

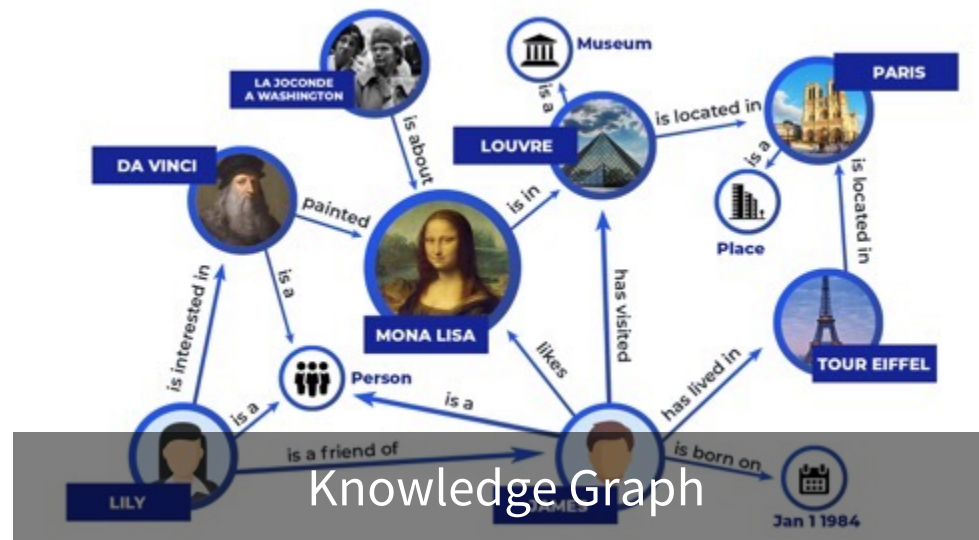
FPX-G: First Person Exploration for Graph

Takahiro Komamizu, Shoi Ito,
Yasuhiro Ogawa, Katsuhiko Toyama
Nagoya University



Graph: a general data structure

Graph $G = (V, E, A)$



Many others: protein-protein interaction, call graph of software, road network, etc.

Graph Search, Exploration and Visualization

- Task: seeking information from a graph

- Graph Search

- Given a graph query (e.g., graph pattern, keyword), find subgraphs matching to the query
- e.g., GraphQL, SPARQL, Cypher

Good when users have
clear information needs.

- Graph Exploration

- Interactive seeking
- Procedure (like browsing Web sites)
 - Repeat: (1) visit a vertex and (2) choose a neighbor to explore

Good when users have
unclear information needs.

- Graph Visualization

- Bird-eye-view of a graph
- e.g., Gephi, Cytoscape, Argo Lite

Good when users want to
analyze graph structures.

Graph Exploration: browsing approach

Nagoya University
From Wikipedia, the free encyclopedia

Not to be confused with Nagoya City University.

Nagoya University (名古屋大学, abbreviated to Meida (名大) or NU) is a Japanese national research university located in Chikusa-ku, Nagoya. It was the seventh Imperial University in Japan, one of the first five Designated National University and selected as a Top Global University Project by the Japanese government. It is the 3rd highest ranked higher education institution in Japan (2nd worldwide).^[1]

The university is the birthplace of the Sakurai School of physics and the Hirasu School of chemistry. As of 2014, six Nobel Prize winners have been associated with Nagoya University, the third most in Japan and Asia behind Kyoto University and the University of Tokyo.^[10]

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History [edit]

Nagoya University traces its roots back to 1871 when it was the Temporary Medical School/Public Hospital. In 1939 it became **Nagoya Imperial University** (名古屋帝国大学), the last Imperial University of Japanese Empire. In 1947 it was renamed **Nagoya University** (名古屋大学), and became a Japanese national university. In 2014, according to the reform measure of the MEXT, all Japanese national universities has been incorporated as a National University Corporation. The university has a profound tradition of physics and chemistry. Many world-class scientific research achievements include Sakurai model, HANE math, Okazaki fragment, Nagaoi asymmetric hydrogenation, and Blue LED were born in Nagoya University.

In the 20th century, NU's Kuno Yasu and Katsumasa Sudo were nominated for the Nobel Prize in Physiology or Medicine, Yuusaku Ohnuki was nominated for the Nobel Prize in Physics. In the 21st century, NU prepares account for half of the total number of Japanese Nobel Prize winners (up to 2014). Among the six winners of the Nobel Prize in Chemistry and the Physics, there are three professors and five alumni. The number of winners is the third among Japanese and Asian universities. In addition, the team under Professor Mutsaers Kunihiro participated in the Scarspanners project by using special nuclear emulsion plates. This led to the discovery in 2017 of new chambers in the great pyramid.^[20]

In March 2012, Nagoya University played host to the International Symposium on Innovative Nanobiodevices.^[21] Three years later, NU was selected as one of the five shangan universities for gender equality by the United Nations Entity for Gender Equality and the Empowerment of Women.^[22]

In March 2018, Nagoya University was selected as one of first five Designated National University. In order to become the largest national higher education corporation in Japan, the Tokai National Higher Education and Research System established by integrating with Gifu University in April 2020, both are major universities in Tokai region.

