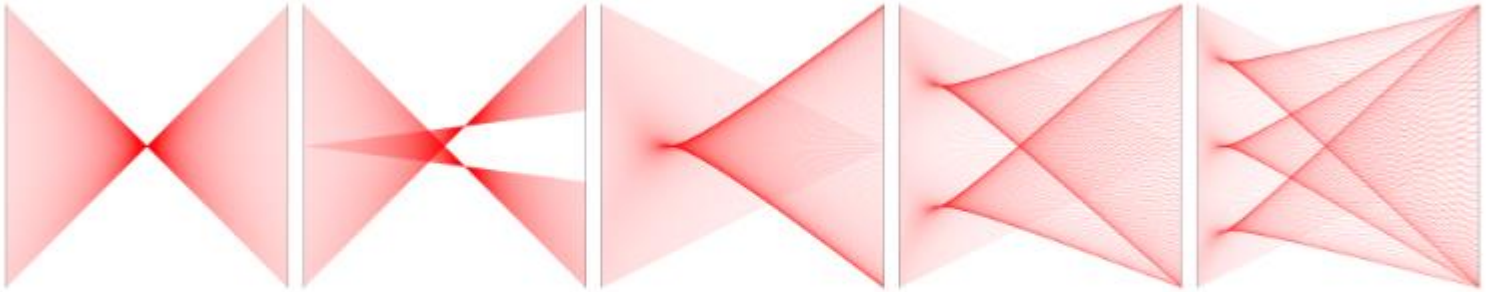


Figure 2: The five stimulus patterns used in the study. From left to right: negative linear relationship, negative linear relationship with a discontinuity, sinusoidal relationships with one, two and three periods respectively.

Johansson et al. – Perceiving patterns in parallel coodinates: determining thresholds for identification of relationships

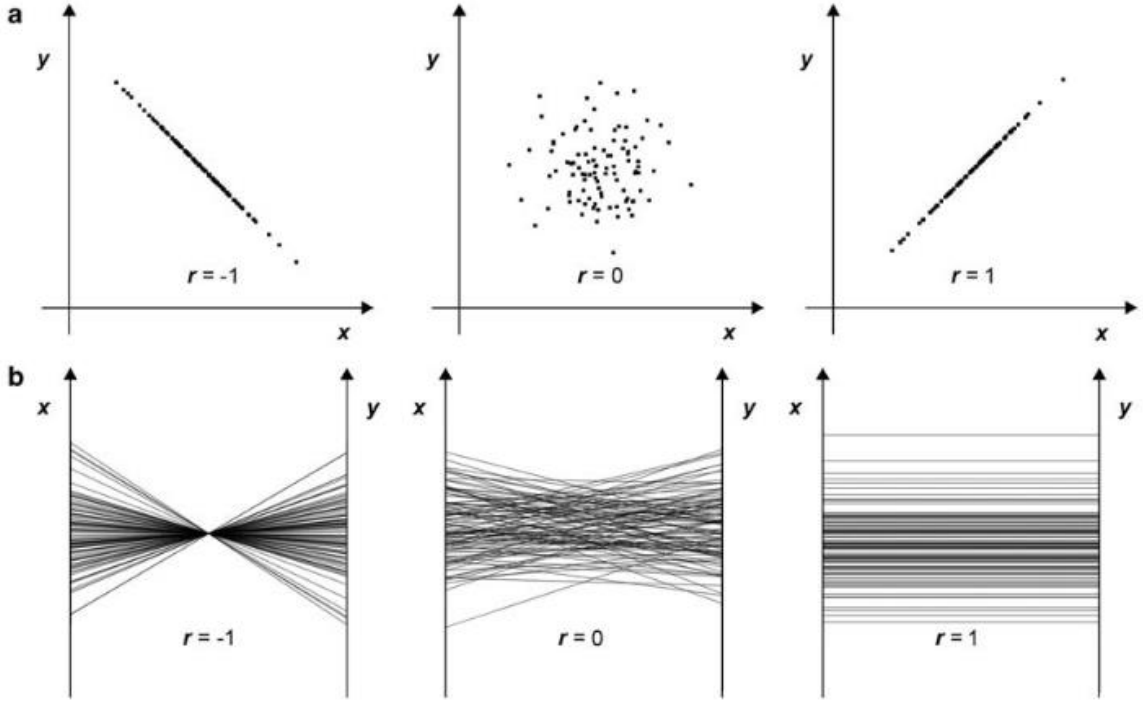


Figure 3: The three extreme values of *r* visualized with (a) scatterplots, and (b) parallel coordinate plots.

Judging Correlation from Scatterplots and Parallel Coordinate Plots, Jing Li et al. 2010, *Information Visualization (IV)*

Extension to 3D

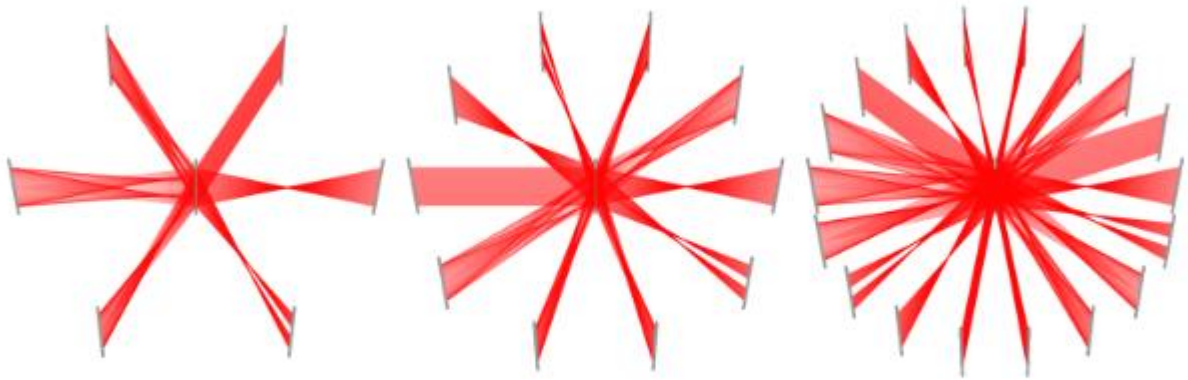
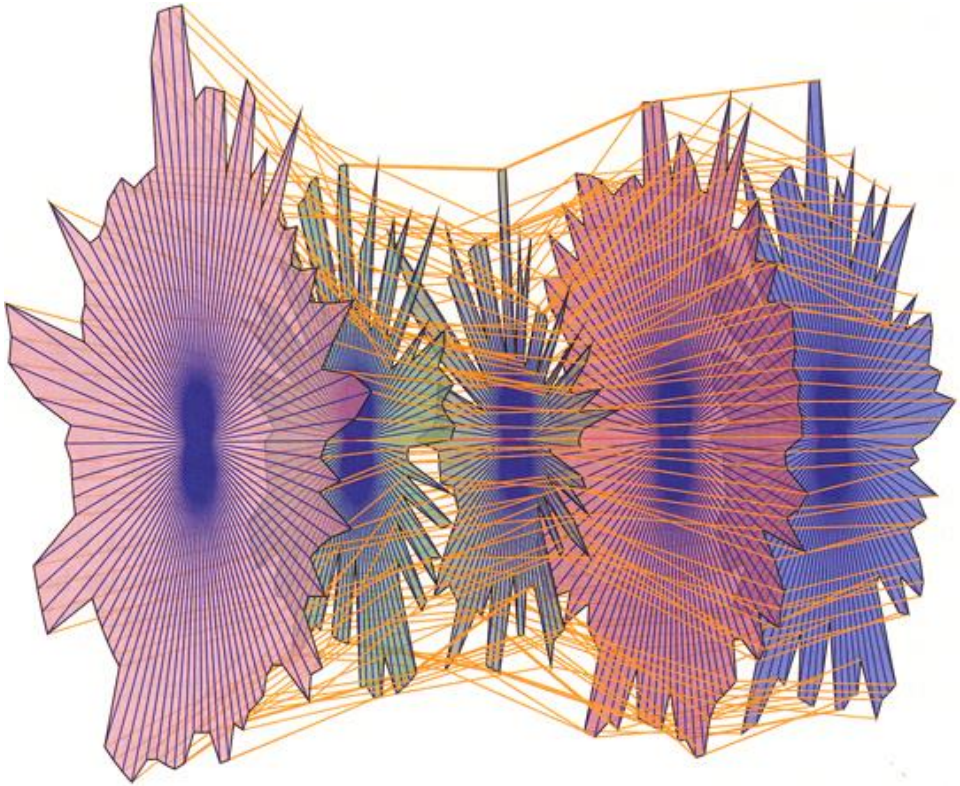


Figure 7: Multi-relational 3D parallel coordinates visualizing a data set consisting of 7 (left), 11 (middle) and 19 (right) variables.

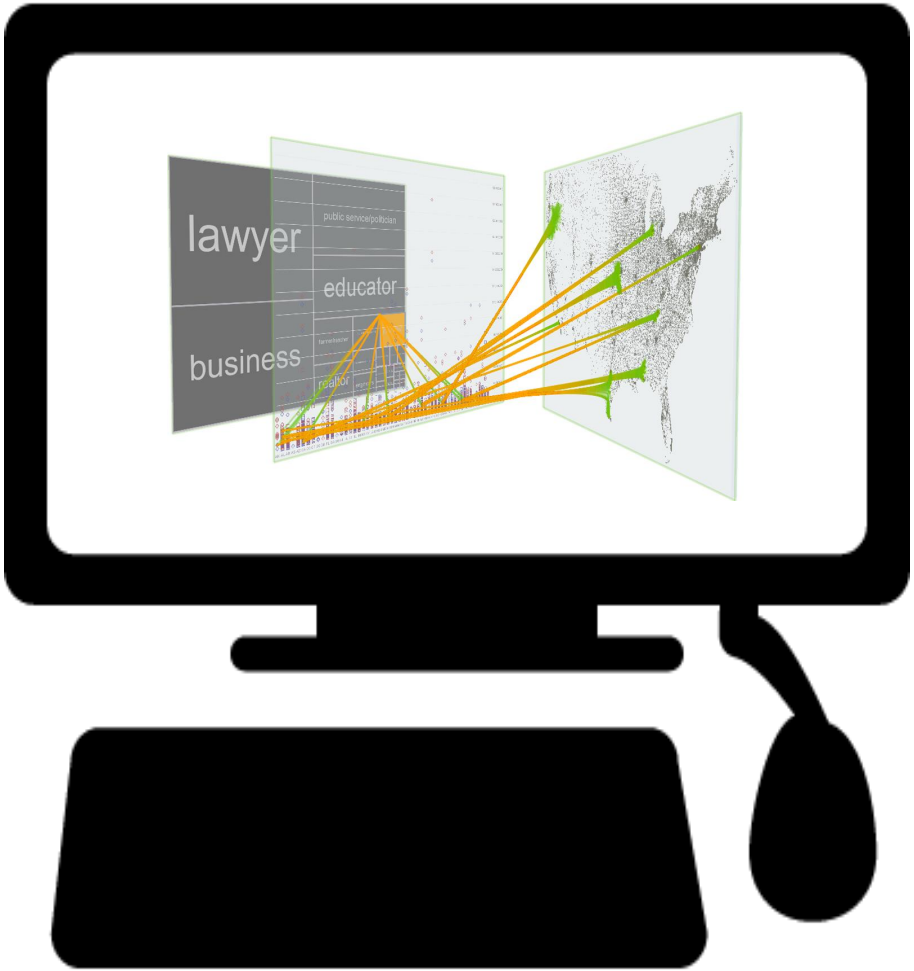
Advanced linked visualisations



Elena Fanea, Sheelagh Carpendale and Tobias Isenberg. **An Interactive 3D Integration of Parallel Coordinates and Star Glyphs**.

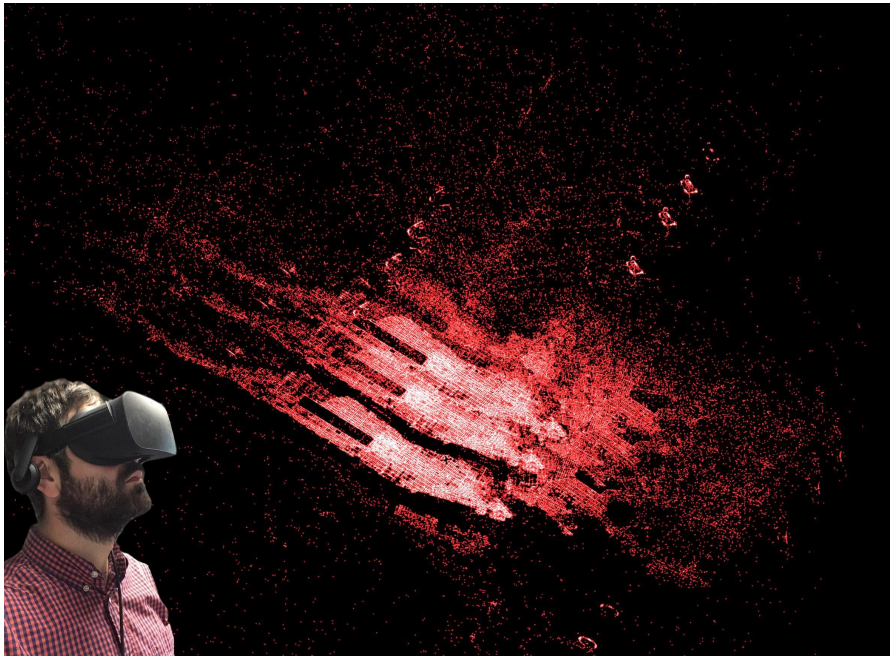
Advanced linked visualisations

Christopher Collins and Sheelagh Carpendale. [VisLink: Revealing Relationships Amongst Visualizations](#).



Microsoft BI
Tableau
Web browser: D3
ggplot in R

Introduction to immersive analytics

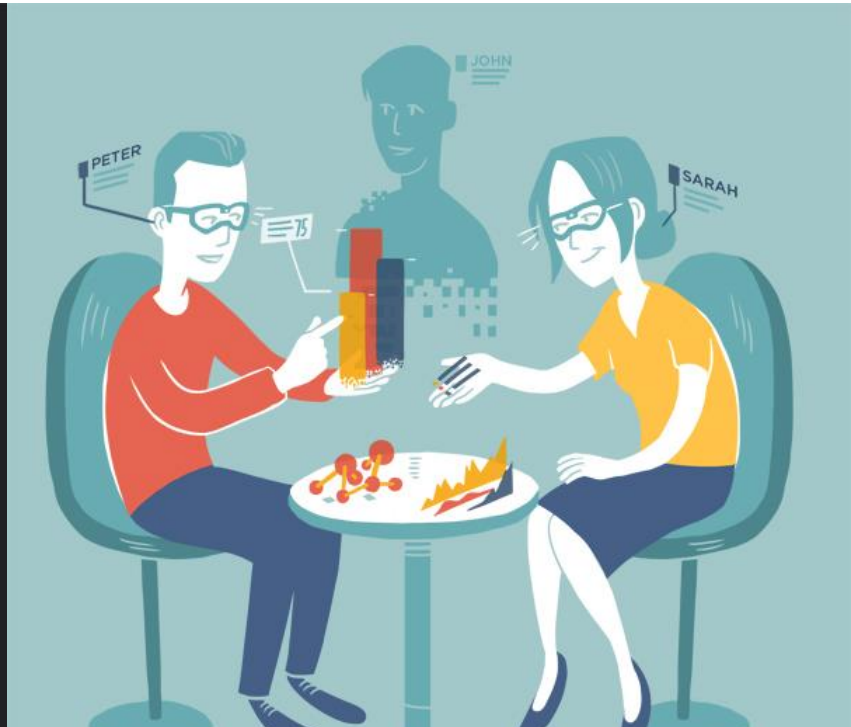


Virtual Reality

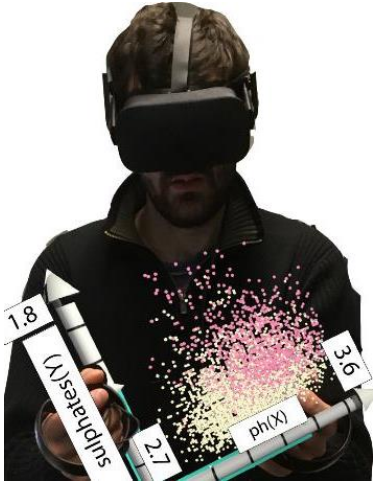
Augmented Reality

Immersive Analytics Goals:

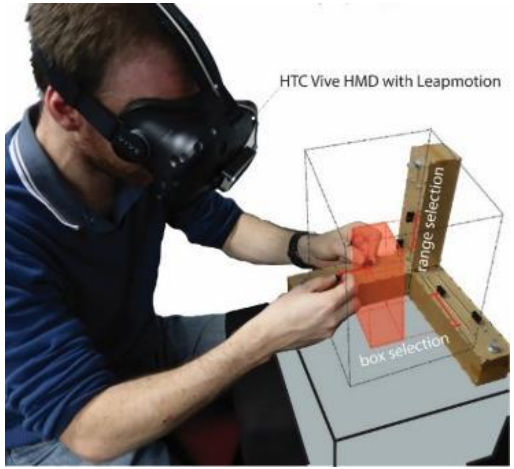
to remove barriers between people, their data and the tools they use for analysis
to support data understanding and decision making everywhere and by everyone
to make embodied tools that are intuitive, engaging,
and make the best possible use of all sensory channels.



