Additional Material for Hybrid Tactile/Tangible Interaction for 3D Data Exploration

Lonni Besançon, Paul Issartel, Mehdi Ammi, and Tobias Isenberg, *Senior Member, IEEE*

Abstract—We present the design and evaluation of an interface that combines tactile and tangible paradigms for 3D visualization. While studies have demonstrated that both tactile and tangible input can be efficient for a subset of 3D manipulation tasks, we reflect here on the possibility to combine the two complementary input types. Based on a field study and follow-up interviews, we present a conceptual framework of the use of these different interaction modalities for visualization both separately and combined—focusing on free exploration as well as precise control. We present a prototypical application of a subset of these combined mappings for fluid dynamics data visualization using a portable, position-aware device which offers both tactile input and tangible sensing. We evaluate our approach with domain experts and report on their qualitative feedback.

Table 1. Ratio of time spent interacting in the different conditions.

ID	1	2	3	4	5	6	7	median	mean	SD
tangible	0.245	0.000	0.000	0.000	0.109	0.163	0.000	0.000	0.074	0.100
tactile	0.000	0.026	0.088	0.000	0.100	0.087	0.000	0.026	0.043	0.047
hybrid	0.723	0.971	0.860	0.995	0.787	0,750	0.953	0.860	0.863	0.112
idle	0.032	0,003	0.052	0.005	0,004	0.000	0.047	0.005	0.020	0.023

Table 2. Ratio of time spent in the tactile and tangible conditions while using the hybrid interaction.

ID	1	2	3	4	5	6	7	median	mean	SD
tangible	0.735	0.731	0.745	0.718	0.735	0.757	0.755	0.735	0.739	0.014
tactile	0.246	0.268	0.255	0.282	0.265	0.243	0.245	0.265	0.261	0.014

Table 3. Ratio of time spent interacting with the different plane/dataset associations while using hybrid interaction.

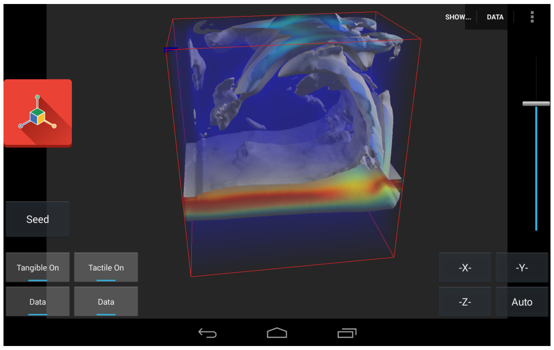
	tangible:	data	plane	plane	data
ID	tactile:	data	plane	data	plane
1		0.064	0.561	0.306	0.070
2		0.362	0.336	0.269	0.033
3		0.016	0.009	0.954	0.021
4		0.863	0.013	0.063	0.061
5		0.218	0.400	0.074	0.308
6		0.034	0.560	0.404	0.002
7		0.107	0.000	0.893	0.000
median		0.107	0.336	0.306	0.033
mean		0.238	0.268	0.423	0.071
SD		0.301	0.257	0.363	0.108

Table 4. Results from Likert-based ratings for different statements, with values ranging from 1 (completely disagree) to 5 (completely agree). Ranking is expressed from 1 to 3, 1 standing for the preferred technique

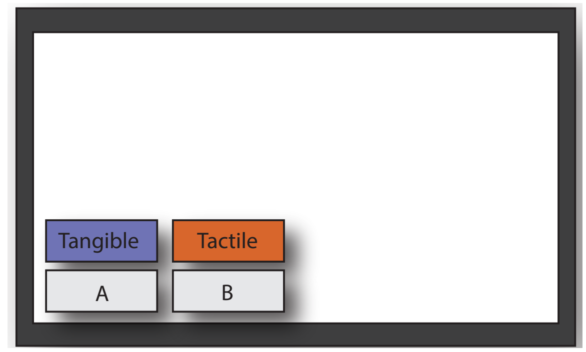
statement	factor	mean	median	SD
3I could do what I wanted.	tangible	3.57	4.00	0.79
	tactile	3.57	4.00	0.98
	hybrid	4.14	4.00	0.90
3I could achieve my goals quickly.	tangible	3.57	3.00	0.79
	tactile	3.86	4.00	1.07
	hybrid	4.14	4.00	0.90
3It could be used without much information.	tangible	3.57	4.00	0.79
	tactile	4.00	4.00	0.81
	hybrid	4.00	4.00	0.58
3It required a lot of mental effort to use.	tangible	3.14	3.00	0.69
	tactile	2.71	2.00	1.11
	hybrid	3.57	3.00	1.13
3overall ranking (1 to 3, 1=best)	tangible	2.57	3.00	0.53
	tactile	2.28	2.00	0.76
	hybrid	1.14	1.00	0.38

Table 5. Particpants' demographics.