Overview [edit]

Ideal [edit]

The ideal written in the Nagoya University Academic Charter is to encourage the intellectualism with courage by providing an education which respects independent thought. Currently, NU's academic style and characteristics are "freedom, openness, and enterprising" when Nagoya Imperial University was just established, the first president was in a passage of the Seven-years-article constitution, and his motto, "Harmony is to be valued," was the basic spirit of the entire university.^[23]

Student population [edit]

Nagoya
From Wikipedia, the free encyclopedia

Not to be confused with Nagoyat.

For other uses, see Nagoya (disambiguation).

Nagoya (名古屋市, *Nagoyashi*) is the largest city in the Chūbu region of Japan. It is Japan's fourth-largest incorporated city and the third-most populous urban area. Located on the Pacific coast on central Honshū, it is the capital of Aichi Prefecture and is one of Japan's major ports along with those of Tokyo, Osaka, Kobe, Yokohama, and Chiba. It is also the center of Japan's third-largest metropolitan region, known as the Chūbu-kyūshū metropolitan area. As of 1 October 2018, 2,327,557 people lived in the city, part of Chūbu-metropolitan-Area's 10.11 million people,^[1] making it one of the 30 largest urban areas in the world.

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Media

Images

Left: Building in Sakae, Nagoya, Nagoya City (To You, Japan's Japan Road), Aonao Park, Aonao, Aonao Shrine

Map

Flag

Seal

Location of Nagoya in Aichi Prefecture

Nagoya Castle
From Wikipedia, the free encyclopedia

For Nagoya Castle in Aichi Prefecture, see Nagoya Castle (Aichi Prefecture).

Nagoya Castle (名古屋城, *Nagoyashi*) is a Japanese castle located in Nagoya, Japan. Nagoya Castle was constructed by the Owari Domain in 1612 during the Edo period on the site of an earlier castle of the Oda clan in the Sengoku period. Nagoya Castle was the heart of one of the most important castle towns in Japan, Nagoyajuku, a post station on the Meiji road linking two of the important Edo Five Routes, the Tokaidō and the Nakasendō. Nagoya Castle became the core of the modern Nagoya and ownership was transferred to the site by the Imperial Household Agency in 1930. Nagoya Castle was destroyed in 1945 during the bombing of Nagoya in World War II and the reconstruction and repair of the castle has been undergoing since 1957.

Meiji (明治), another shorthand way of pronouncing Nagoya Castle (名古屋城), is used for many Nagoya city institutions such as Meiji Park, the Meiji Line of the Nagoya Municipal Subway, and Meiji University, reflecting the cultural influence of this historic structure. The castle has also historically been called *Kiyō* (清), which means "Violet Castle".