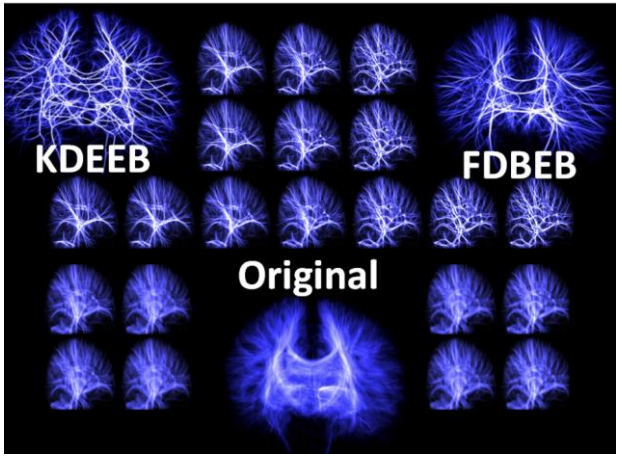
Immersive Analytics Research at Monash



- ImAxes



- Tangible visualisation in Augmented Reality



- Scientific visualisation in Virtual Reality

ImAxes: Immersive Axes as Embodied Affordances for Interactive Multivariate Data Visualisation

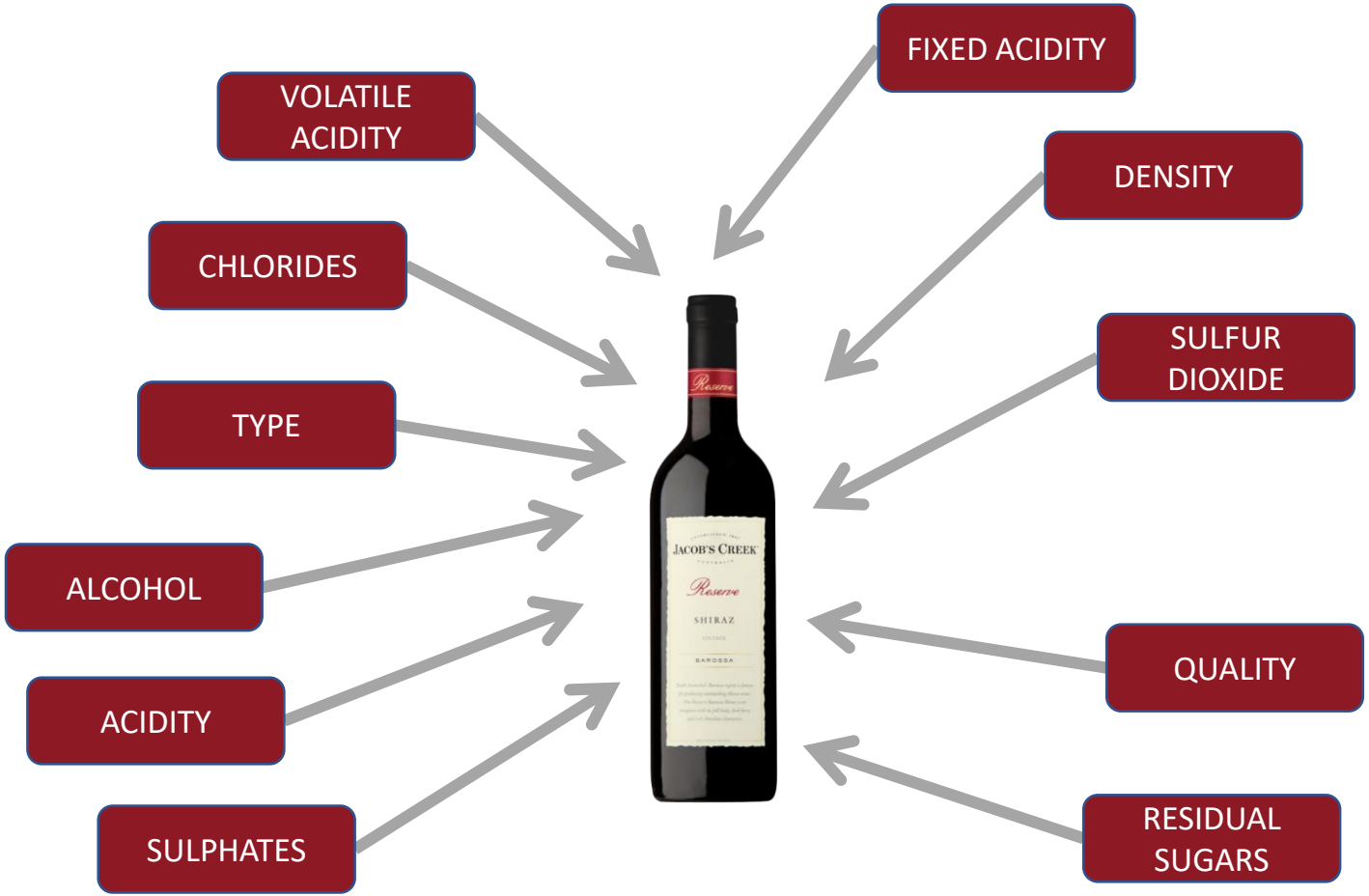
Maxime Cordeil
Andrew Cunningham
Tim Dwyer
Bruce H. Thomas
Kim Marriott

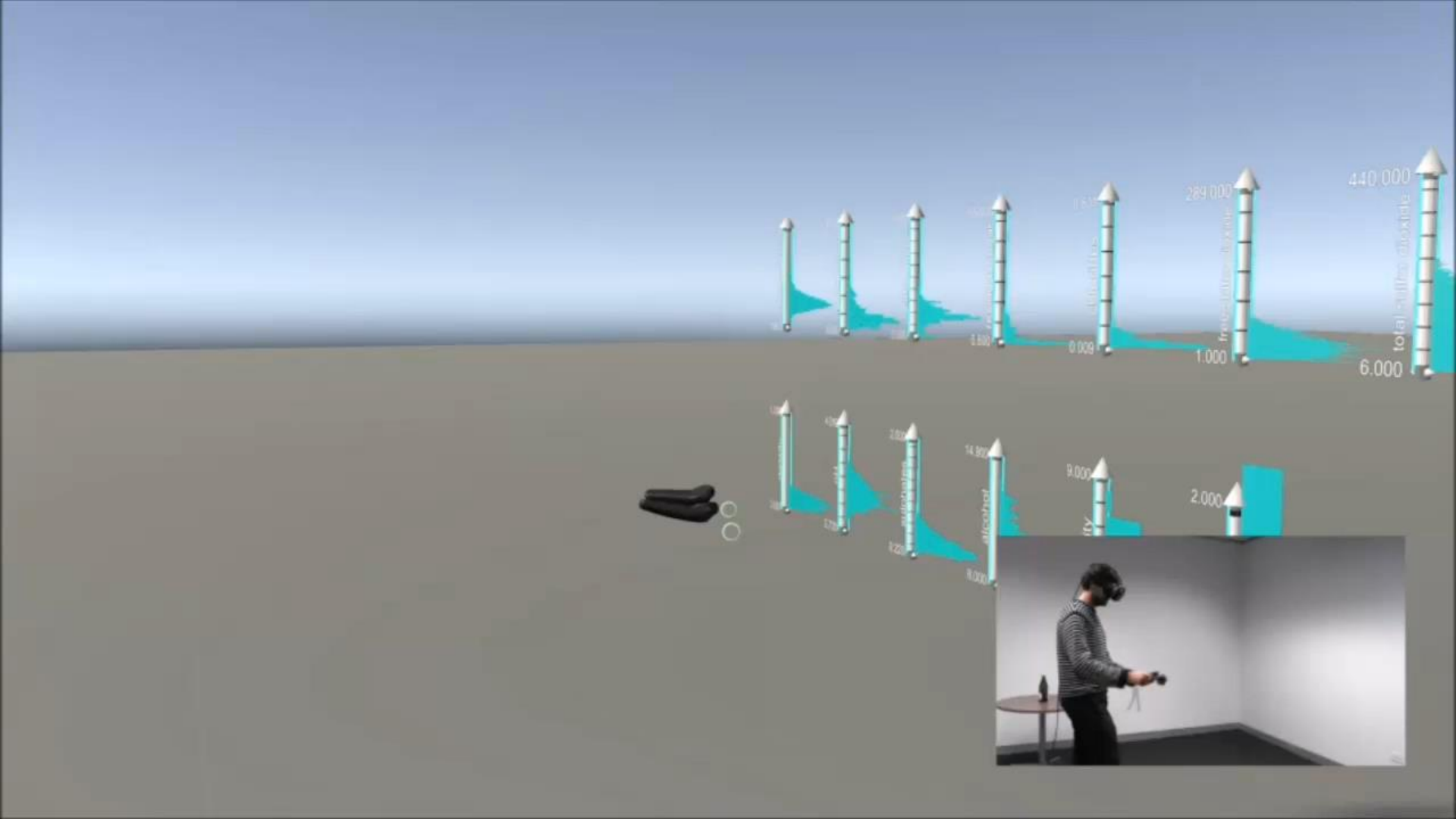
MONASH University

UIST 2017

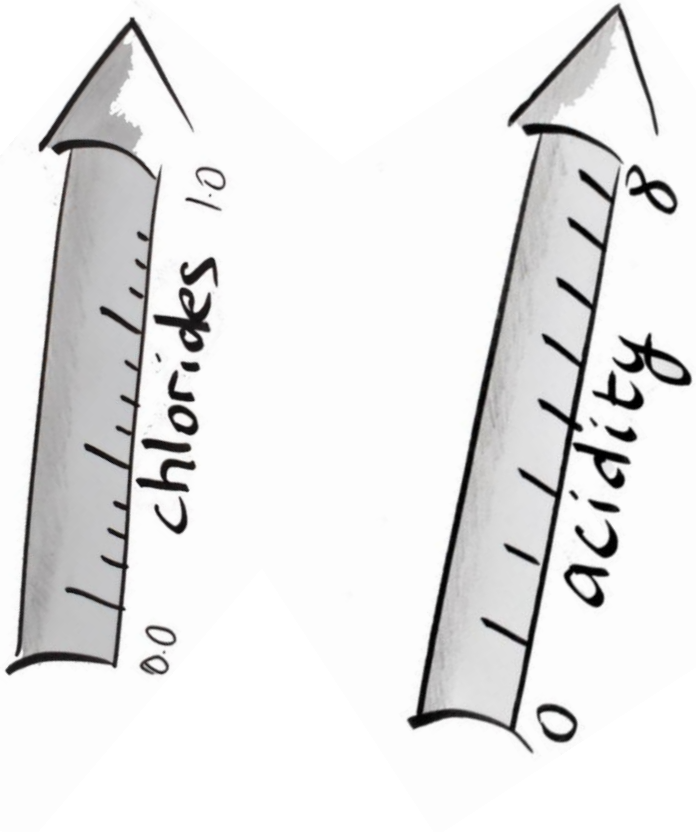
University of South Australia

Multidimensional data



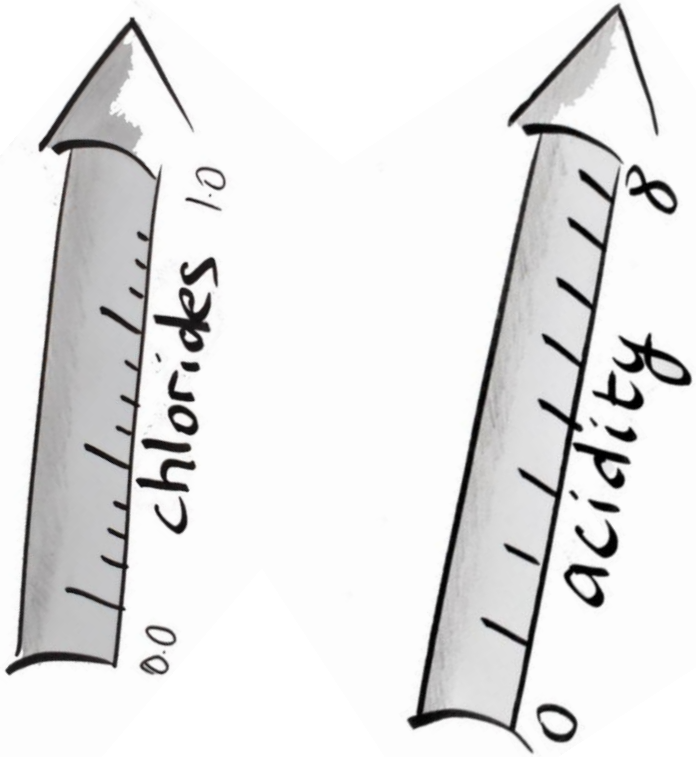

440.000
289.000
0.009
1.000
6.000
9.000
2.000

Axes as embodied* affordances**

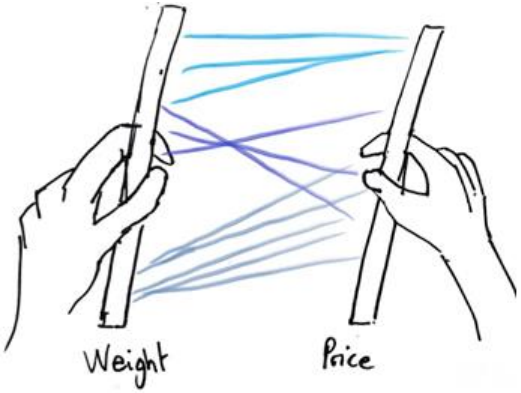


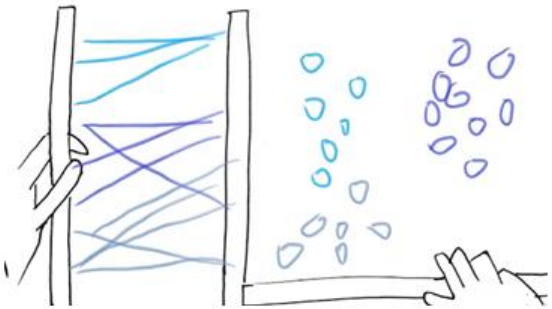
* Dourish, P. (2004)
** DA Norman (2002)

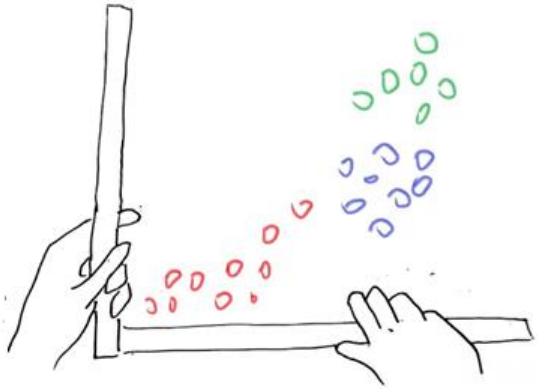
Axes as embodied* affordances**

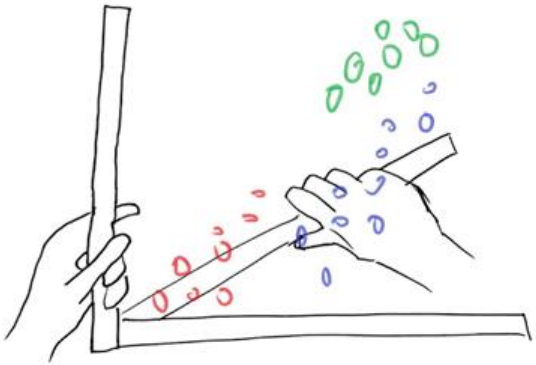


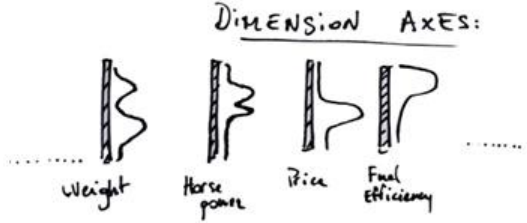
* Dourish, P. (2004)
** DA Norman (2002)