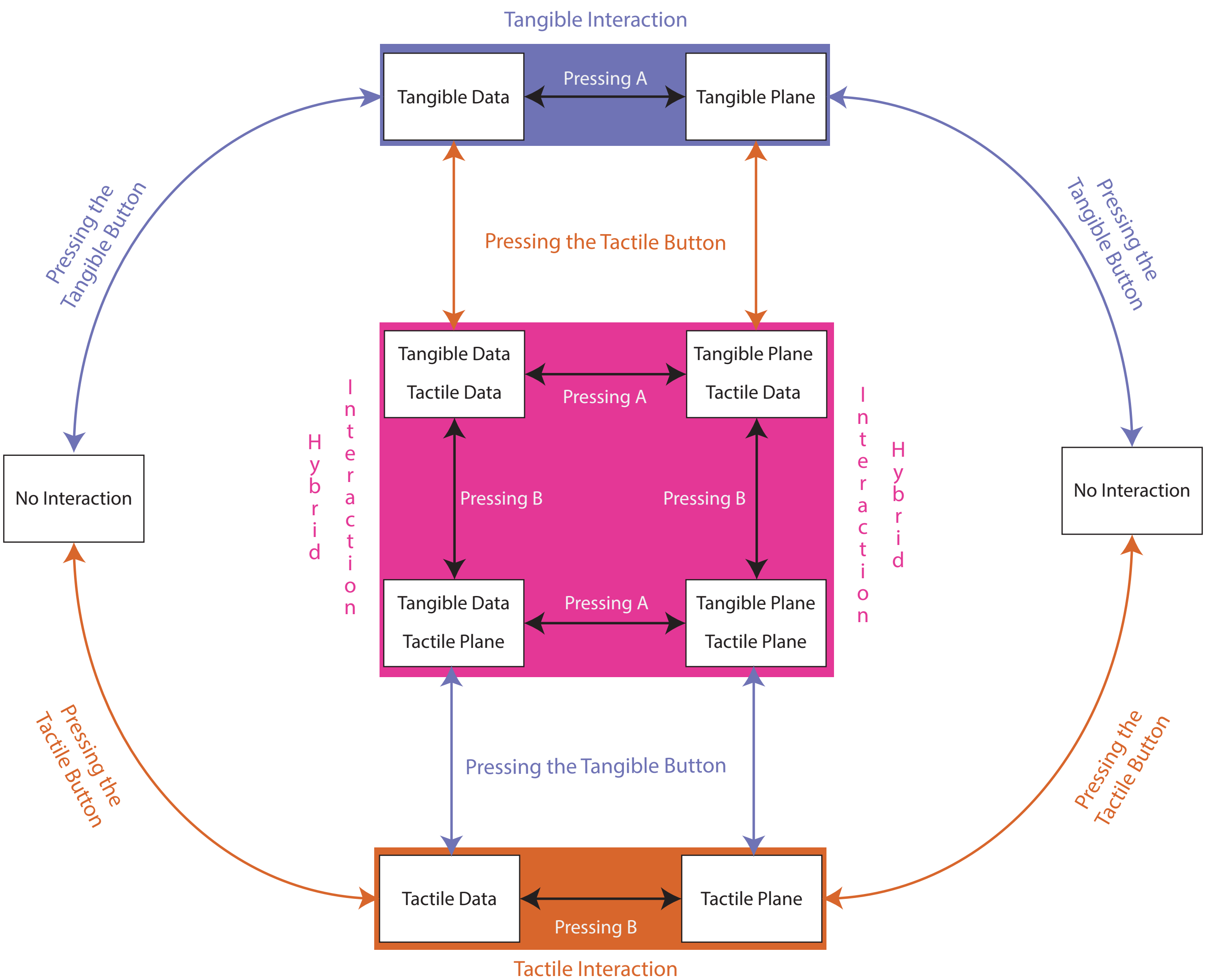
ID	1	2	3	4	5	6	7	median	mean	SD
age	32	44	25	31	34	61	23	32	35.71	13.06
years of post-master experience	9	21	2	8	11	38	1	9	12.86	12.90
gender	M	M	M	M	M	M	M			



(a)



(b)



(c)

Fig. 1. State diagram of all the possible interactions that users had access to, also showing how to access these interaction modes. Fig. 1(a) represents the complete interface; Fig. 1(b) represent a diagram of the buttons involved in mode transitions; Fig. 1(c) represents all the different interaction modes accessible.