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 - Early restoration and expansion
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 - 21st century and future plans
- Layout
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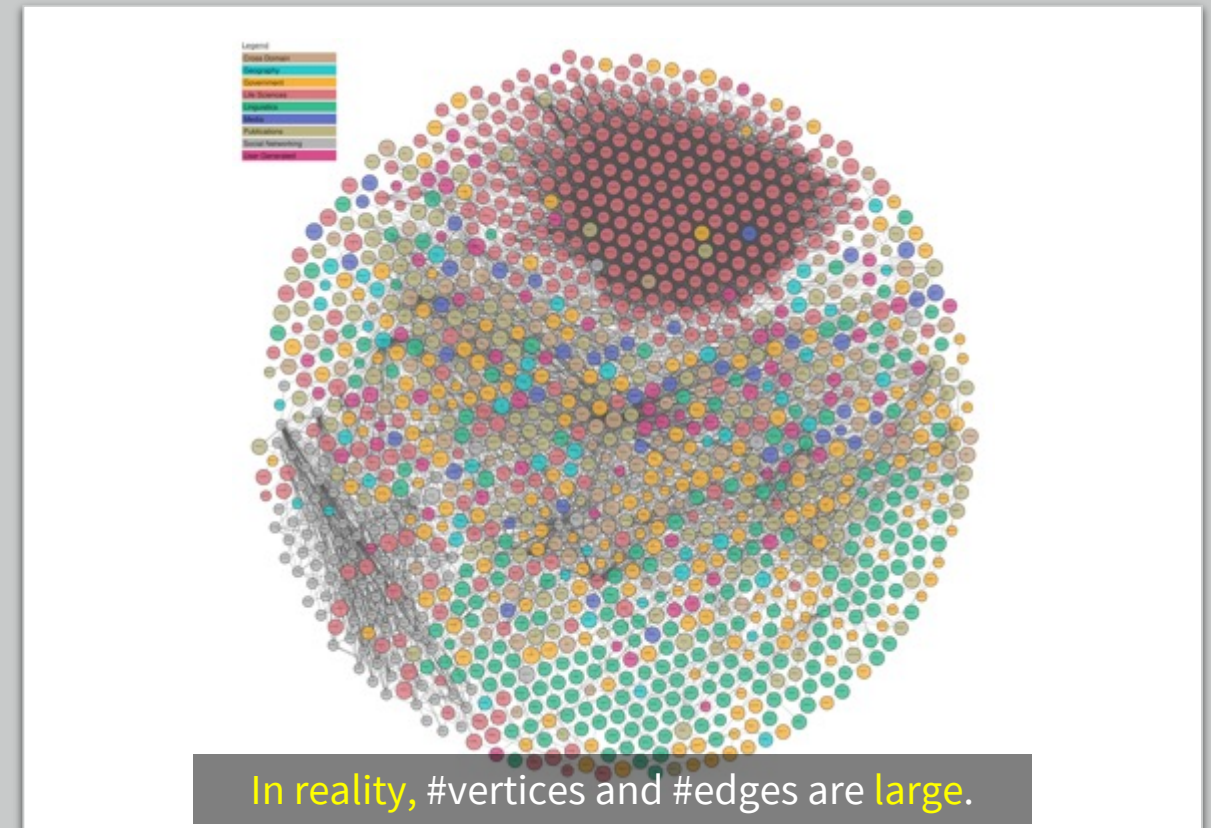
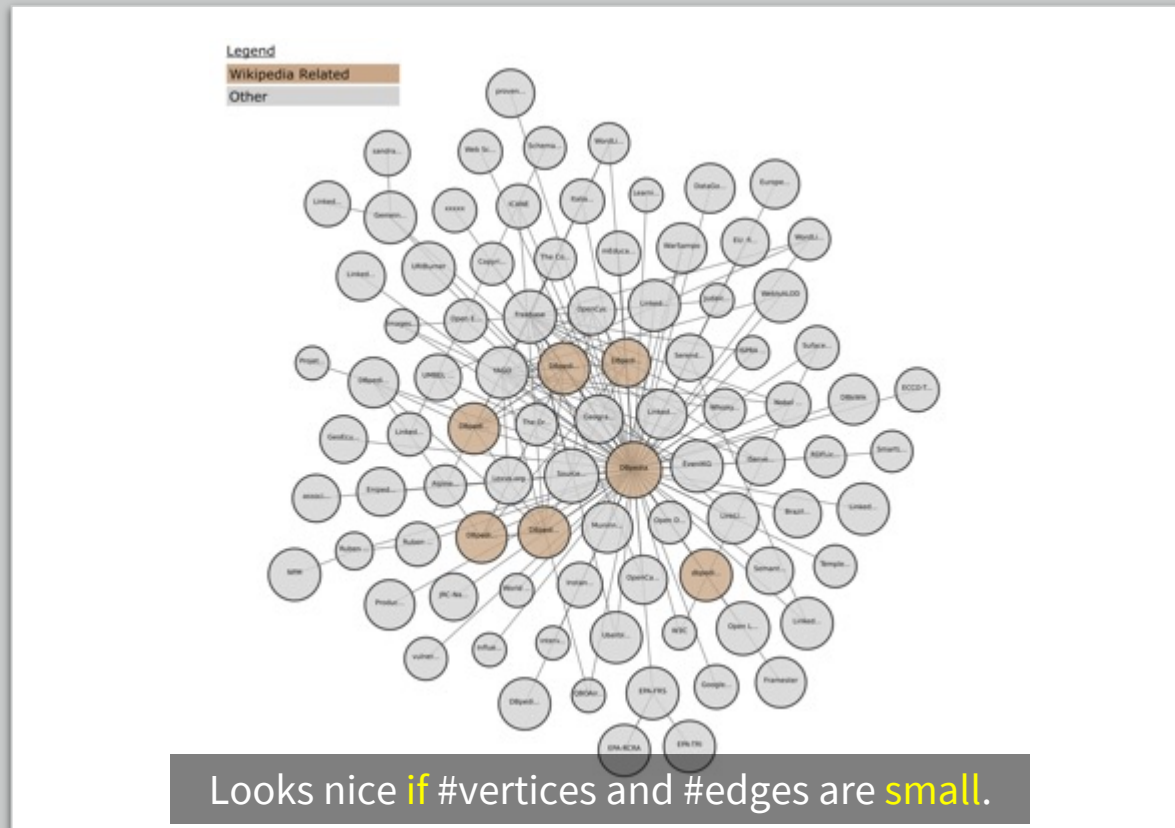
History [edit]