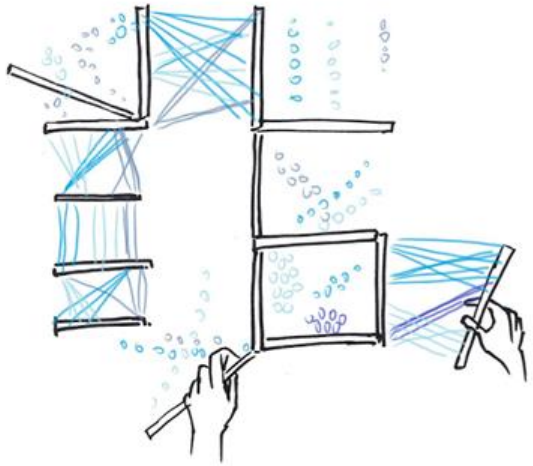

Weight
Price



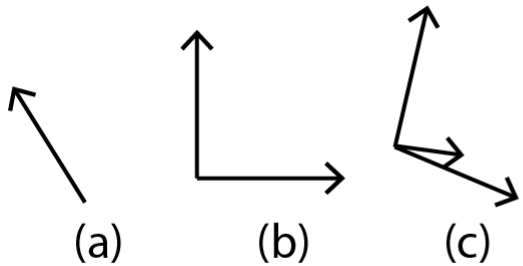




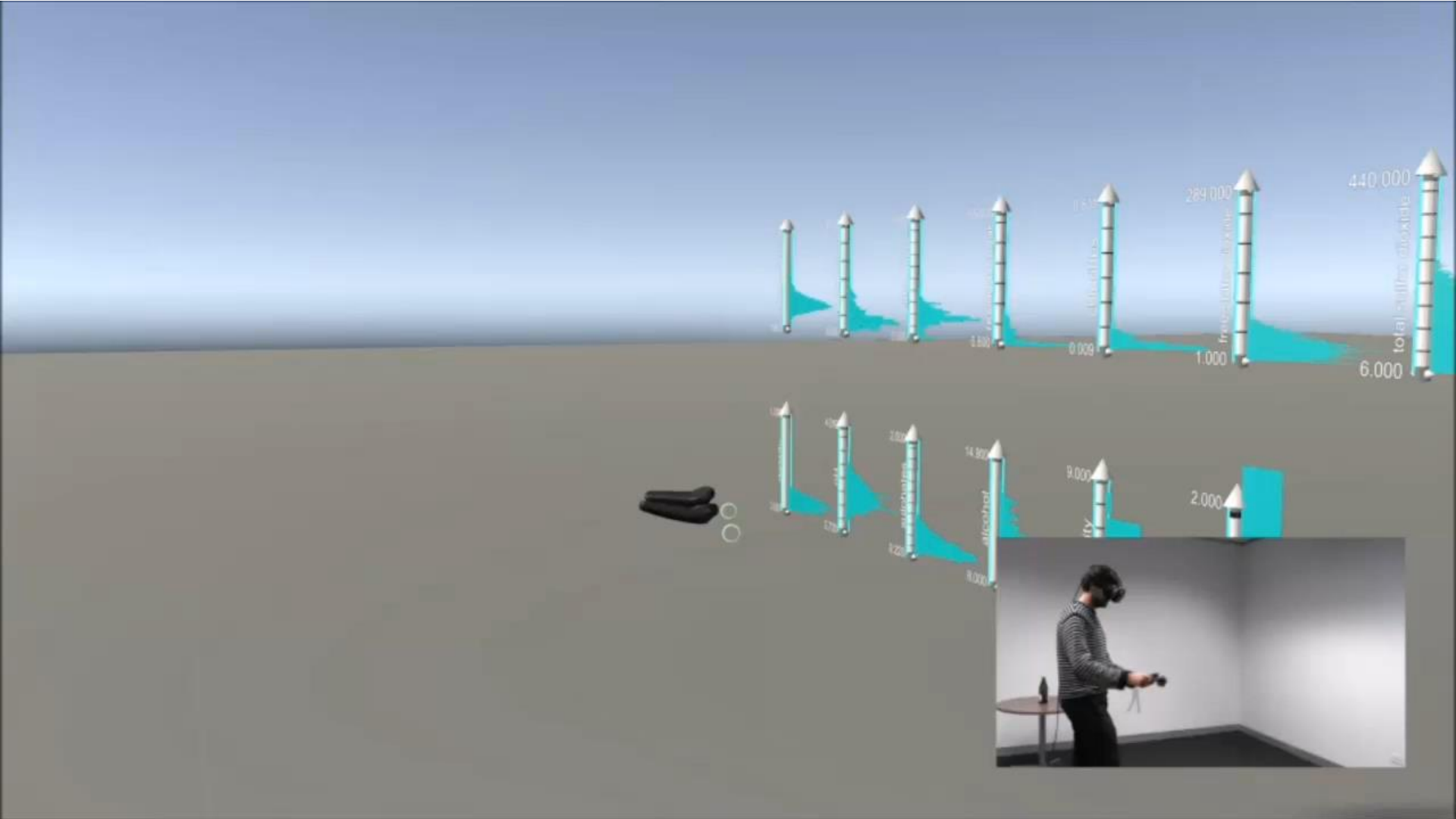

DIMENSION AXES:
Weight
Horse power
Price
Fuel Efficiency

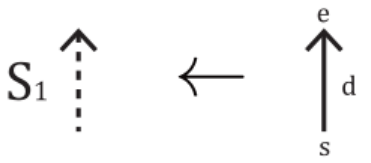


spatial grammar

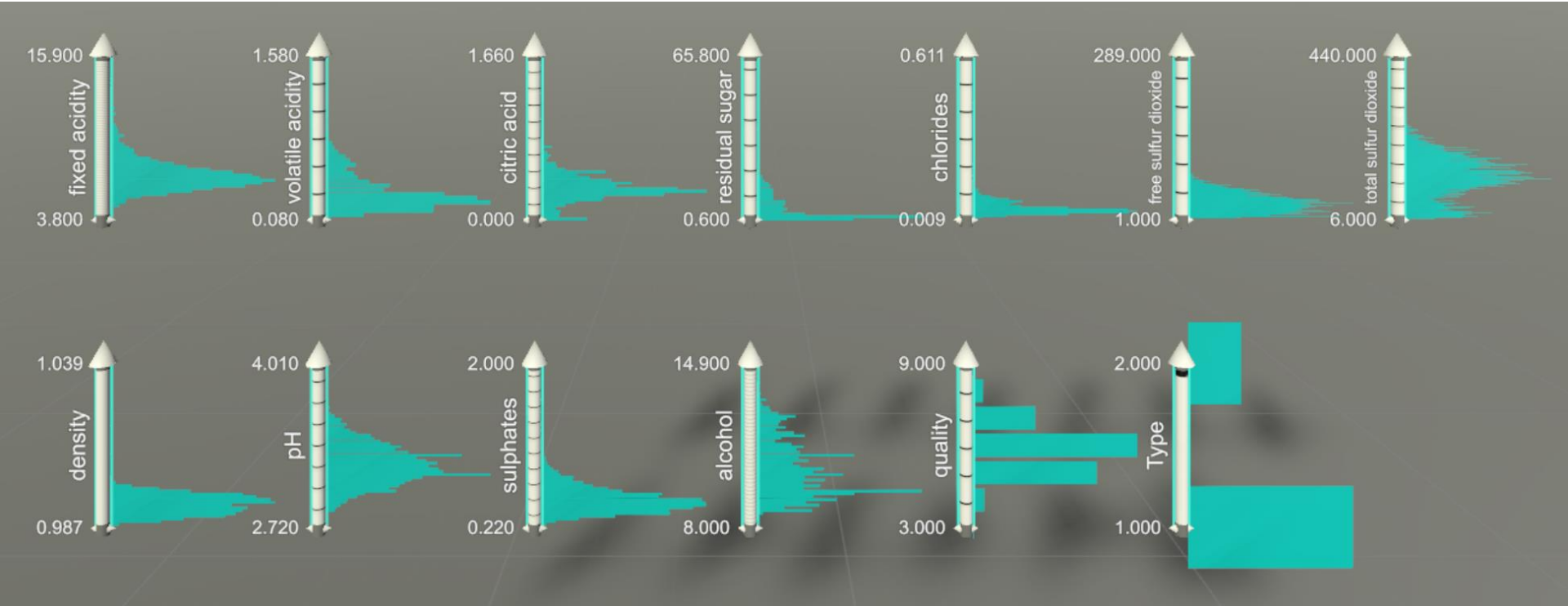


- direction, orthogonal, parallel, contact
- S1,S2,S3

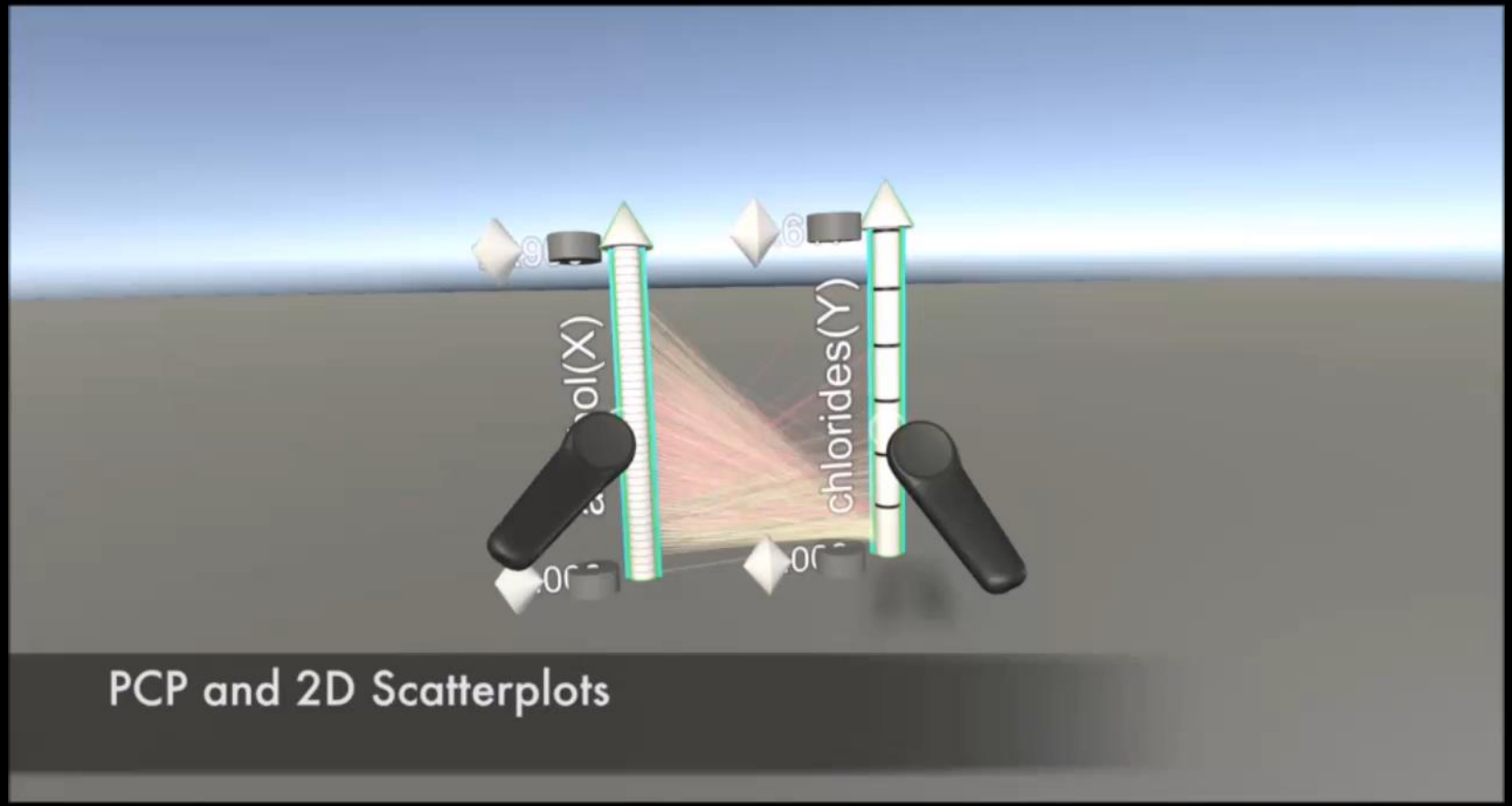

440.000
total sulfur dioxide
269.000
1.000
6.000
9.000
2.000



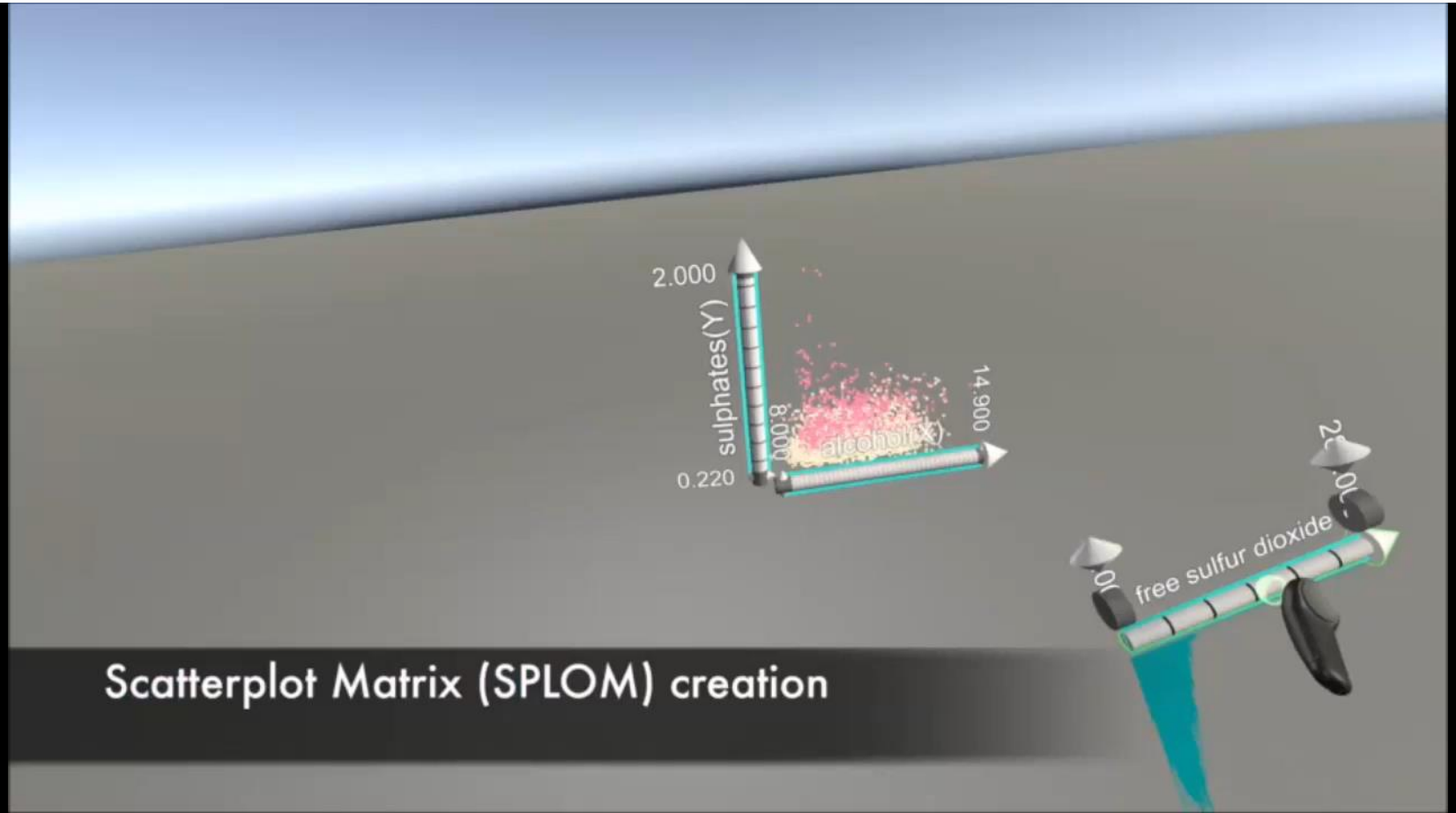
$$S_1(dir(s,e),\{axis(s,e,d)\}) \leftarrow axis(s,e,d)$$



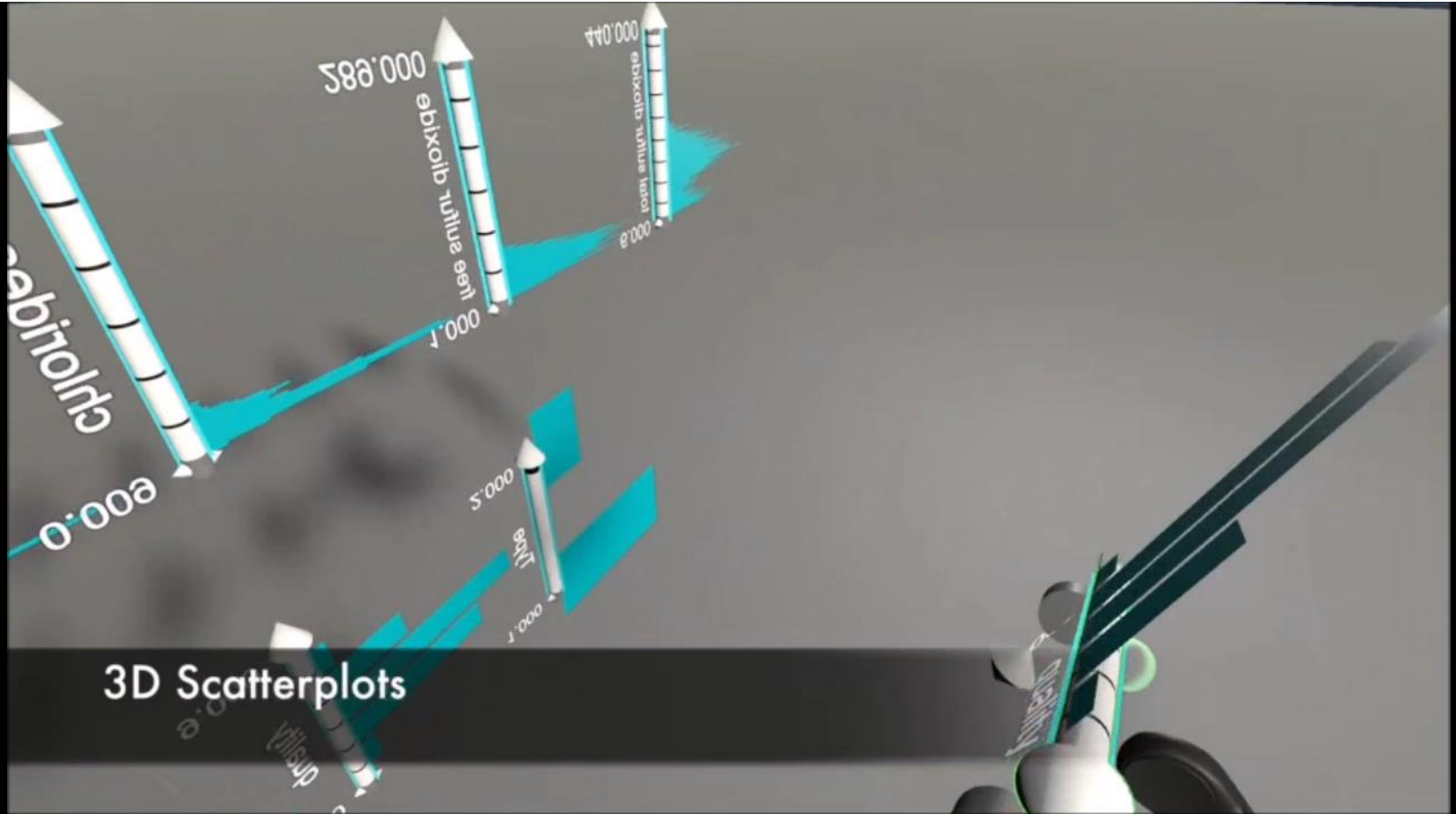
$$S_2(\vec{v}_1, \vec{v}_2, A_1, \{a\}) \quad \leftarrow \quad S_1(v_1, A_1), S_1(\vec{v}_2, \{a\}) \qquad \perp(\{\vec{v}_1, \vec{v}_2\}) \wedge \otimes(A_1, \{a\})$$



