APG Oral Exam Key Points

The professor mentioned that the exam will consist of 5 questions:

- 1 question on Coursework 1
- 1 question on Coursework 2
- 3 questions on course concepts

Each question has a 3-minute time limit, and the professor may help if you get stuck or ask you to move on and return to a question later.

Key Areas to Prepare

1. Mesh Data Structures (Week 1)

- **Halfedge data structure** - key components and advantages
- Understanding of **Euler characteristics** formula: V - E + F = 2(1-g)
- Efficient traversal methods (one-ring traversal)
- Dual graph/dual polyhedron concepts

2. Registration and ICP (Week 2)

- **ICP (Iterative Closest Point) algorithm** - core steps and variations
- Point-to-point vs. point-to-plane approaches
- Rotation computation using SVD
- Handling of outliers and partial overlaps

3. Differential Geometry (Weeks 3-4)

- **Curves**: arc-length parameterization, Frenet frame, curvature and torsion
- **Surfaces**: tangent plane, first and second fundamental forms
- **Curvature**: principal curvatures, Gaussian curvature, mean curvature
- Gauss-Bonnet theorem and its significance

4. Implicit/Explicit Representations (Week 5)

- Conversion between representations (marching cubes, fast marching)
- Signed distance fields
- Boolean operations on implicit surfaces
- Advantages/disadvantages of each representation

5. Laplace-Beltrami Operator (Week 6)

- Discrete formulations (uniform vs. cotangent)
- Applications in smoothing, parameterization, spectral analysis
- Four key equation types involving Laplace-Beltrami:
    1. Harmonic equation ($\Delta f = 0$)

2. Poisson equation ($\Delta f = g$)
3. Eigenvalue problem ($\Delta \phi = \lambda \phi$)
4. Heat equation ($\partial f / \partial t = \Delta f$)

6. Mesh Smoothing (Week 6)

- **Explicit vs. implicit smoothing** approaches
- Volume shrinkage problem and solutions
- Connection to mean curvature flow ($\Delta x = -2Hn$)

7. Spectral Analysis (Week 7)

- Eigenvectors of Laplace-Beltrami and their geometric meaning
- Low vs. high-frequency components
- Applications in mesh compression and shape analysis

8. Parameterization (Week 7-8)

- **Tutte embedding** and its properties
- Conformal (angle-preserving) methods
- Boundary handling techniques
- Distortion metrics and trade-offs

9. Remeshing (Week 8)

- Delaunay triangulation and its properties
- Centroidal Voronoi diagrams (CVD)
- Surface-based vs. parameterization-based approaches
- Feature preservation techniques

10. Mesh Deformation (Week 9)

- Laplacian-based deformation
- Cage-based deformation
- Detail preservation techniques

Potential Exam Questions

Based on the materials and the professor's hints, here are some potential questions that might come up in your oral exam:

Coursework 1 Questions

1. "Explain how you implemented the halfedge data structure in your coursework. What were the key components and how did they enable efficient traversal?"
2. "In your implementation of ICP, how did you handle outliers and what strategies did you use to improve convergence?"

3. "Explain the difference between point-to-point and point-to-plane ICP. Which one did you find more effective and why?"

Coursework 2 Questions

1. "How did you estimate curvature in your coursework? Compare the uniform Laplacian and cotangent Laplacian approaches."
2. "Explain the spectral reconstruction you implemented. How did the number of eigenvectors affect the quality of reconstruction?"
3. "Compare explicit and implicit Laplacian smoothing from your implementation. When would you prefer one over the other?"

Concept Questions

1. "Explain the four key equation types involving the Laplace-Beltrami operator and give an application for each."
2. "What is the Gauss-Bonnet theorem and why is it significant in geometry processing?"
3. "Compare implicit and explicit surface representations. What are the advantages and disadvantages of each?"
4. "Explain the Marching Cubes algorithm. How does it convert from implicit to explicit representation?"
5. "What is Tutte embedding and why is it guaranteed to produce a valid parameterization?"
6. "How does the Fast Marching method work for computing distance fields?"
7. "Explain how mesh deformation can be formulated as a Laplacian system."
8. "What is the relationship between the mean curvature vector and the Laplace-Beltrami operator applied to vertex positions?"

Preparation Tips

1. Focus on **understanding core concepts** rather than memorizing formulas. The professor mentioned that questions won't require you to recite formulas.
2. Practice **explaining algorithms** concisely within the 3-minute timeframe. Structure your answers with:
    - A clear definition/main idea
    - Key steps or components
    - Advantages/limitations
    - Applications or examples
3. Make **connections between topics**, as the professor highlighted that making these connections is what makes the course interesting.
4. Be prepared to **think on the spot** for application-based questions where you need to apply course concepts to a new problem.
5. Review your **coursework implementations** to understand the main algorithms and decisions you made, without memorizing code details.

Good luck with your exam!