In order to advance into Owari Province, the military governor of Suruga Province, Imagawa Uda-Naka, built Yamagino-maru, a precursor castle at Nagoya, between 1527 and 1528 during the Tōei era for his son, Imagawa Ujōjima. It was located near the site of the later Niromaru residence. Oda Nobuhito seized it from Imagawa Ujōjima in March 1530 (Jyūroku 5), residing there and changing the name to Nagoya Castle. His son, Oda Nobunaga, was reportedly born there in 1534 (Tenroku 3), although this is subject to debate. After he defeated Oda Nobuomaru at Kiyosu Castle in April 1555 (Kei 1), he established his residence there. Around 1562 (Tenbō 10), the castle at Nagoya was abandoned.

Exploration process is go-and-back the links.

Graph Visualization as an Exploration Tool

Graph visualization is mainly done in 2D space.



Our approach for Graph Exploration

- Drawbacks of existing approaches
 - Browsing approach
 - Neighboring vertices can be only accessible.
 - Visualization approach
 - Limitation of 2D space for visualization
 - When the size of a graph is large, visualization may not be recognizable.
- Our approach (FPX-G) utilizes 3D space.
 - Motivated to realize an approach in-between existing approaches
 - Visualizing a subgraph in 3D space
 - Vertices in some hops away can be accessible.
 - VR (virtual reality) technology
 - Users can access vertices in a walk-through manner.

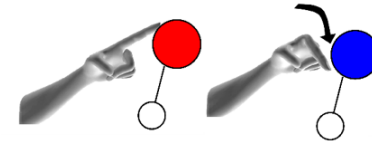
Related Work: Graph + VR

- Graph visualization with gesture-based interaction [24]

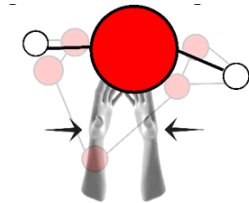
- Bird-eye-view based visualization
- Hand gesture-based interactions: shift, highlight, rotate, and group



(a) Move a node: Use five fingers to grab the node, and can move it until release.



(c) Highlight a node: First put up the index finger, target it on the node and put it down and up back.



(g) Group: Put two palms face to face, with a little distance, then clap quickly.

Part of Fig.1 of [24]

- Dynamic graph analysis [26]

- Bird-eye-view based visualization
- Analysis: topological analysis
- Interactions
 - Changing analytical views between overview and detailed
 - Changing analytical views in time axis