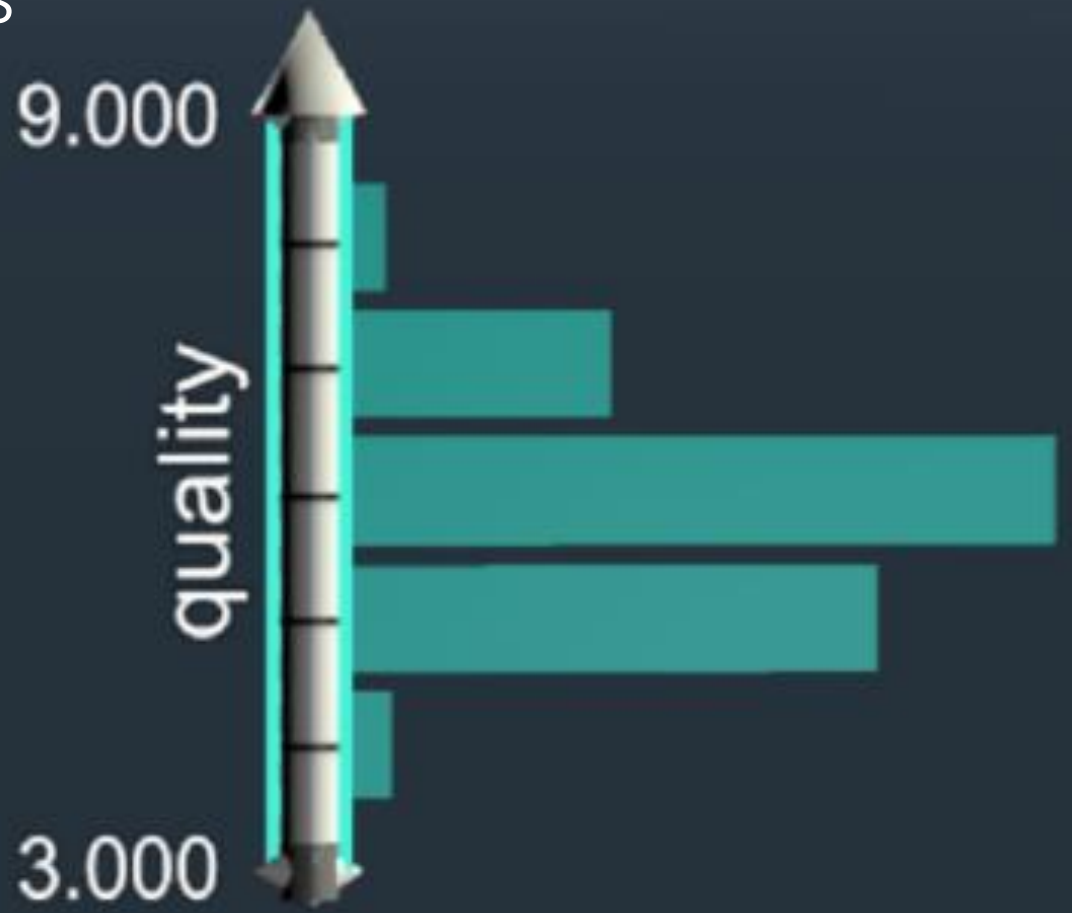
$$S_2(v_1, v_2, A_1, A_2 \cup \{a\}) \leftarrow \quad S_2(\vec{v_1}, \vec{v_2}, A_1, A_2), S_I(v, \{a\}) \quad \| \, (\vec{v_2}, \vec{v}) \wedge \otimes (A_1, A_2 \cup \{a\})$$



$$S_3(\vec{v}_1,\vec{v}_2,\vec{v}_3,A_1,A_2,\{a\}) \leftarrow S_2(\vec{v}_1,\vec{v}_2,A_1,A_2), S_1(\vec{v}_3,\{a\}) \quad \perp(\{\vec{v}_1,\vec{v}_2,\vec{v}_3\}) \wedge \otimes(A_1,A_2,A_3 \cup \{a\})$$