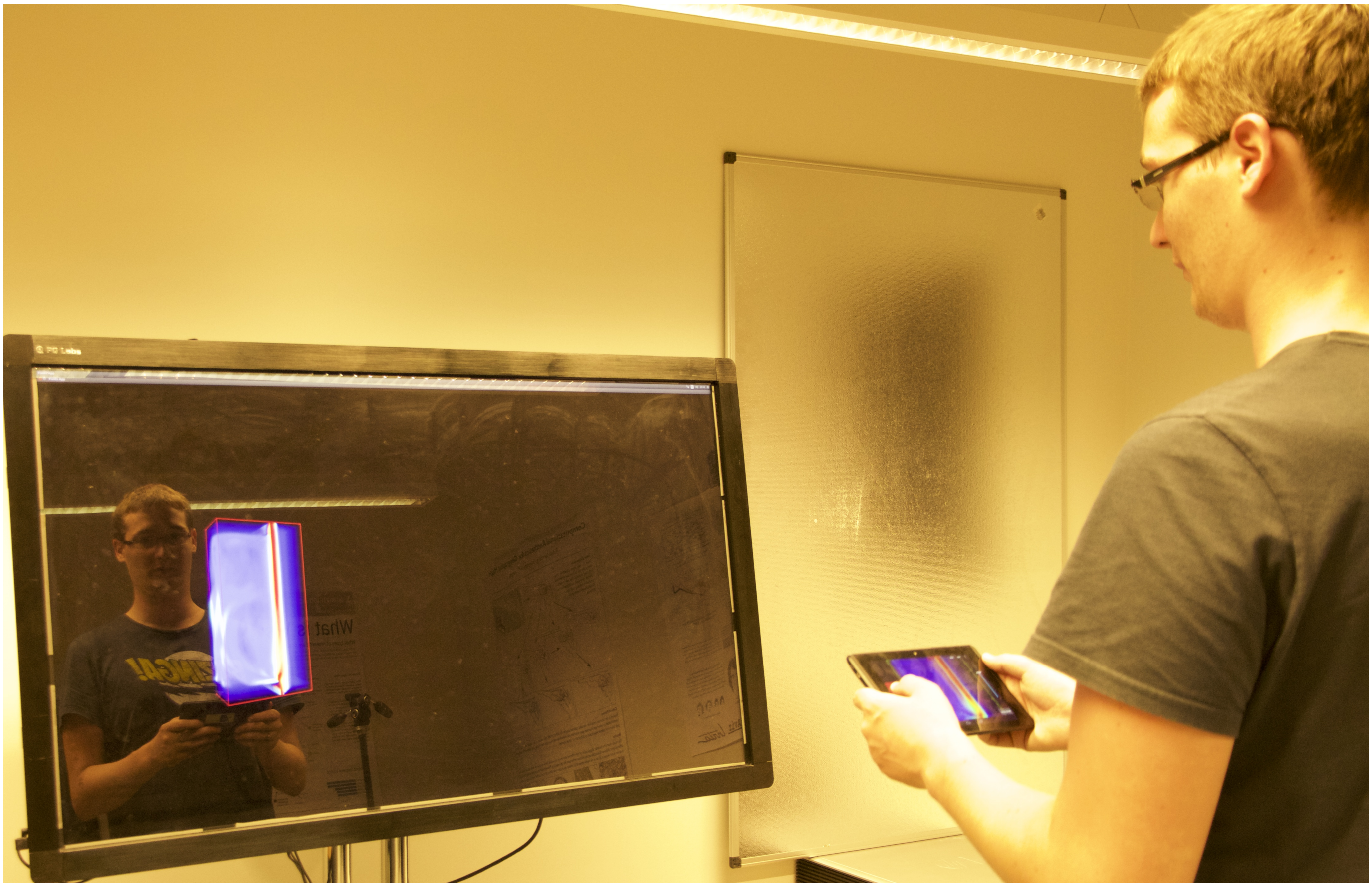


Fig. 2. Experimental setup.

Implementation Details

The vertical display is handled by a computer running Ubuntu 14.04 and the Google Tango tablet is running Android 4.4. Our implementation uses the VTK library[1] to load and process the datasets on both the tablet and the vertical display. The dataset was rendered using OpenGL ES 2.0 on the tablet and OpenGL 3.0 on the vertical display. Communication between the devices used the UDP protocol.

To ensure that packet loss would not be critical to the synchronized views, we sent absolute transformation matrices over the network. To save computational power and battery of the tablet, elaborate computations and visualizations were restricted to the vertical display. For instance, the input information for particle tracing/seeding was captured by the tablet but processed and rendered by the vertical display's computer, and the external display also showed a 2D view of the slicing plane to ease the understanding of the sliced data.

The code is based on C++ for the vertical display and on both Java and native C++ for the tablet. Communications with the large display and input capturing is done with Java and then transmitted to the native code via the JNI. We make use of the Tango Java API to retrieve positioning and orientation information. We improve the later by combining information retrieved from the built-in sensors available in all tablets (i. e. gyroscope, accelerometer). Even though we use a Tango Tablet with the corresponding API, our implementation was made so that it is possible to substitute it with an other position aware device and API without changing much of the code. Only the java code handling the retrieval of the positions and orientations needs to be changed to adapt to other devices. Similarly, the code running on the vertical display can be adjusted to fit any display size.

As of this day, the prototype supports all *.vti* and *.vtk* datasets.

[1] http://www.vtk.org/