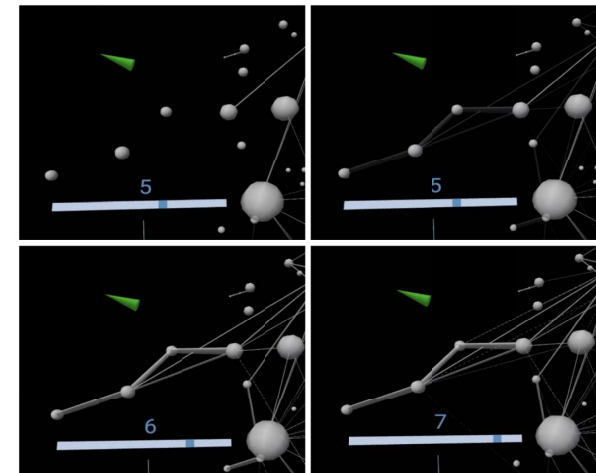


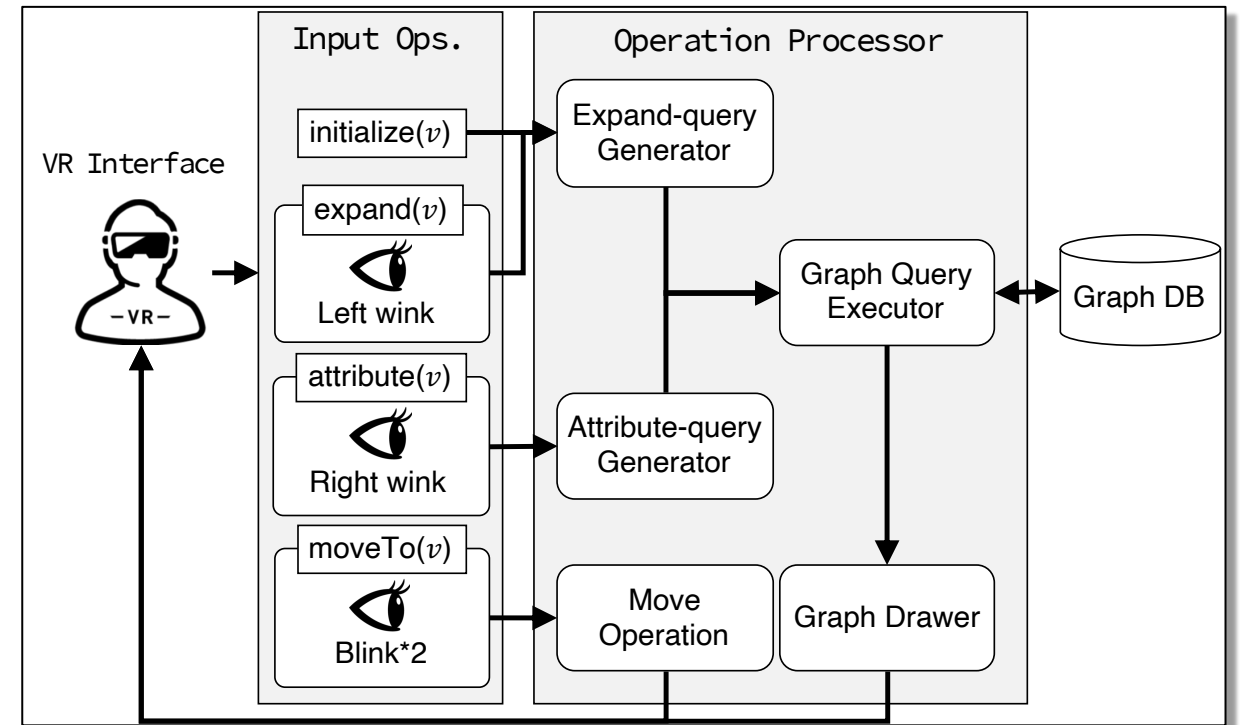
Fig.3 of [26]

[24] Y. Huang, et al., “A Gesture System for Graph Visualization in Virtual Reality Environments,” in PacificVis17, 2017, pp. 41–45.

[26] J. Sorger, et al., “Immersive Analytics of Large Dynamic Networks via Overview and Detail Navigation,” in AIVR19, 2019, pp. 144–151.

FPX-G: our approach

- VR interface for graph exploration
 - Related works (such as [24] and [26]) focused on graph visualization and not on graph exploration.
- Graph database-based data access
 - To realize general interface
 - Two basic operations for graph
 - Expand and Attribute
- Eye-tracking based operations
- Graph drawing: Physical model
 - Spring model and electric force by the Coulomb's law



Operation/Query for Graph DB

- [Op.1] Expand: load (1) neighbor vertices and (2) edges between them

$E_1^{(e)}$

```
SELECT ?u WHERE {v ?p ?u}
```

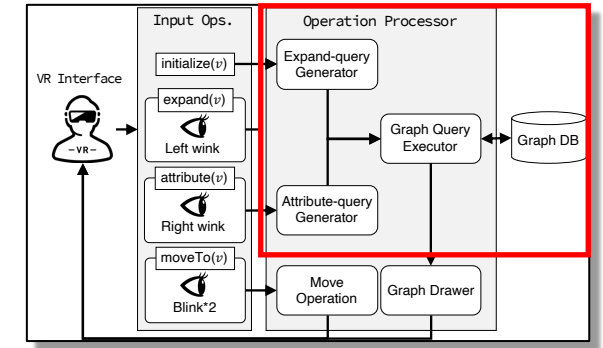
$E_2^{(e)}$

```
SELECT ?u1 ?u2
WHERE {v ?p1 ?u1; ?p2 ?u2. ?u1 ?p3 ?u2}
```

- [Op.2] Attribute: load attributes of a vertex

```
SELECT ?p ?o
WHERE {v ?p ?o. FILTER(isLiteral(?o))}
```

- Here, SPARQL Endpoint is assumed for Graph DB.
 - SPARQL Endpoint is a graph DB for RDF data.
 - Note that other queries (GraphQL and Cypher) can be used for other graph DBs.



User Interface

Operations	Controller	Eye-tracking
Vertex selection	Pointing	Gaze
Expand	Left hand Trigger	Left wink
Attribute	Right hand Trigger	Right wink
Move	Both hand Trigger	Blink*2

- Motivation for eye tracking-based operation
 - To realize hand-free operations
 - Hands should be used for more complicated operations.
 - Keyboard inputs
 - Hand gestures proposed in [24]
 - Shift, highlight, rotate, and group
- Current implementation uses HTC VIVE Pro Eye and Unity.