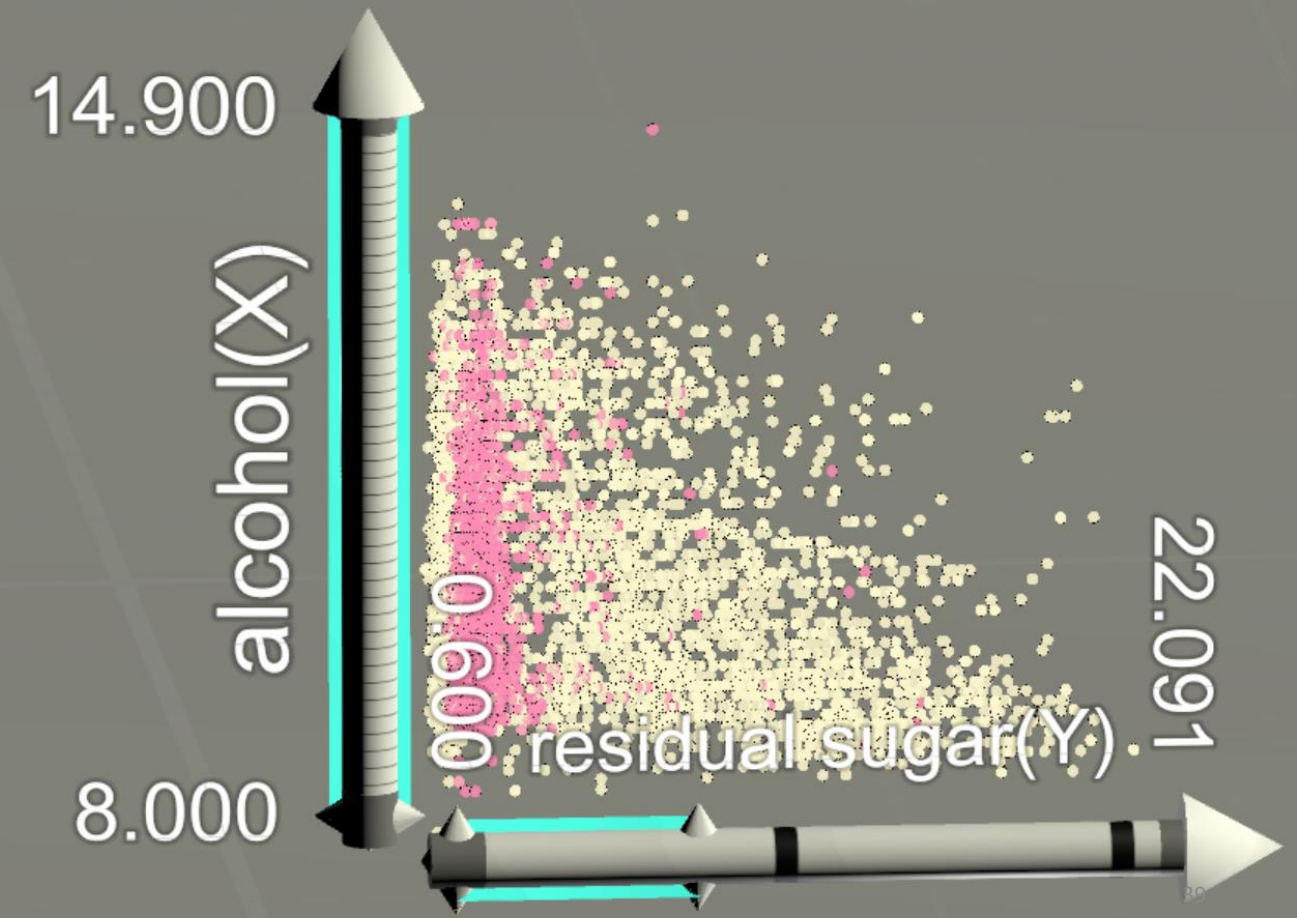


Standard visualisations



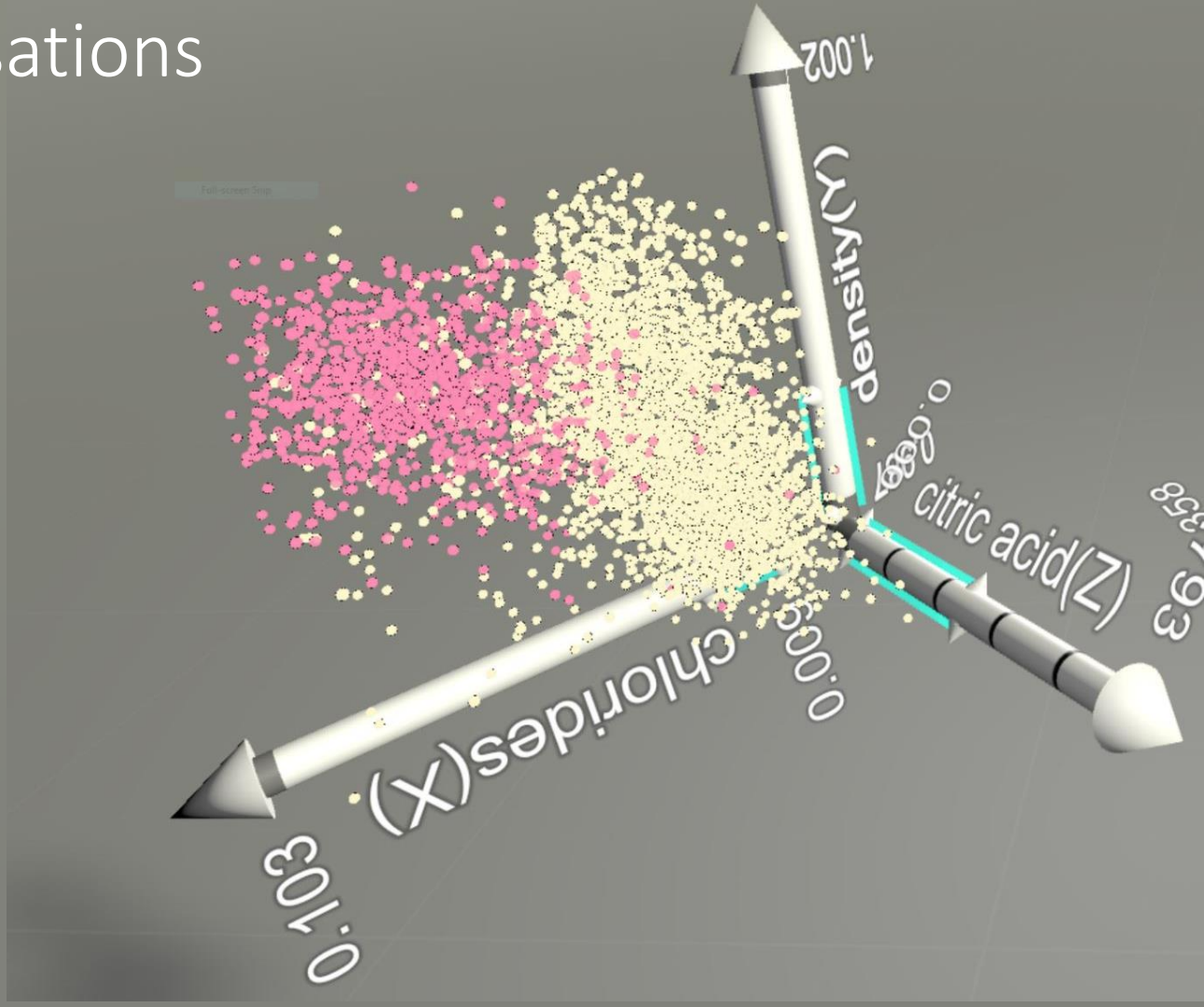
histogram

Standard visualisations



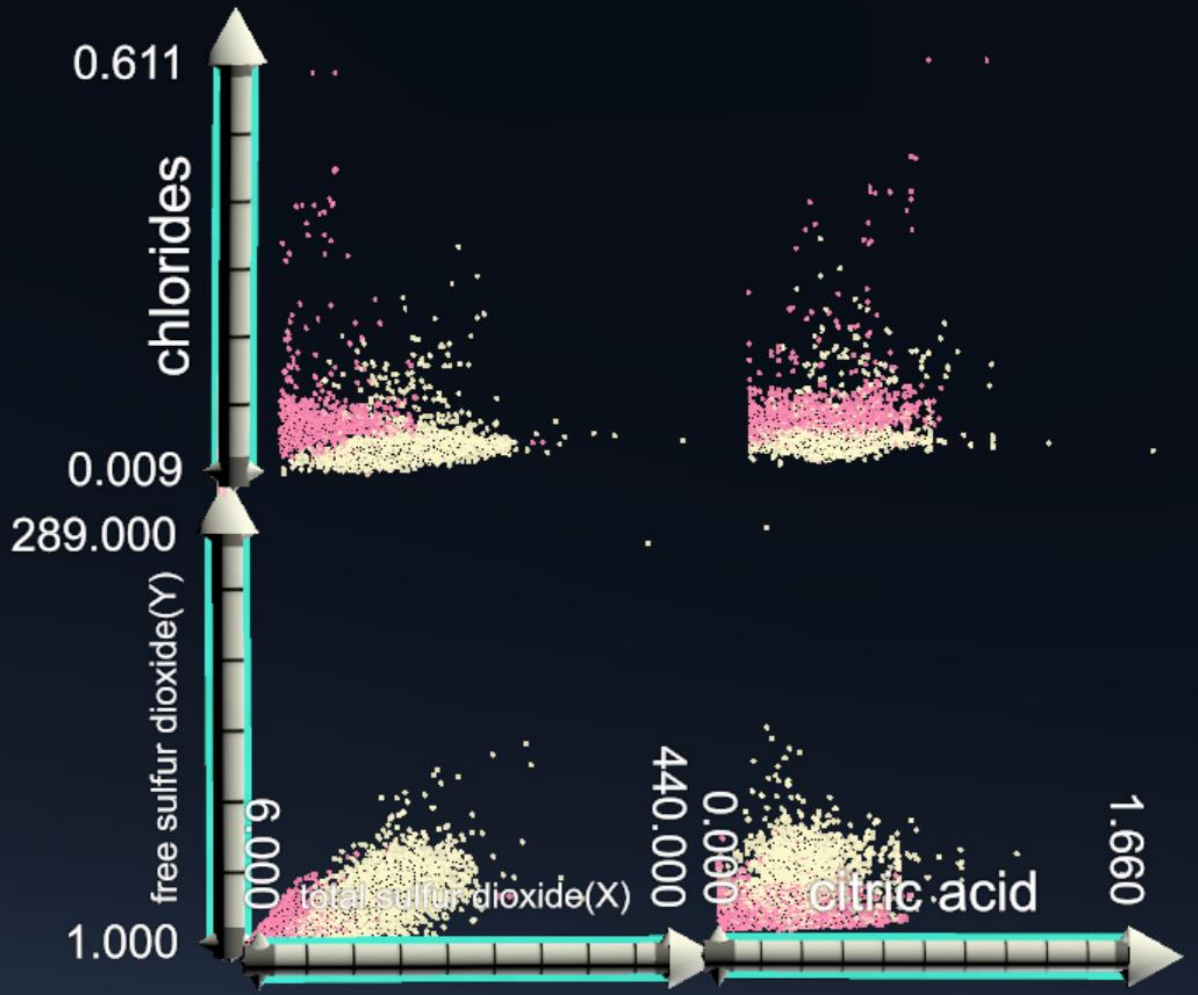
2D scatterplot

Standard visualisations



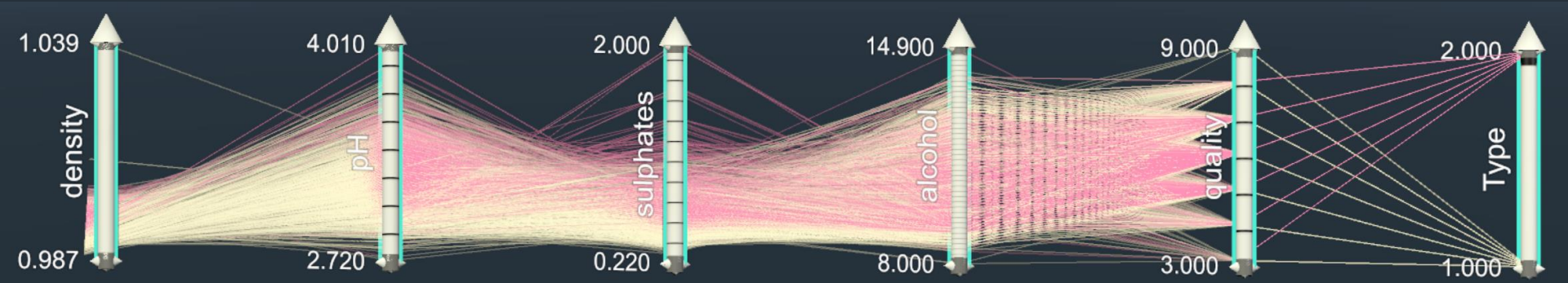
3D scatterplot

Standard visualisations



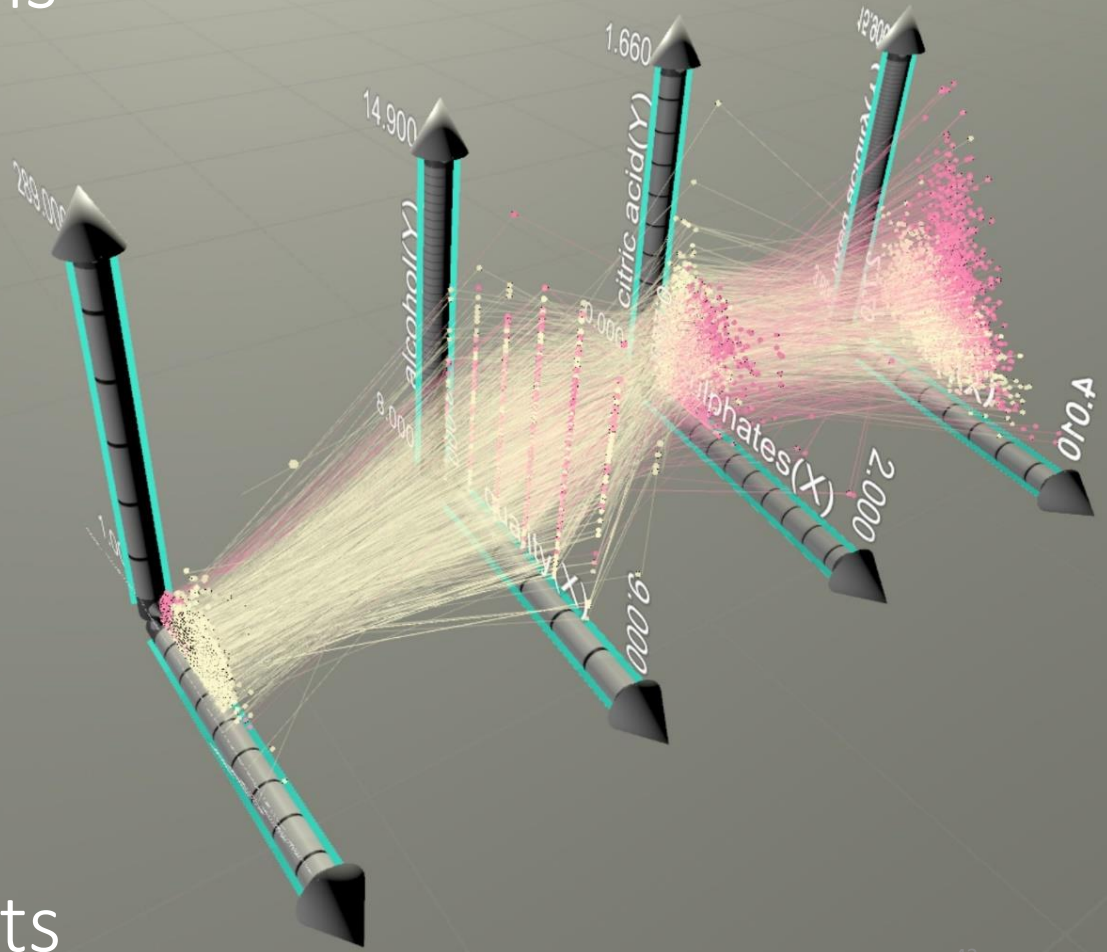
Scatterplot matrix

Standard visualisations



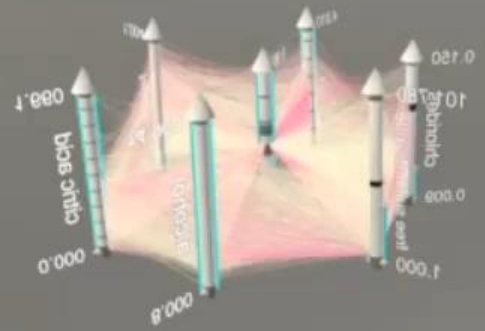
parallel coordinates plot

Standard visualisations



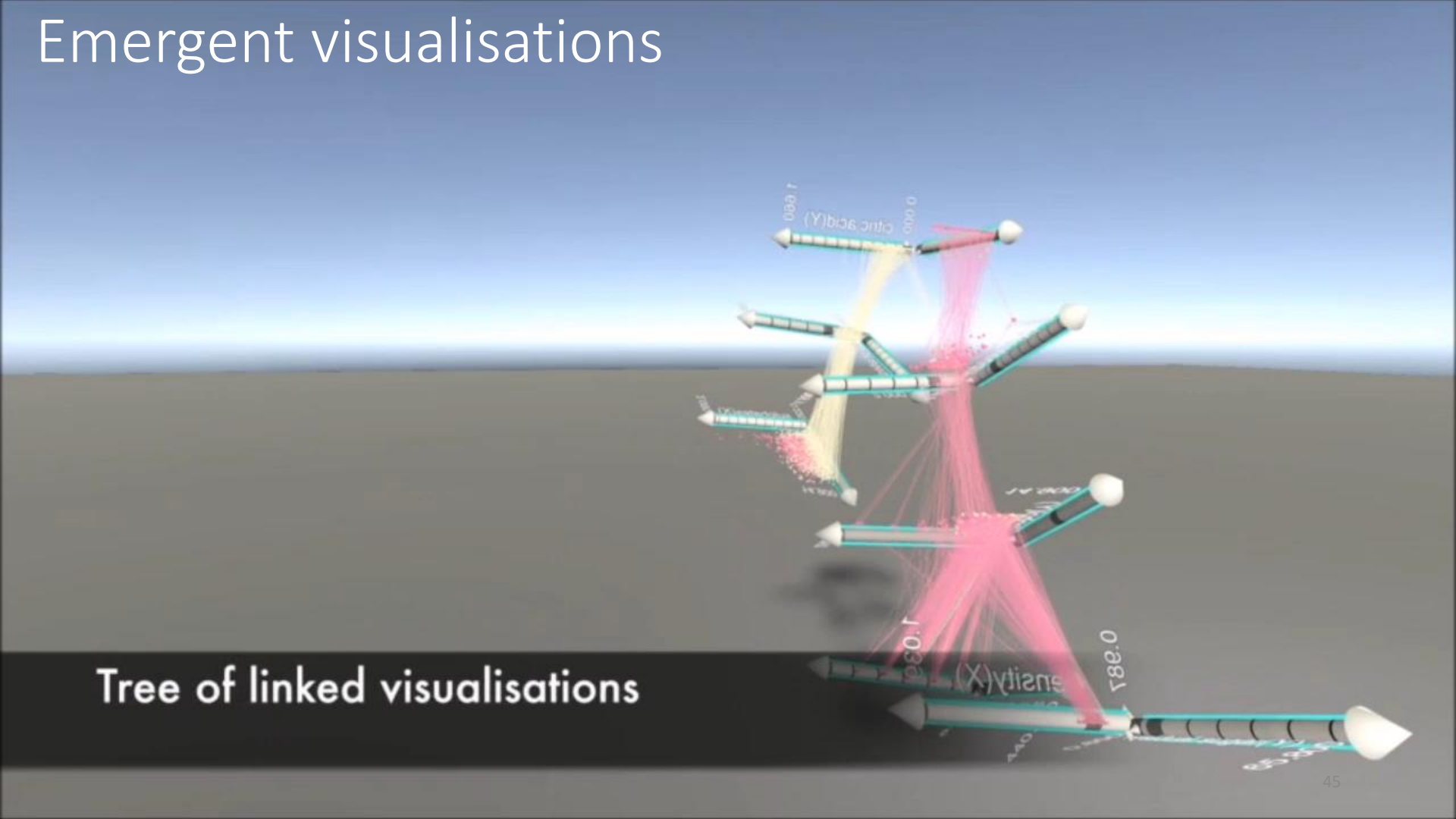
2D linked scatterplots

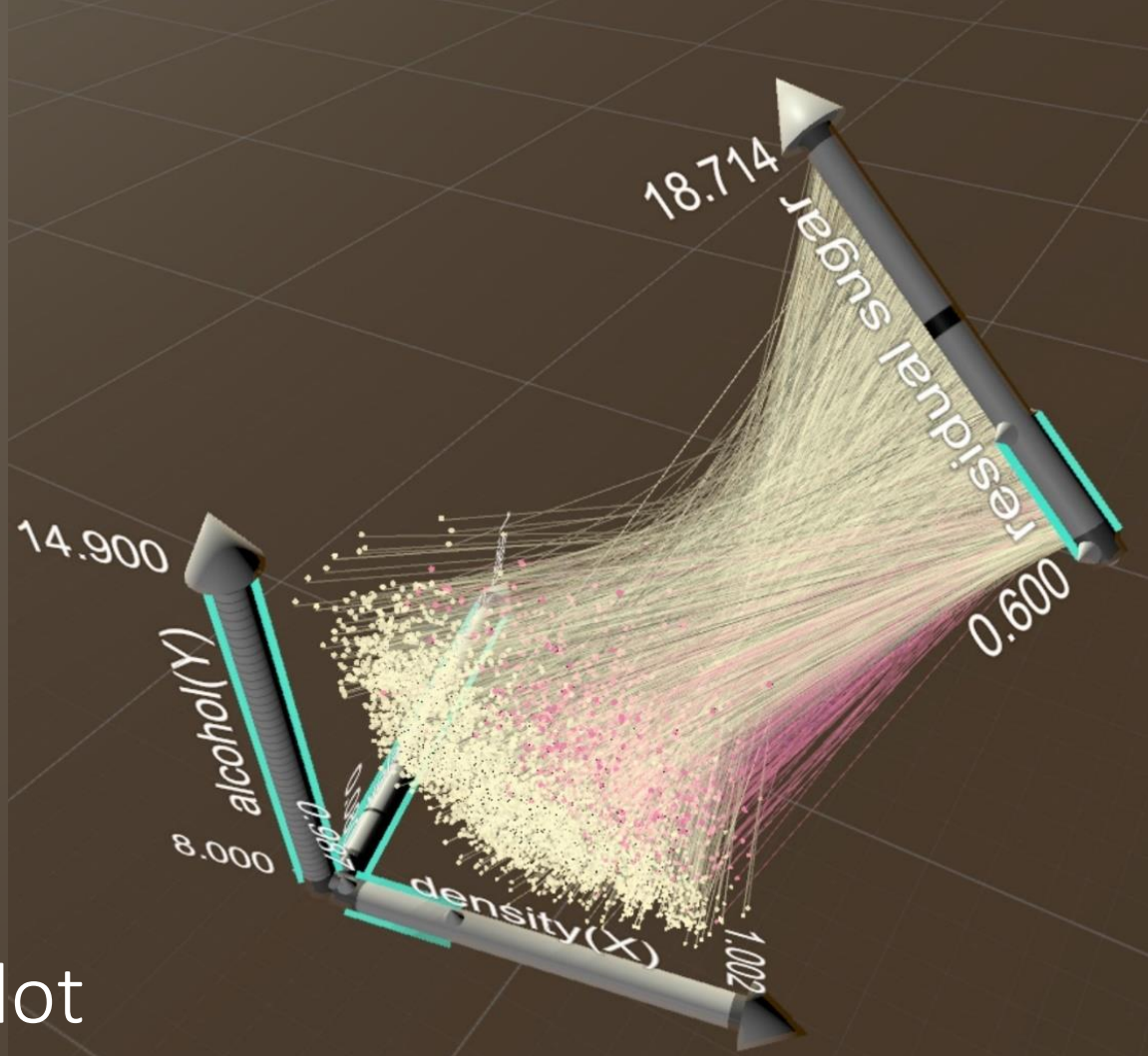
Emergent visualisations



3D Circular connected PCPs

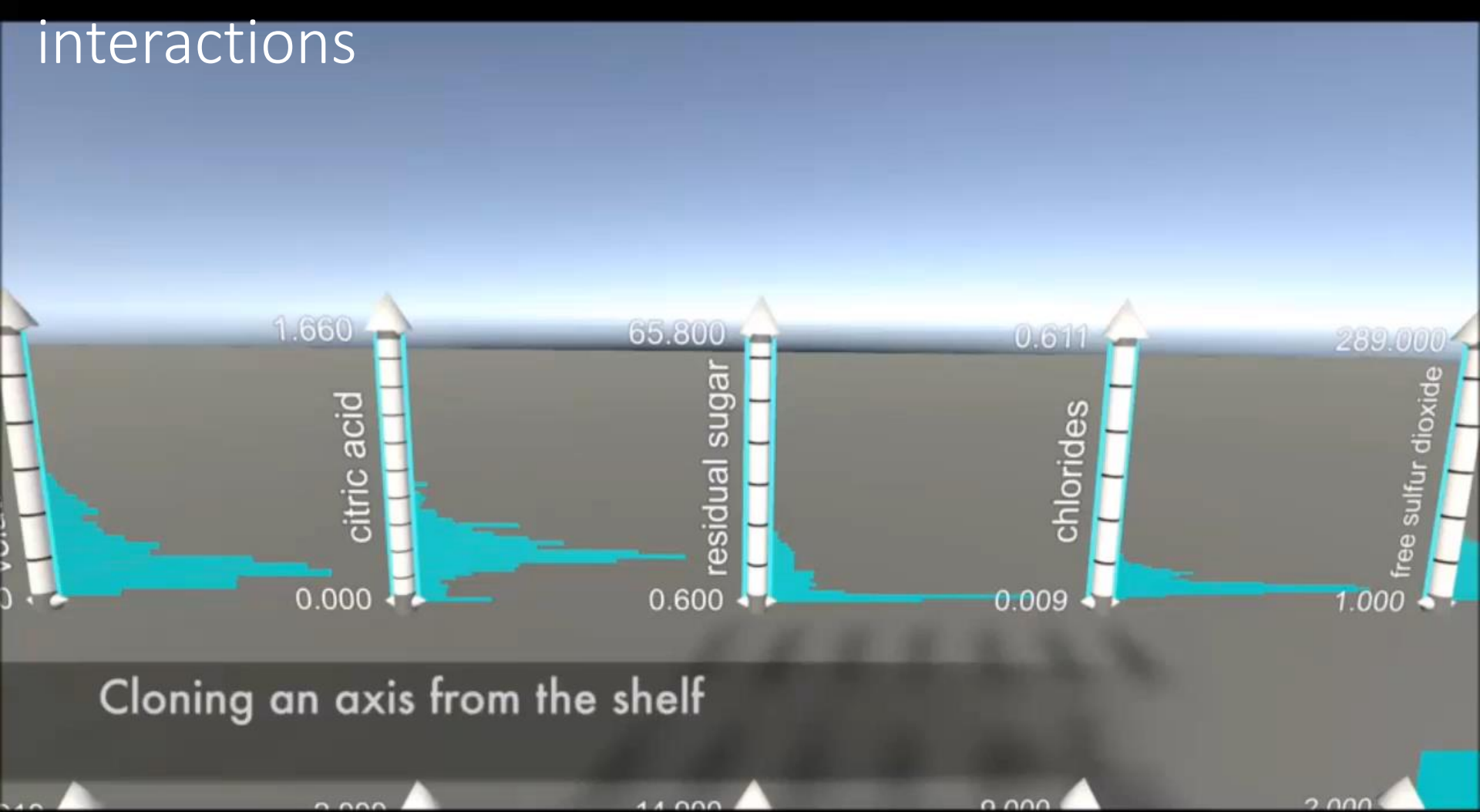
Emergent visualisations



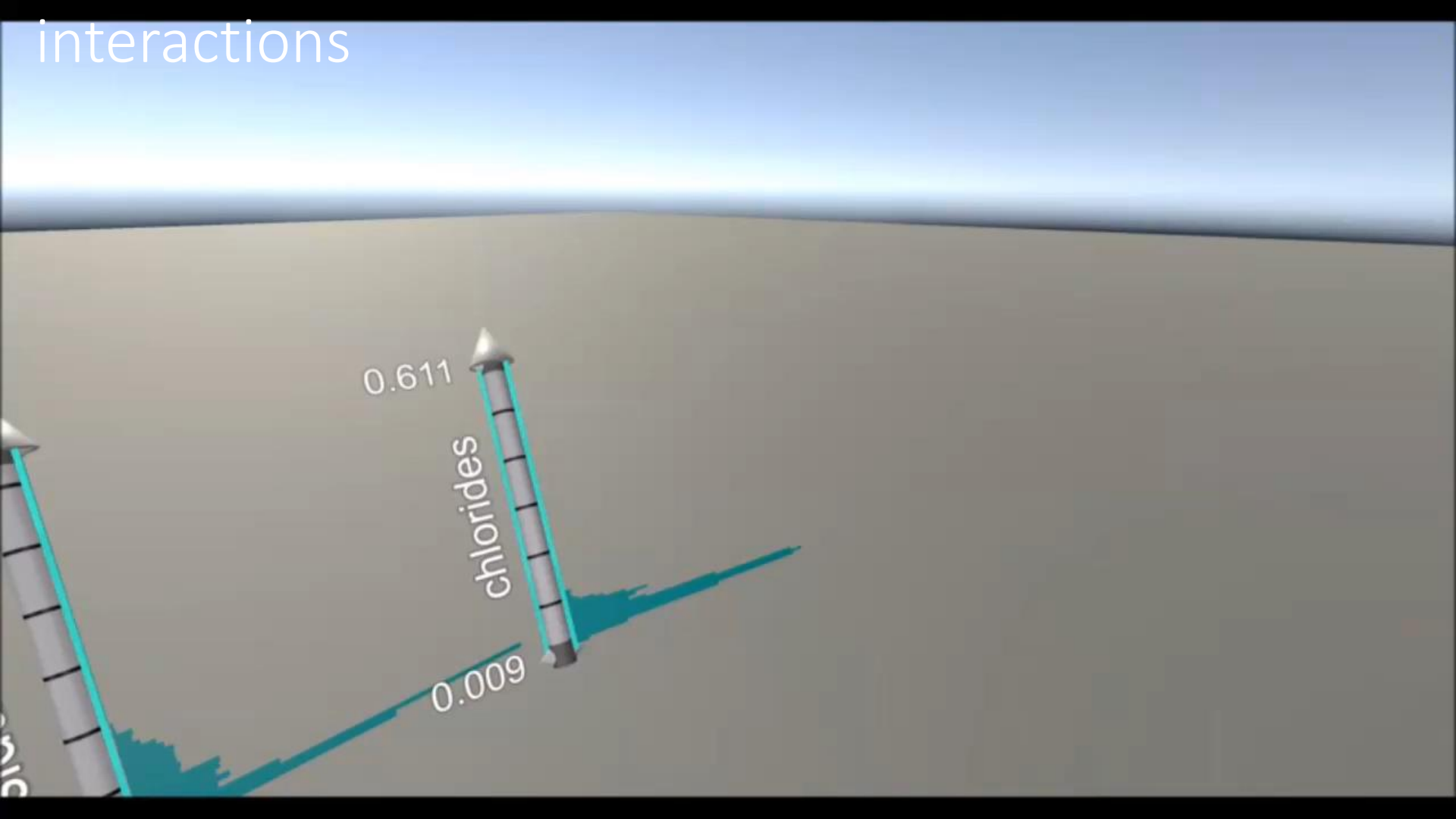


