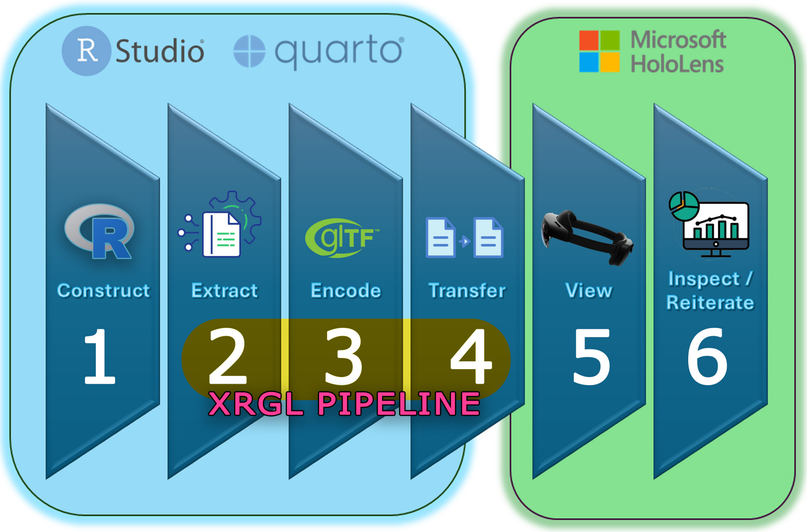
From Notebooks to Immersion:
Integrating Augmented Reality into Data Science Workflows

PROBLEM

AR and immersive display technologies provide stereoscopic views of 3D data that support spatial perception and reasoning [1][2].

Interactive data-science notebooks are a primary environment for exploratory analysis and increasingly support interactive 3D visualization [3].

In practice, notebook-based 3D views remain monoscopic, while many immersive analytics systems require leaving established notebook workflows or adopting specialized tools.



XRGL workflow illustrating the separation between notebook-based analysis and 3D immersive inspection.

Visualizations are constructed and exported within the notebook before being viewed in augmented reality.

XRGL WORKFLOW

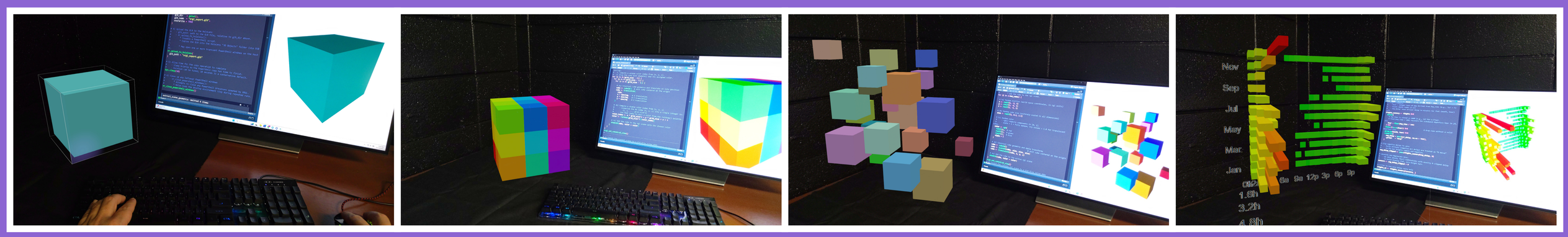
XRGL provides a notebook-native workflow for immersive inspection of 3D visualizations while preserving established notebook-based analysis and authoring practices.

Visualizations are constructed and exported for immersive inspection using a standardized 3D model representation [4].

Exported scenes are transferred to an optical see-through AR device and opened using the device's native 3D viewing application for spatial inspection [5].

The workflow supports iterative movement between desktop-based analysis and immersive AR viewing without requiring custom AR application development.

EXAMPLE NOTEBOOK-GENERATED VISUALIZATIONS



Representative case study tasks used to demonstrate XRGL across a range of 3D visualizations, including geometric primitives, structured grids, and data-driven datasets.

EVALUATION

Post-Session Questionnaire

For questions 1 – 7, please indicate how much you agree or disagree with the following statements.

(1 = Strongly Disagree, 5 = Strongly Agree)

	AVERAGE RESPONSE
1. I found the system easy to use. (1 2 3 4 5)	4.75
2. I was able to understand the 3D data better when using the immersive view. (1 2 3 4 5)	4.75
3. Switching between desktop and immersive modes felt smooth and intuitive. (1 2 3 4 5)	4.75
4. I felt comfortable using the headset during the session. (1 2 3 4 5)	4.75
5. I would consider using a tool like this in my academic or professional work. (1 2 3 4 5)	4.75
6. I did not experience physical discomfort (e.g., eye strain, dizziness). (1 2 3 4 5)	4.5
7. I was able to complete the tasks without frustration. (1 2 3 4 5)	4.25

8. What did you like most about the system?
"Switch between views", "gain more insights", "much easier to visualize multiple axes of data", "great way to gauge complex 3D"

9. What would you change or improve?
"Integrate with ggplot", "get rid of Copy & Replace", "directions of the text", "limited field of view of the Hololens"

10. Any additional comments or suggestions?
User noted they could not rotate the model as easily as RGL view
"So cool", "gained a fast understanding", "really liked it"

An exploratory evaluation was conducted to assess the feasibility and usability of the XRGL workflow.

Participants completed representative notebook-based visualization tasks with immersive AR inspection.

Participants reported smooth transitions between desktop-based analysis and immersive AR viewing.

Several participants noted that immersive inspection supported perception of spatial structure.

SIGNIFICANCE

Demonstrates the feasibility of integrating immersive AR inspection into established data-science notebook workflows.

Preserves familiar tools and practices by separating 2D analysis from 3D immersive inspection.

Suggests a lightweight integration path for immersive analytics that does not require custom AR application development.

REFERENCES

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