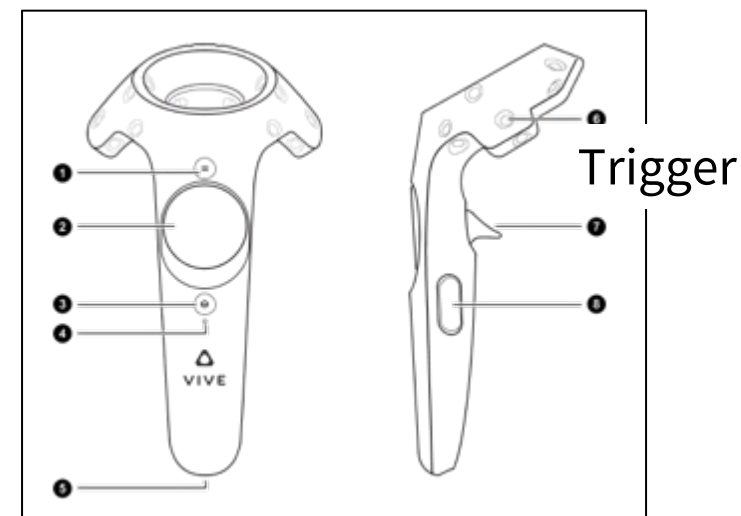
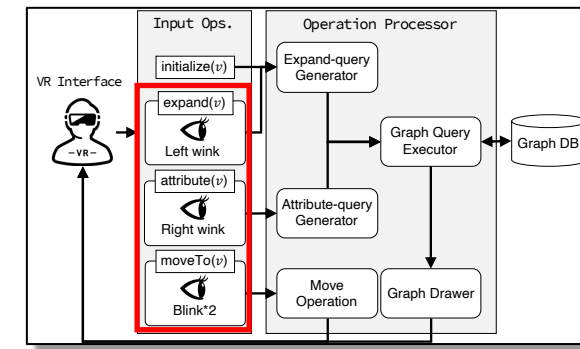


image from https://www.vive.com/eu/support/vive-pro-eye/category_howto/about-the-controllers---2018.html

System view (Overview and Gaze)

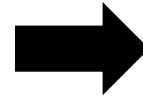


Attribute and Expand Operations

Attribute Operation



Right wink



Expand Operation



Left wink



Simulation-based Evaluation

- Question: *How fast users can reach a desired vertex from a user-specified starting vertex through graph exploration?*
 - Users are assumed to have no idea about the desired vertex until they reach to it.
- Evaluation metrics: the number of vertices visited during an exploration from the starting vertex to the destination vertex.
 - Sum over randomly selected 1,000 starting-destination vertex pairs.
- Comparison: FPX-G and a browsing approach
- Graph data (synthetic): 200 vertices
 - Perfect m -ary tree ($m = 5$ in this experiment)
 - Watts-Strogatz graph (small-world property)
 - Short average path length, high clustering coefficient.
 - Barabasi-Albert graph (scale-free property)
 - Degree distribution follows the power law.

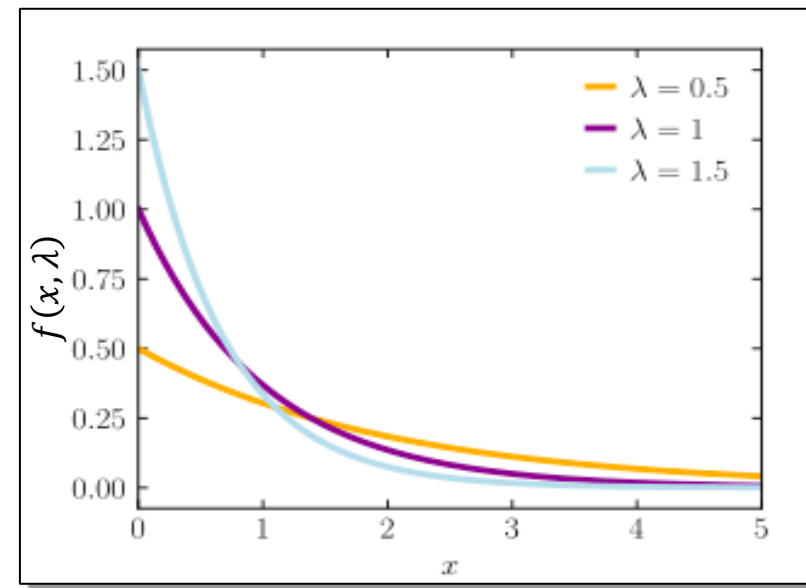
User models

- User model in the browsing approach (2D user model)
 - Random surfer model
 - Randomly access to neighbor vertices and occasionally go back to the source vertex.
 - User model in FPX-G (3D user model)
 - Basic idea: randomly access to visible vertices
 - User preference
 - Some users prefer to access near vertices
 - Some users prefer to access far vertices
- ➔ This is captured by an exponential distribution.