links to 3D scatterplot

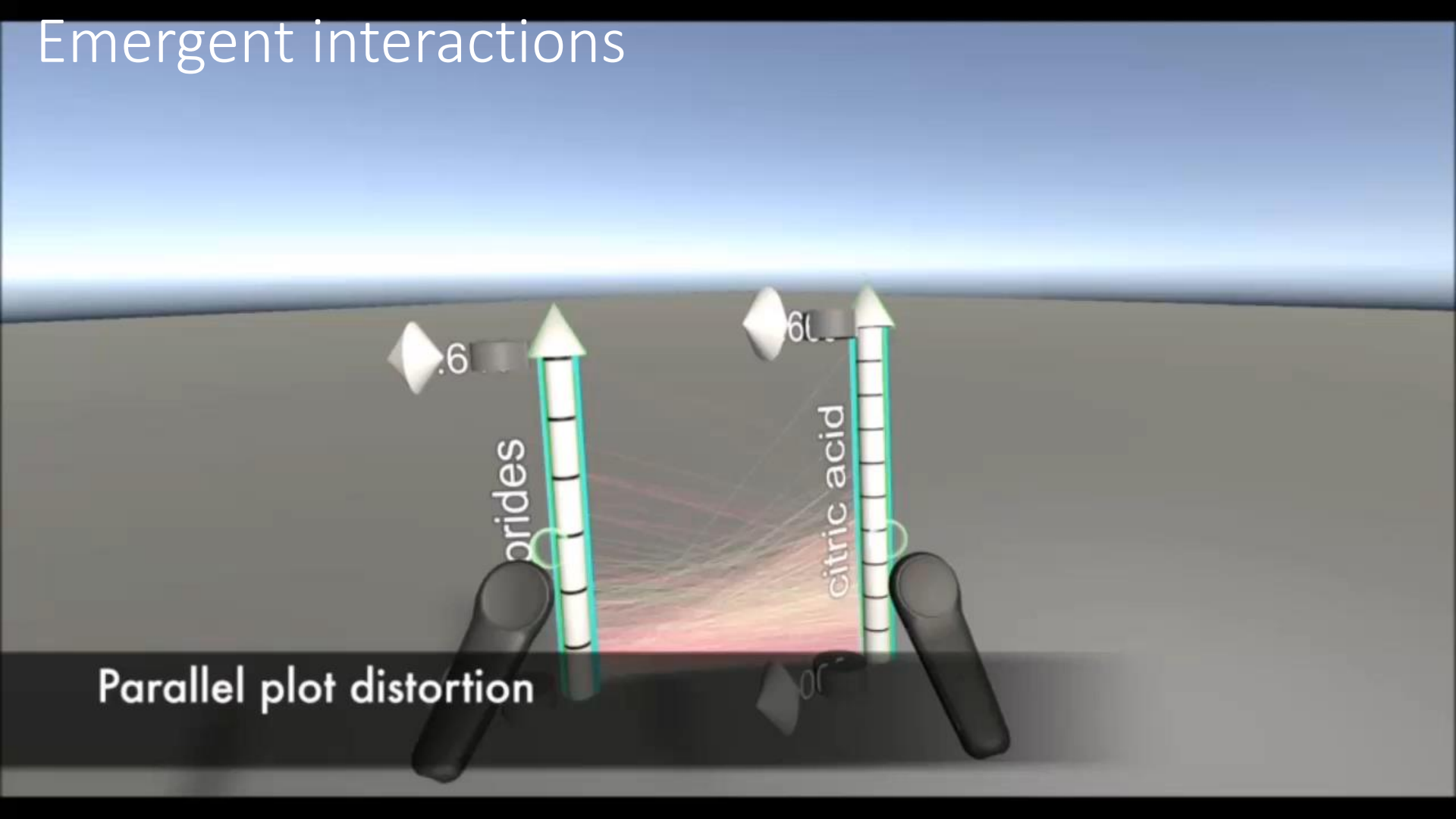
interactions



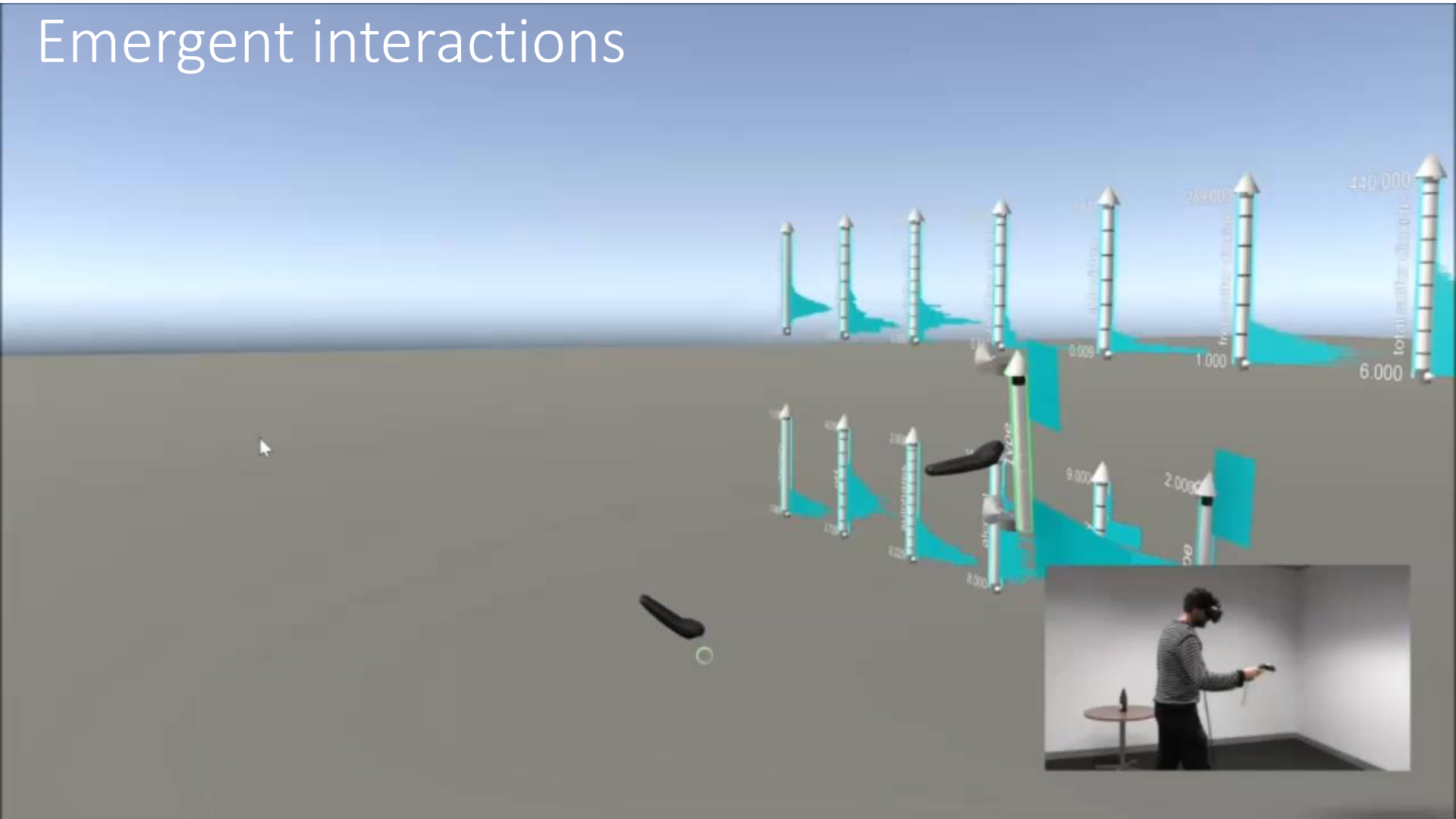
interactions



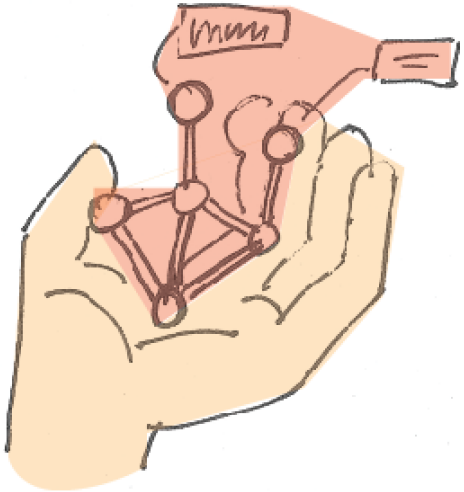
Emergent interactions

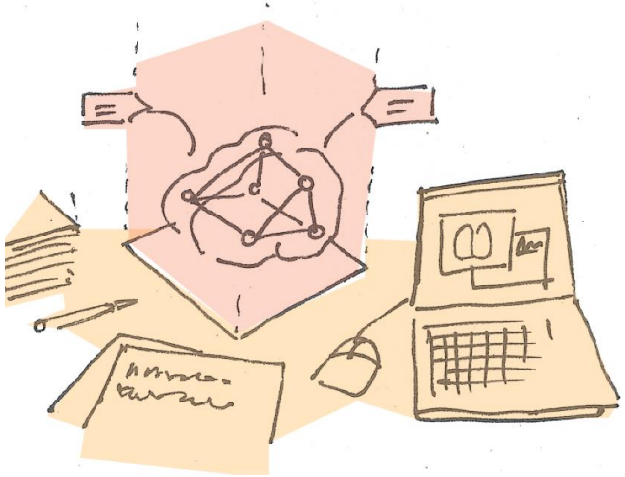


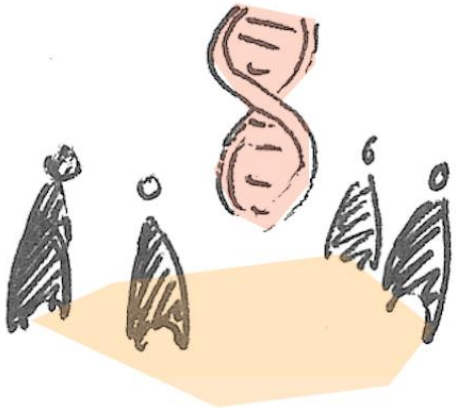
Emergent interactions



A Design Space for **Spatio-Data Coordination**: **Tangible Interaction Devices** for Immersive **Information Visualisation**

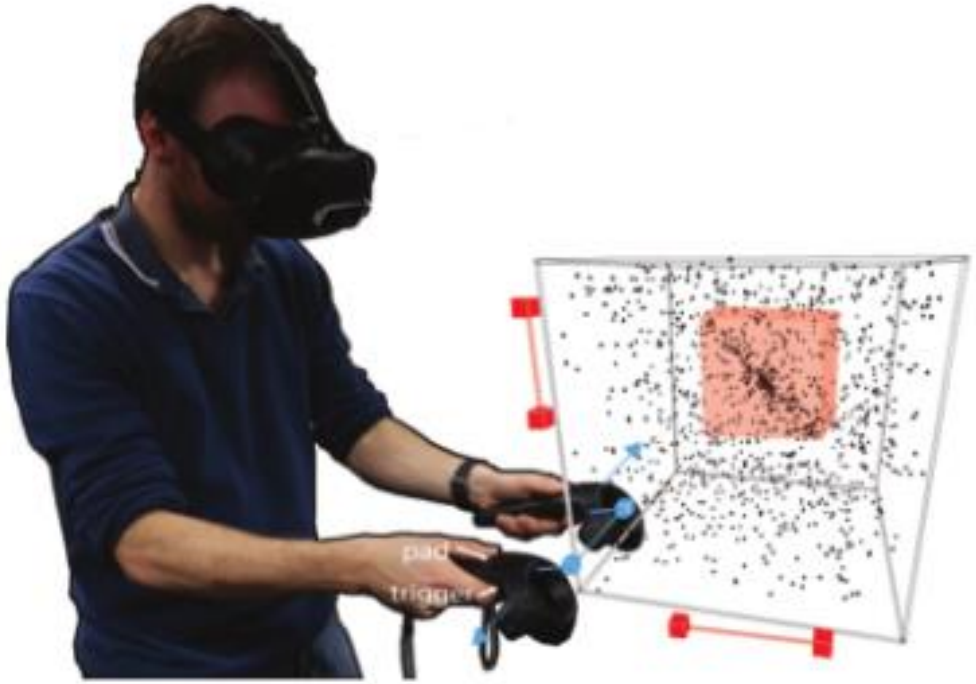


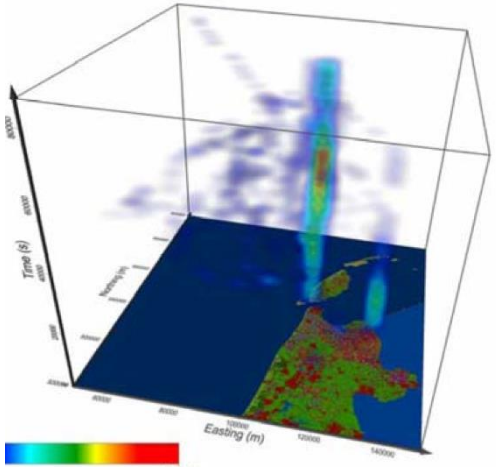


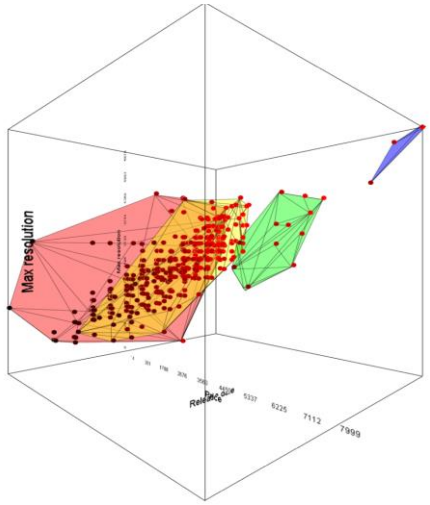


Cordeil, Bach, Li, Wilson and Dwyer

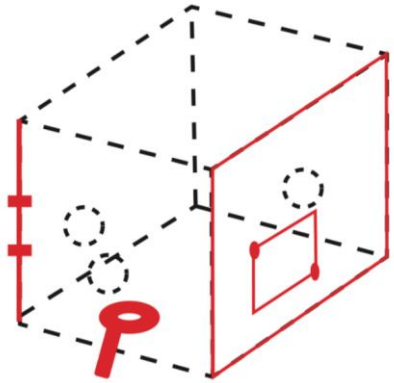
IEEE PacificVis 2017


pad
trigger

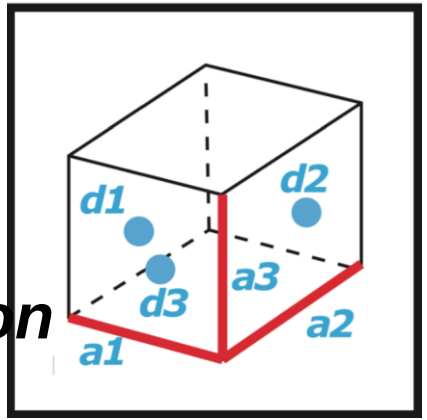

Time (s)
Northing (m)
Easting (m)