$$f(x, \lambda) = \begin{cases} \lambda e^{-\lambda x}, & x \geq 0 \\ 0, & x < 0 \end{cases}$$

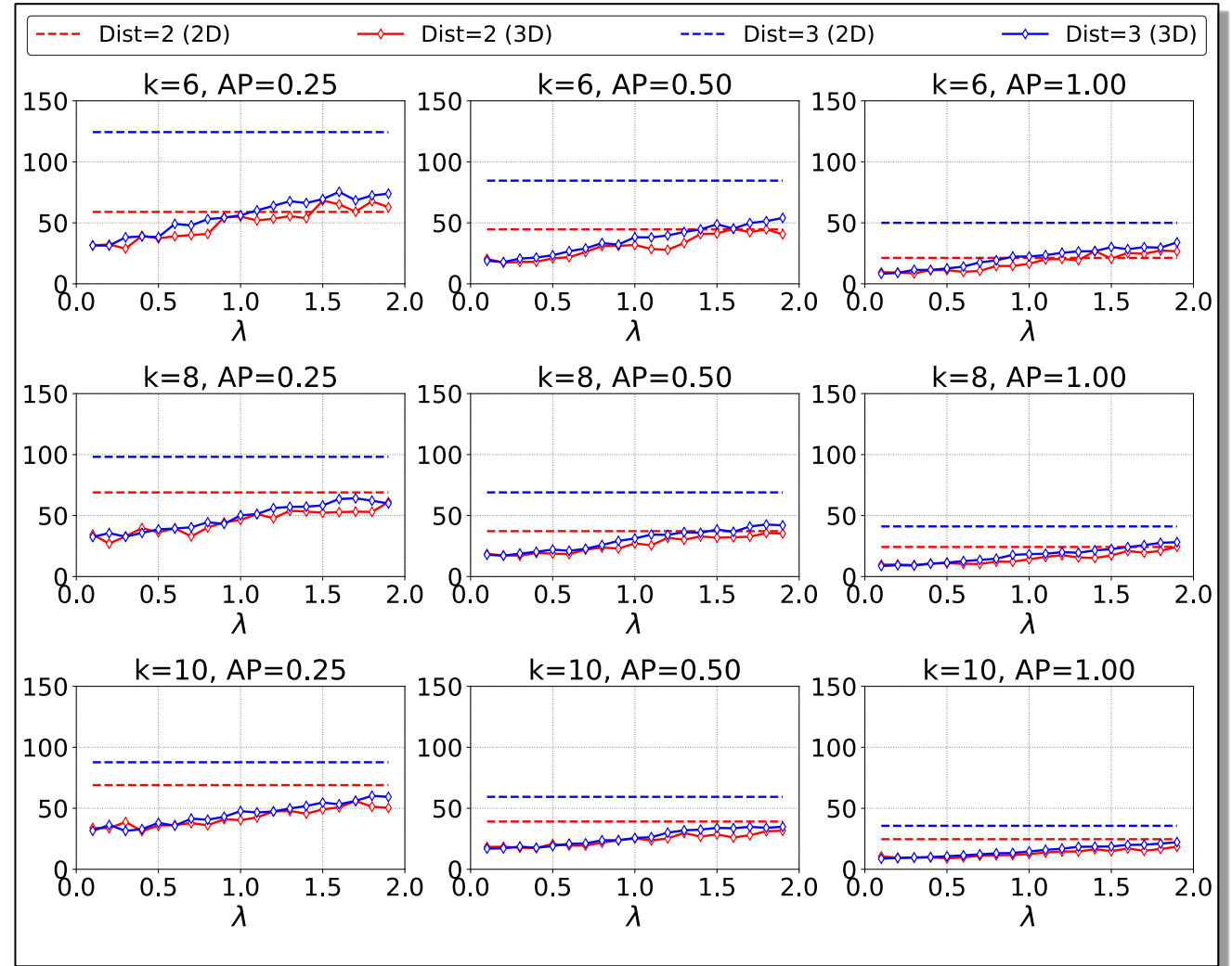
where $\lambda > 0$ is a parameter for the user preference for distance.

- Higher λ , the more users prefer closer vertices.



Result on Watts-Strogatz graph

- The larger distance from source to destination (large Dist), the larger gap between 2D and 3D user models.
- Users prefer further distance (small λ) can reach to the destination vertex faster.
- In denser graph (large k), the 3D user model is superior to the 2D user model.



- Dist means the distance from source to destination vertices.
- k is the mean degree parameter of Watts-Strogatz model.
- AP means awareness prob. that users notice the destination.

Conclusion

- Summary

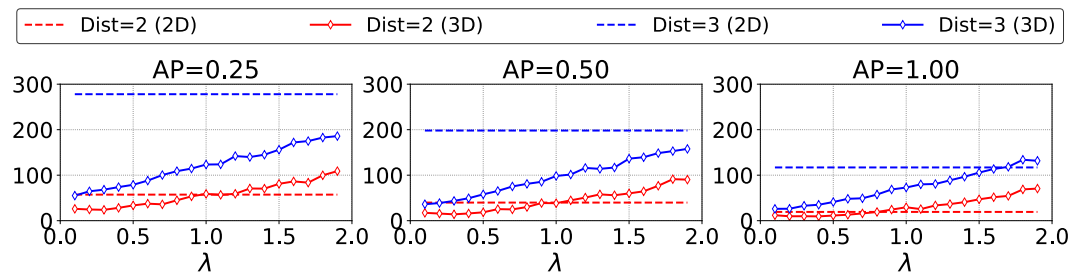
- FPX-G: Graph exploration using VR technology
 - Users can see vertices in several hops away from the visited vertices.
 - Demo video: <https://vimeo.com/512228512>
- Simulation-based evaluation shows its superiority to the traditional approach (i.e., browsing approach).

- Future direction

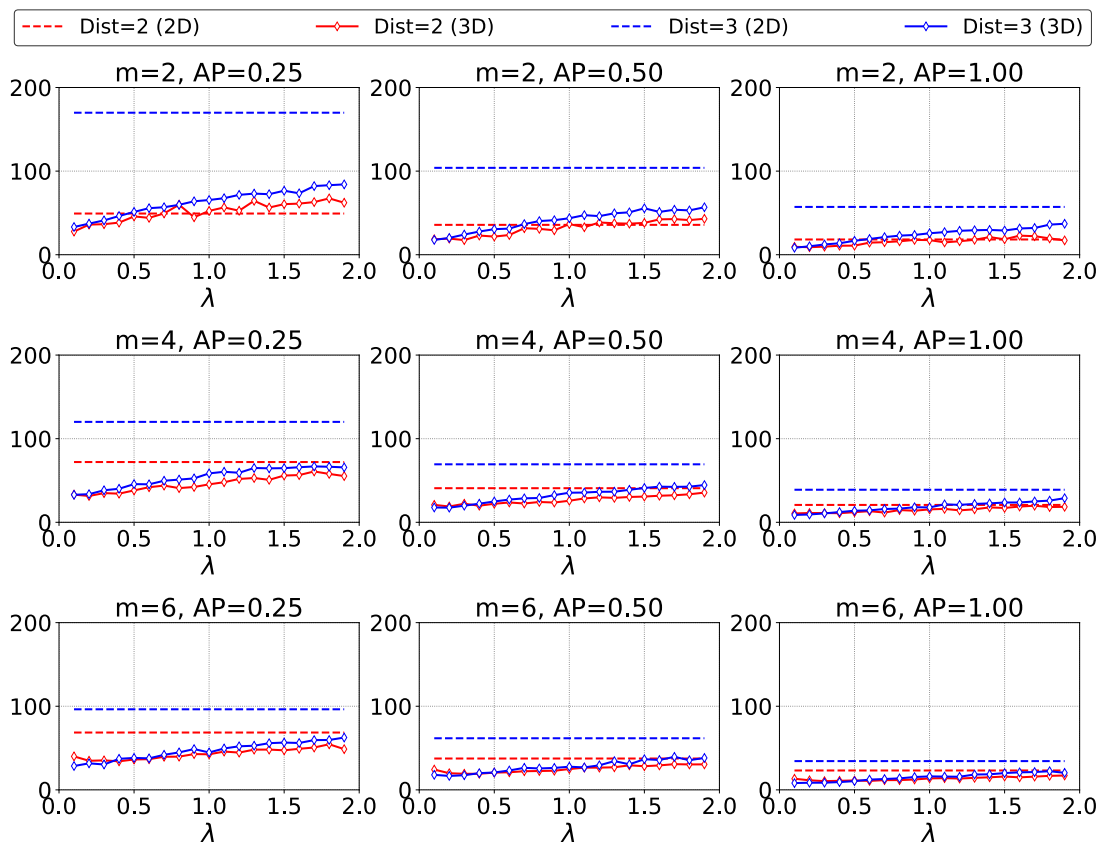
- User study (maybe after the current situation of COVID-19)
- Improvements
 - Graph drawing in VR space
 - Interactive exploration: filtering operation during exploration
 - Other input methods for more advanced operations

Results

Perfect 5-ary tree



Barabasi-Albert graph



Watts-Strogatz graph