Max resolution
Relative Size
5337
6225
7112
7999

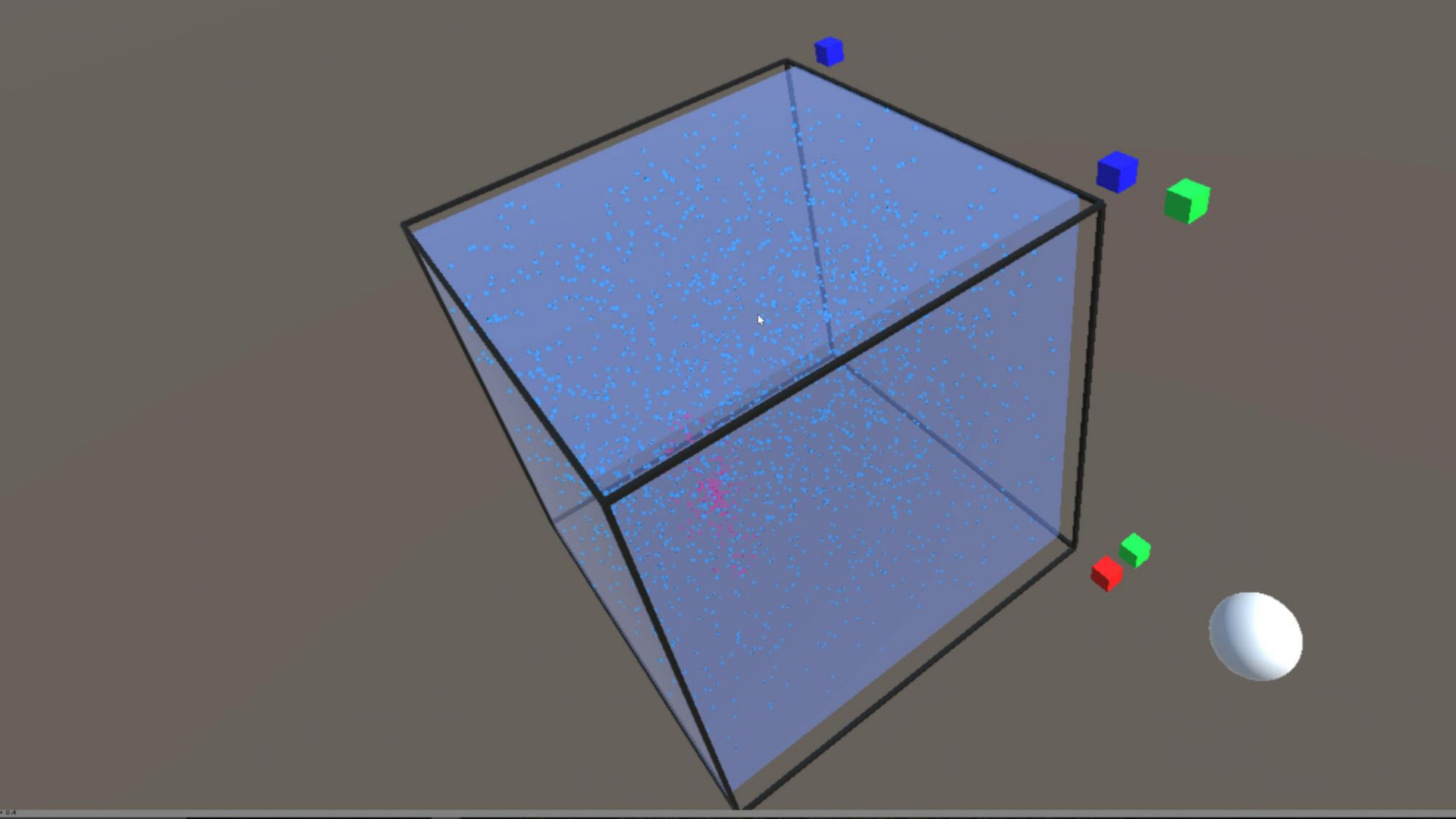
Interaction Space

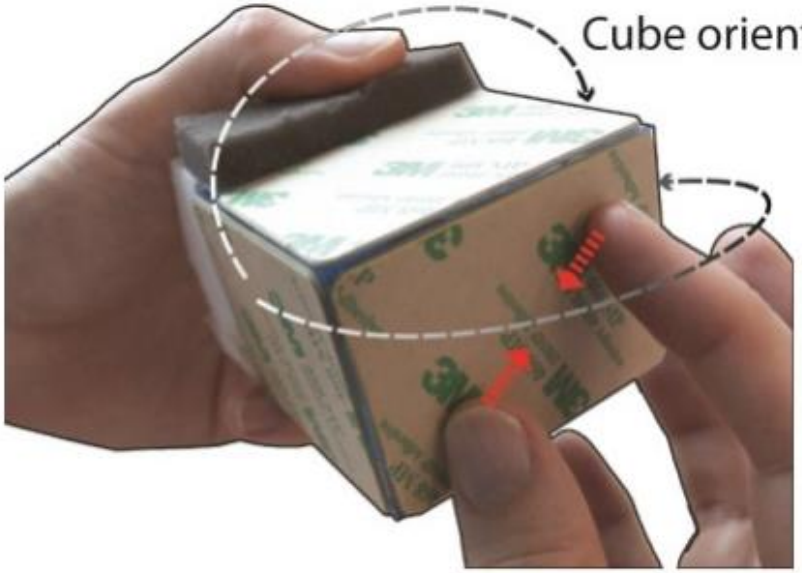


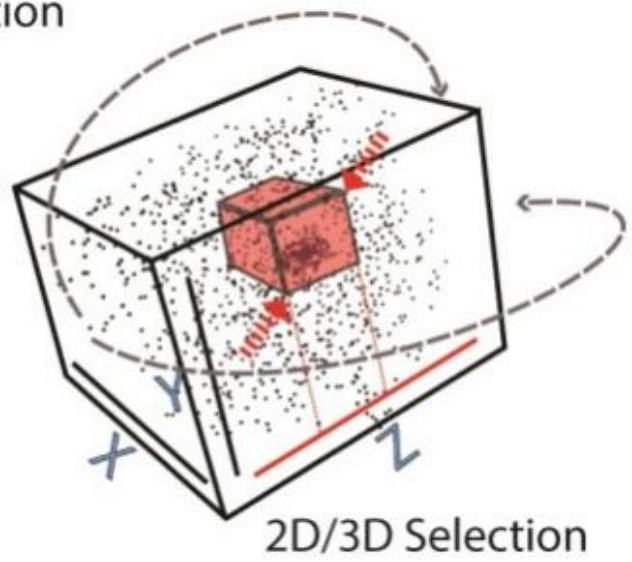
Display Space



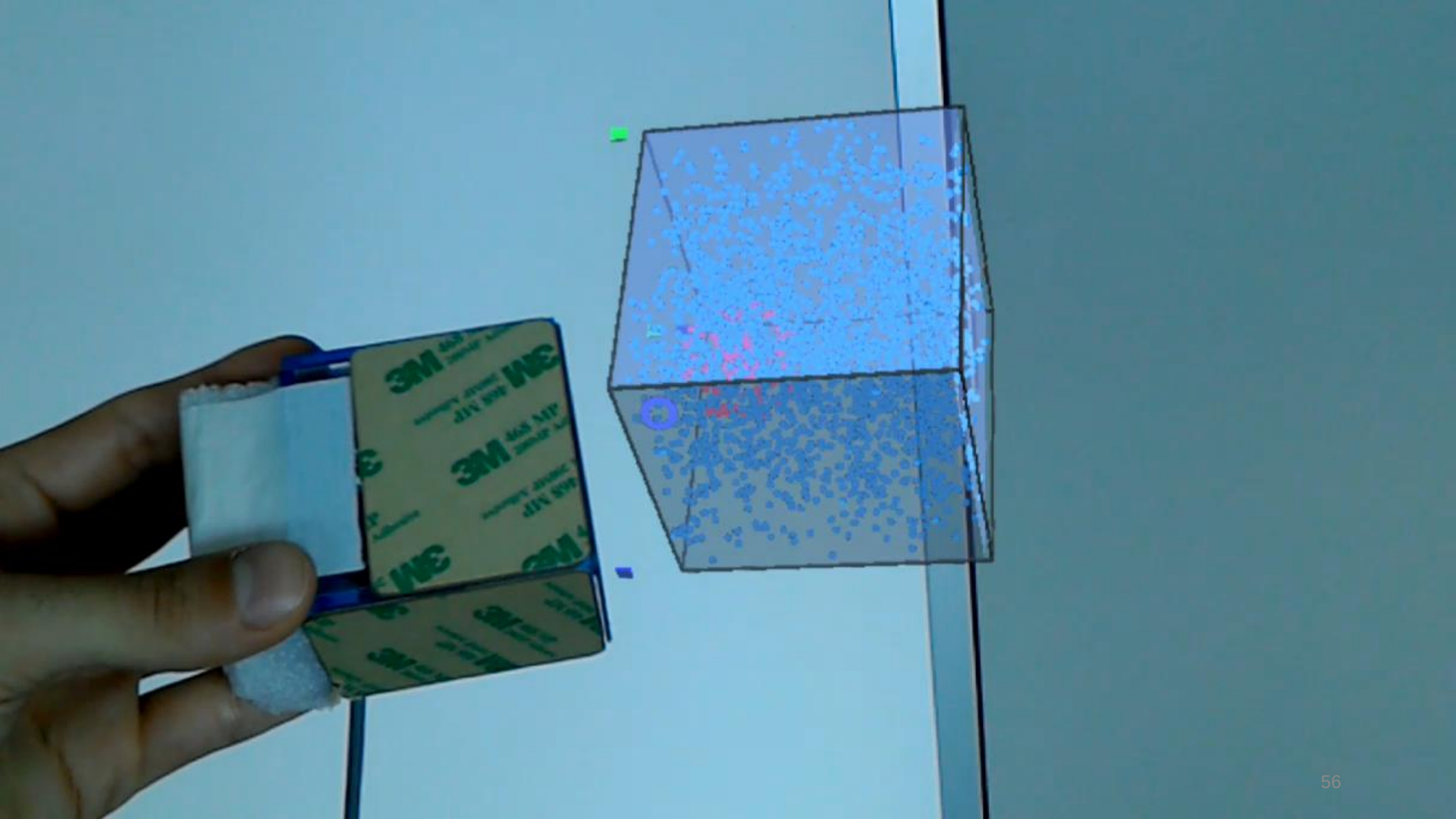
Spatio-Data coordination

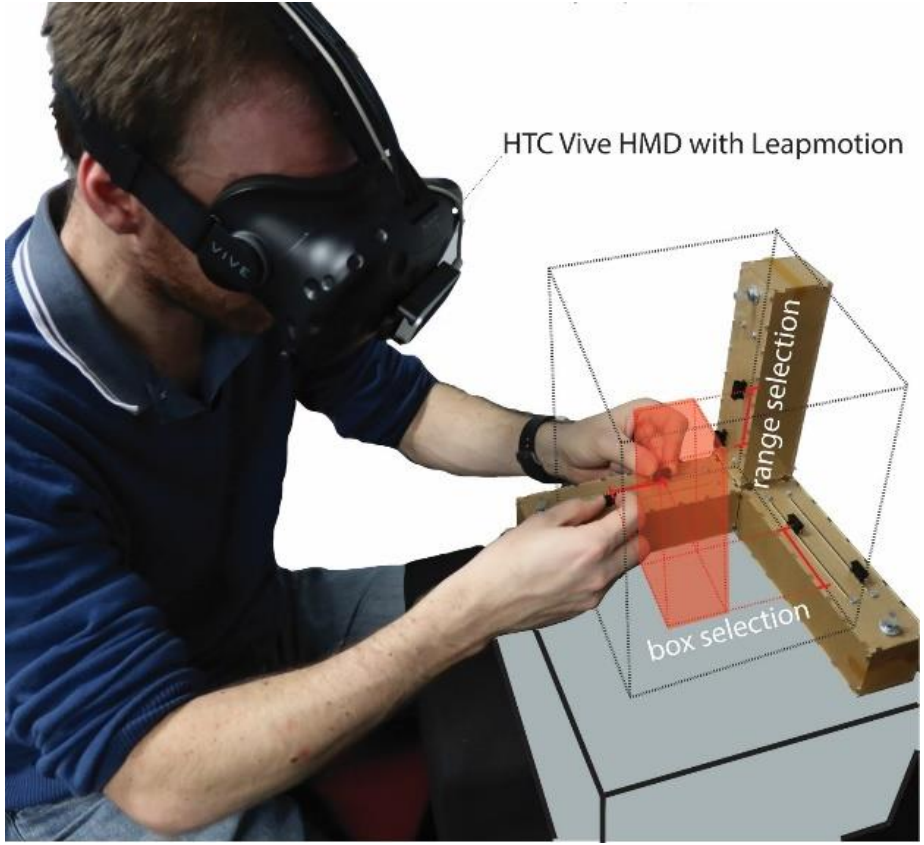


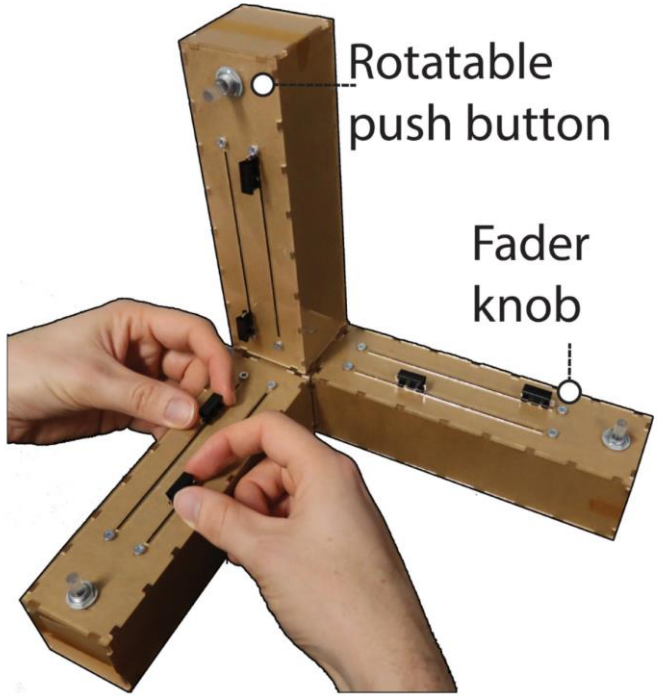


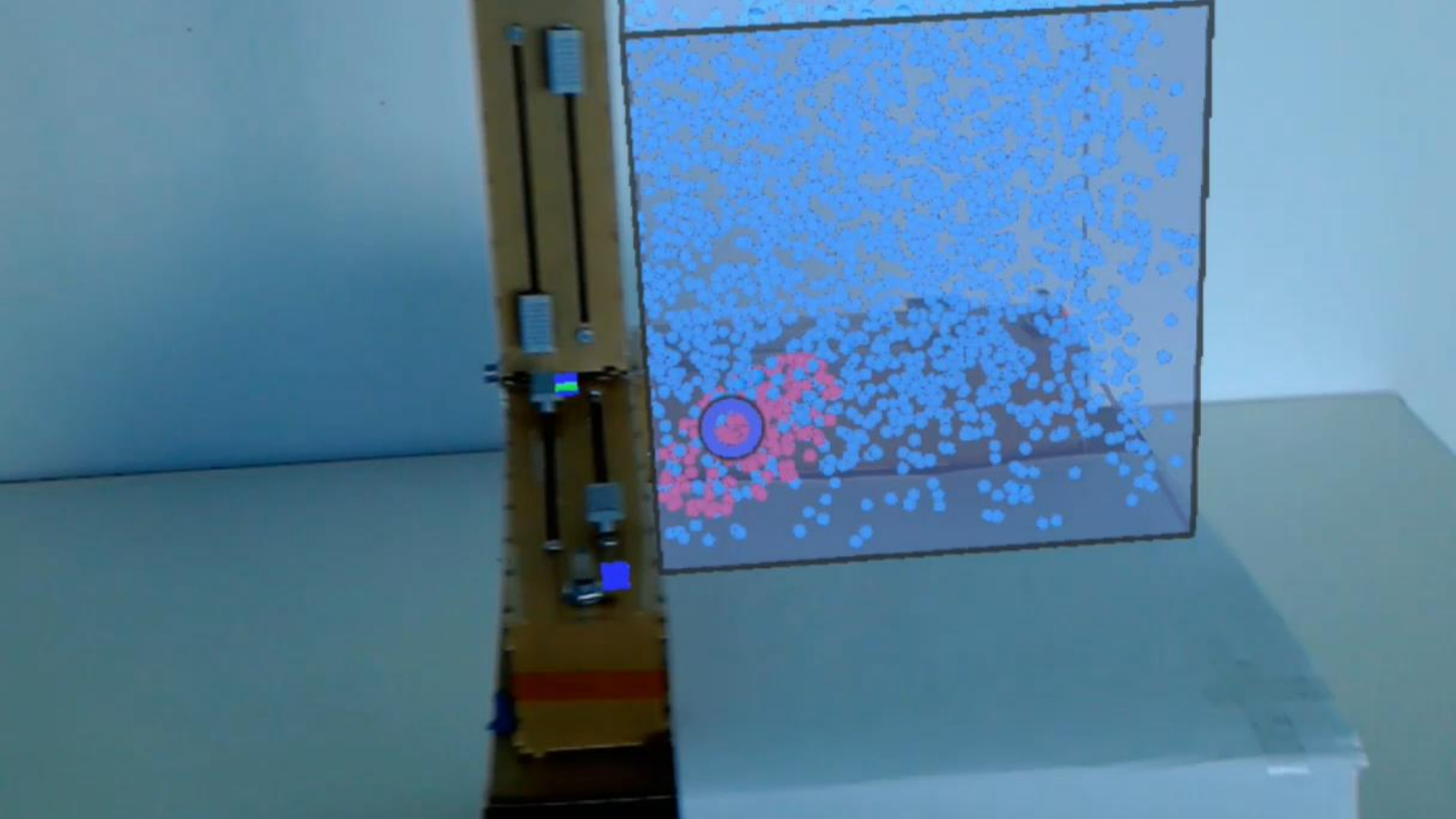


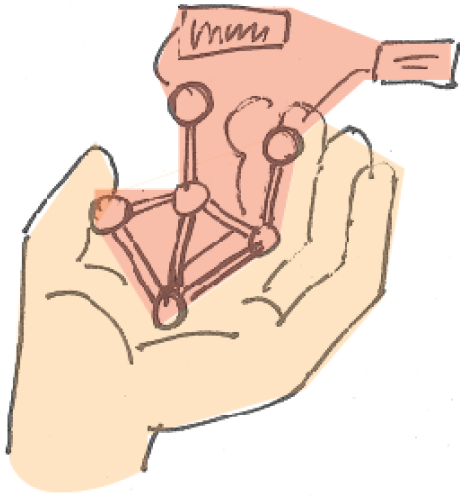
2D/3D Selection

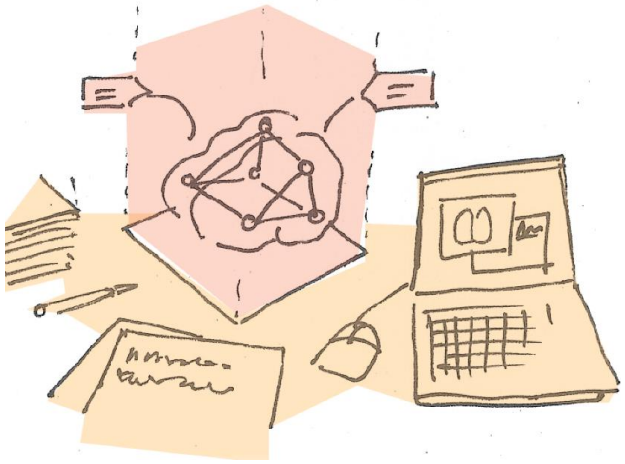

3M
3M
3M

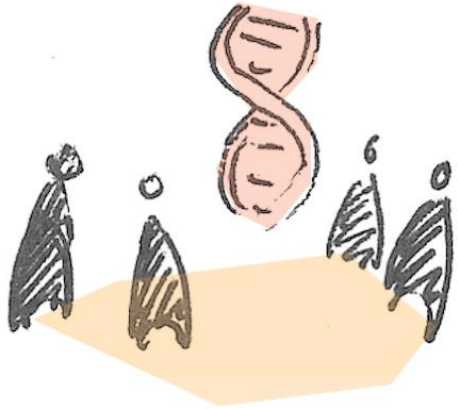

HTC Vive HMD with Leapmotion
range selection
box selection


Rotatable
push button
Fader
knob



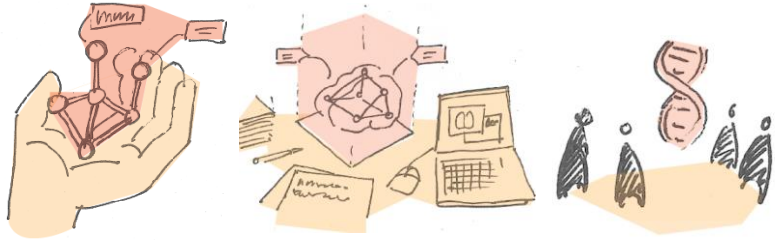






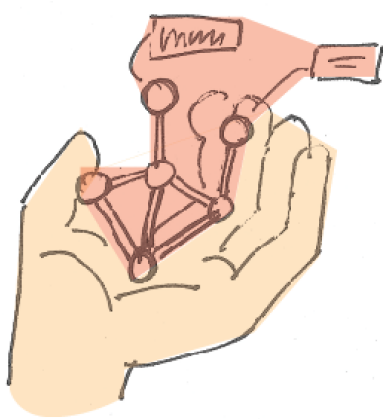
What is the design space for spatio-data coordinated systems for immersive visualisation?

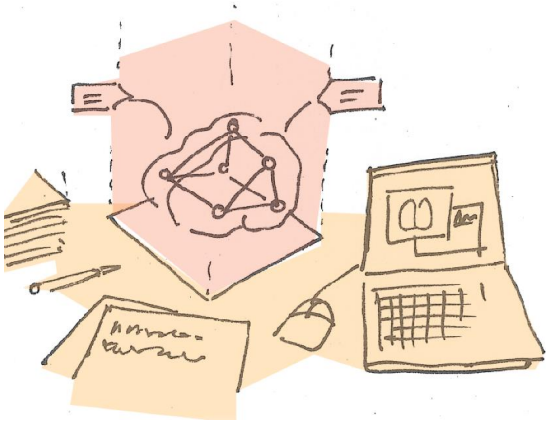
Design space



1. **Interaction Space Size**
2. **Degree of Physicality**
3. Navigation Support
4. Support for Menu-Interaction
5. **Display Space**
6. **Mapping between Interaction Space and Display Space**

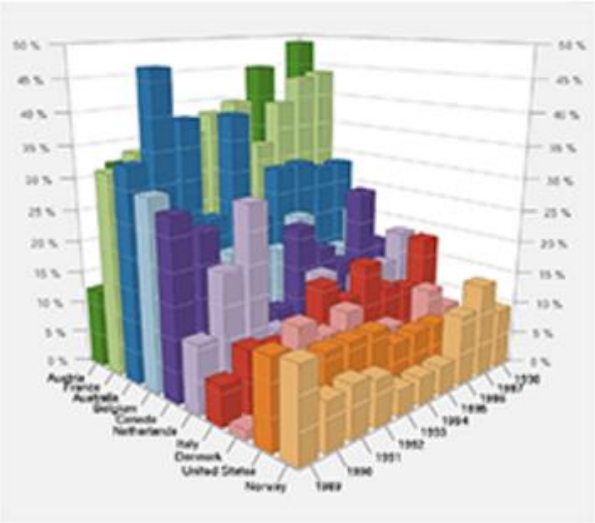
Dimension 1: **Size**

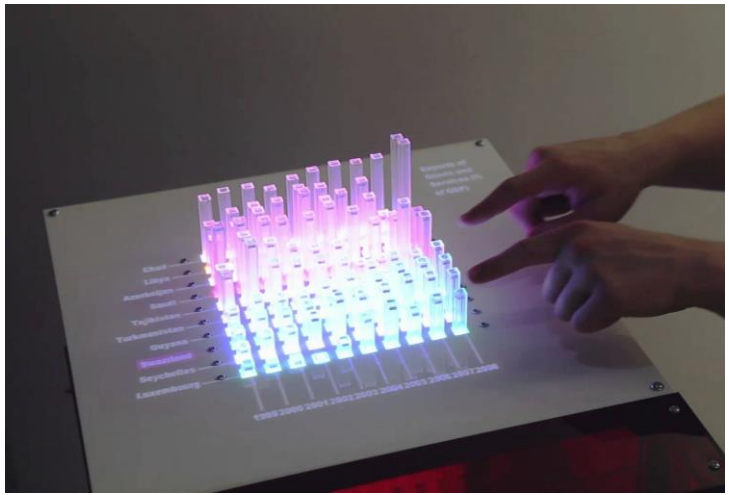




hand → **room**

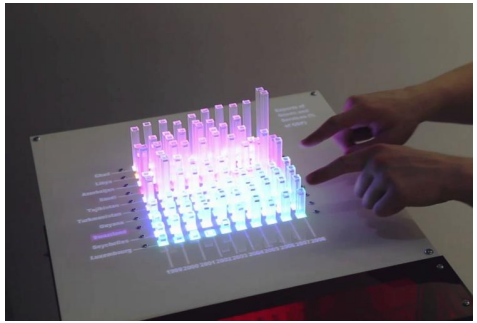
Dimension 2: **Physicality**





not physical → **physical**

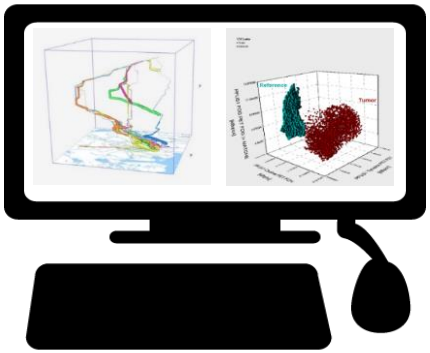
Dimension 5: **Display Space**

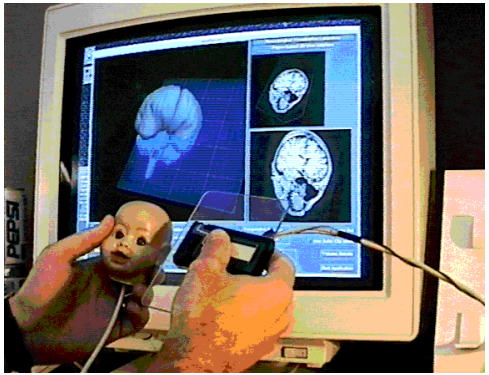


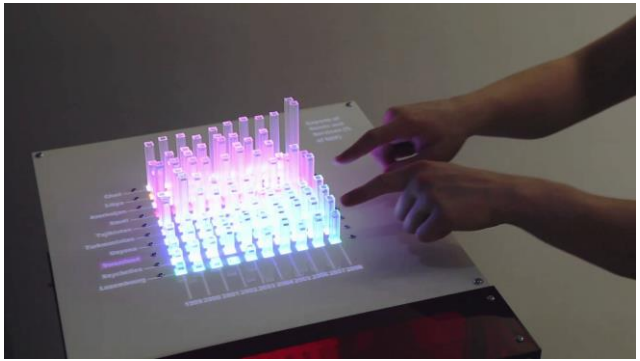
Limited 2D → **3D and beyond**

2.5D

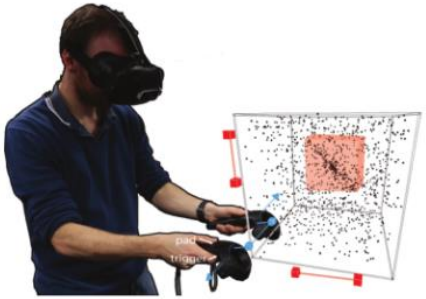
Dimension 6: **Spatial mapping**

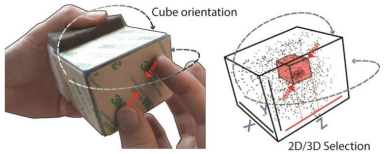


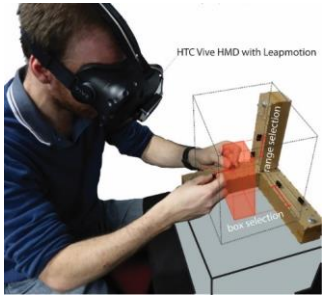




indirect → **direct**

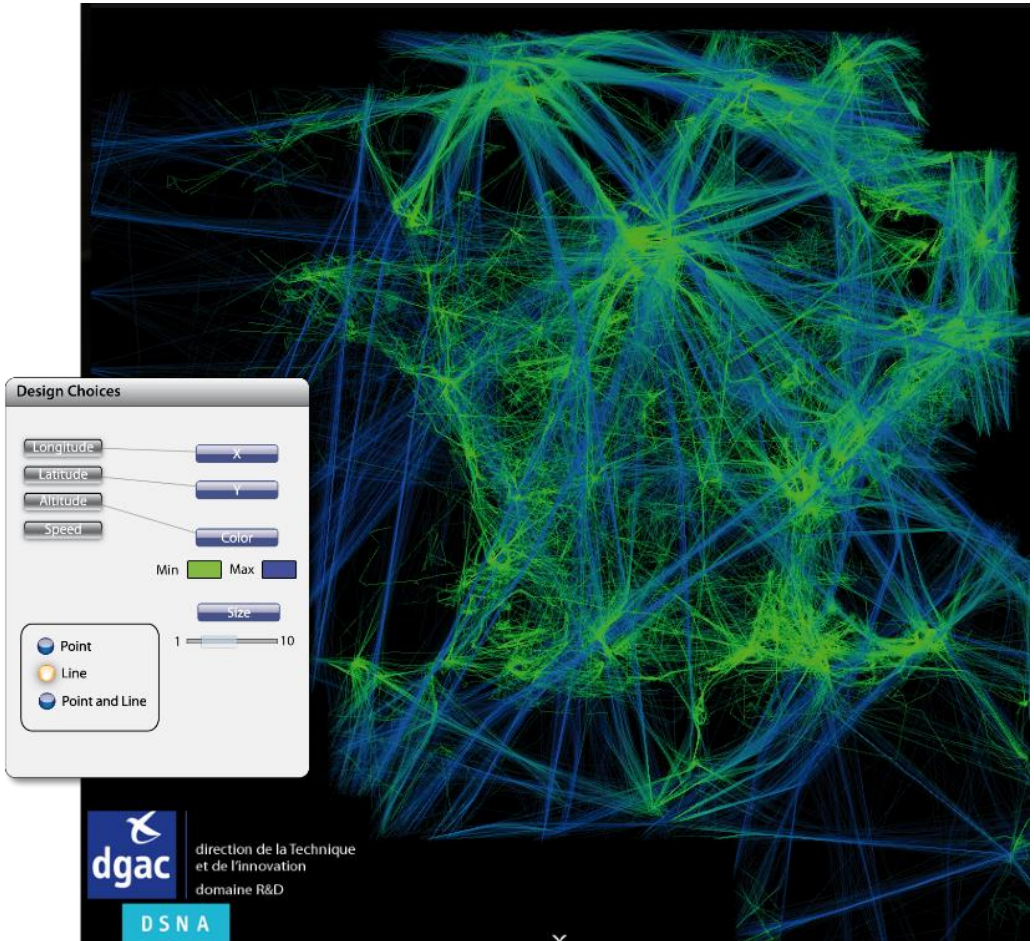




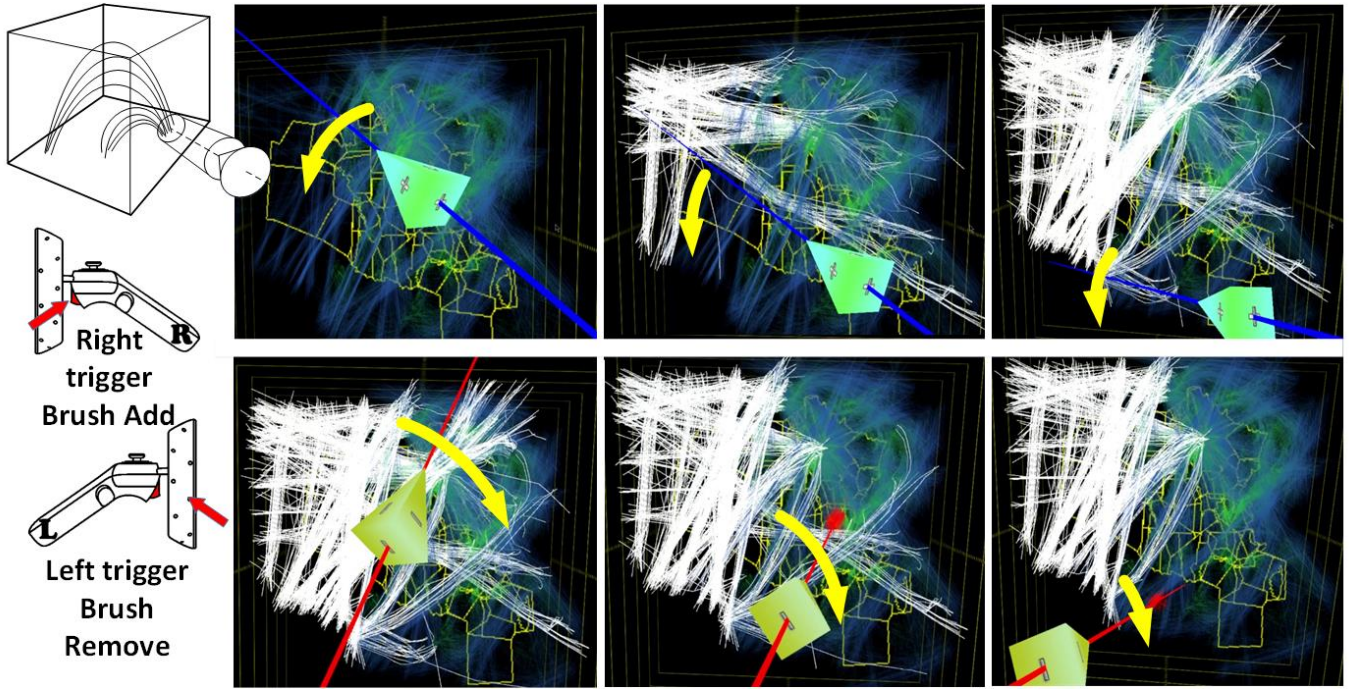


DIMENSION	Virtual Mid-air	Touch-Sensitive Cube	Physical Axes
SIZE	Room size	Hand size	Desktop size
PHYSICALITY	Mid-air Gestures	Physical edges, faces	Physical axes
SPATIAL MAPPING	Direct spatial mapping	Indirect spatial mapping	Direct spatial mapping

Exploration of multivariate trajectories in Virtual Reality

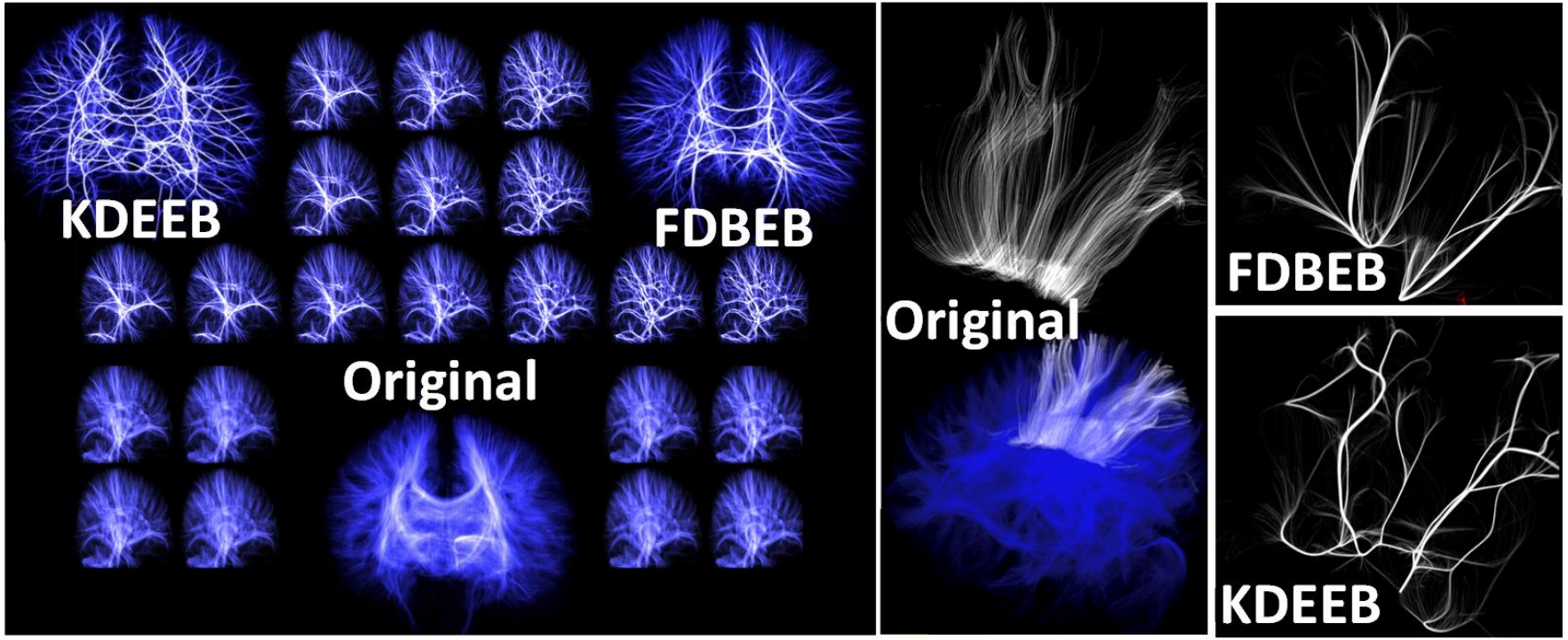


FibreClay – Immersive 3D curves exploration



Hurter, Riche, Drucker, Cordeil, Alligier, Vuillemot – IEEE TVCG 18

Immersive Analytics Opportunities for DH



Conclusion

- Multivariate data are ubiquitous
- A lot of different techniques to visualise and analyse MV data
- Immersive Analytics, a new research initiative

thanks

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- @MaximeCordeil