口语考试题目预测

L.C.

基于第一周的内容(数字图像基础)

重点:

1. **Sensors：比较CCD和CMOS传感器的主要区别和各自优缺点。**
   Compare the main differences, advantages and disadvantages between CCD and CMOS sensors.

CCD vs CMOS: "The main differences are in their **architecture** and **readout process**. For **CCD**, signals are **transferred pixel by pixel** through a common output circuit, providing **low noise** but **slower readout**. For **CMOS**, each pixel has its own **amplifier**, enabling **parallel readout** and **higher speed**. CCD advantages: **better image quality**, **lower noise**, **higher dynamic range**. CMOS advantages: **lower power consumption**, **faster frame rates**, **lower cost**, **on-chip integration**."

对比图:

```
| 特性          | CCD           | CMOS          |
|-------------|--------------|--------------|
| 功耗          | 高             | 低             |
| 噪声          | 低             | 较高           |
| 帧率          | 低             | 高             |
| 制造复杂度     | 复杂           | 简单           |
```

2. **解释图像数字化过程中的采样(Sampling)和量化(Quantization)步骤，并说明它们各自的作用。**
   Explain the sampling and quantization steps in image digitization process and their respective roles.

Sampling and Quantization: "**Sampling** converts **continuous spatial coordinates** to **discrete pixels**. According to **Nyquist theorem**, sampling rate must be **twice the highest frequency** to avoid **aliasing**. **Quantization** converts **continuous intensity values** to **discrete levels**, like using **8 bits** for **256 gray levels**. Main effects: sampling causes **spatial resolution loss**, quantization causes **intensity resolution loss**."

过程	是否可逆	示例问题
采样	可逆	混叠（锯齿边缘）
量化	不可逆	伪轮廓

3. *什么是暗电流(Dark Current)？它如何影响图像质量？如何减少暗电流的影响？*
   What is Dark Current? How does it affect image quality? How can we reduce its impact?

Dark Current: "**Dark current** is **thermal noise** generated even without light. It causes **random brightness variations** and **reduces image quality**. Solutions include: **sensor cooling**, **dark frame subtraction**, **shorter exposure time**. The effect is more significant in **long exposures** and **high temperature** conditions."

4. *什么是几何分辨率(Geometric Resolution)和辐射分辨率(Radiometric Resolution)？请举例说明它们的区别。*
   What are Geometric Resolution and Radiometric Resolution? Please explain their differences with examples.

Resolution Types: "**Geometric resolution** refers to **spatial details**, measured in **pixels per inch** or total pixel count like **1920×1080**. **Radiometric resolution** refers to **intensity levels**, like **8-bit** (256 levels) or **12-bit** (4096 levels). Example: a **low geometric resolution** image looks **pixelated**, while **low radiometric resolution** shows **false contours**."

非重点:

1. Explain the concept of HDR imaging and how it relates to radiometric resolution. 解释HDR成像的概念以及它与辐射分辨率的关系。

HDR Imaging: "**HDR** captures **wider dynamic range** than standard imaging. Related to **radiometric resolution** as it needs **more bits per pixel**. Usually achieved by **multiple exposures** and **tone mapping**. Helps capture details in both **bright** and **dark** regions."

2. 详细解释数字相机中的Bayer Pattern是什么，它是如何工作的?
   Explain in detail what is the Bayer Pattern in digital cameras and how does it work?

Bayer Pattern: "**Color filter array** with **RGGB pattern**, uses **interpolation** to reconstruct full color."

3. 描述成像过程中的透视投影(Perspective Projection)模型，并写出其基本方程。
   Describe the perspective projection model in imaging process and write down its basic equations.

Perspective Projection: "Maps **3D world** to **2D image plane** using **pinhole camera model**, equation: **x'=f*X/Z**."

4. 解释数字图像中像素的概念，以及为什么我们需要为每个像素使用多个位(bits)来存储信息。
   Explain the concept of pixels in digital images and why we need multiple bits to store information for each pixel.

Pixels and Bits: "**Pixels** are **smallest image units**, need **multiple bits** for **intensity resolution**."

5. 在图像处理中，我们通常使用什么样的数据类型来表示图像？为什么?
   What data types do we typically use to represent images in image processing? Why?

Data Types: "Usually use **unsigned char** for **8-bit**, **short** for **16-bit**, **float** for **processing**."

6. 比较单通道图像和多通道图像的区别。
   Compare the differences between single-channel and multi-channel images.

   Single vs Multi-channel: "**Single channel** for **grayscale**, **multi-channel** for **color** (like **RGB**)."

基于第二周的内容(图像分割)

重点:

1. **解释什么是Thresholding, ROC(Receiver Operating Characteristic)曲线，以及如何使用它来评估分割算法的性能。**
   Explain what is the Thresholding, ROC (Receiver Operating Characteristic) curve and how it is used to evaluate segmentation algorithm performance.

Thresholding and ROC: "**Thresholding** converts image to **binary** by comparing with **threshold T**. **ROC curve** plots **True Positive Rate** vs **False Positive Rate** at different thresholds. **Area Under Curve (AUC)** measures performance - **closer to 1 is better**. Used for **evaluating segmentation quality** and **choosing optimal threshold**."

- **完美分类**：ROC曲线为左上角点（0,1）。
- **随机分类**：ROC曲线为对角线。

```
for x in 0 to width:
    for y in 0 to height:
        if I(x,y) >= T:
            B(x,y) = 1  # 前景
        else:
            B(x,y) = 0  # 背景
```

2. **详细描述连通组件标记算法(Connected Components Labeling)的工作原理，4-连通和8-连通有什么区别?**
   Describe in detail how Connected Components Labeling algorithm works. What's the difference between 4-connectivity and 8-connectivity?

"Algorithm **groups connected pixels** sharing same properties. Key difference: **4-connectivity** considers only **horizontal and vertical neighbors** (4 pixels), while **8-connectivity** includes **diagonal neighbors** (8 pixels). Process uses **recursive labeling** or **sequential scanning**. Applications in **object counting** and **blob detection**."

深度优先搜索

3. **K-means聚类和Mean Shift算法在图像分割中有什么区别？各有什么优缺点?**
   What are the differences between K-means clustering and Mean Shift algorithm in image segmentation? What are their respective advantages and disadvantages?

"**K-means**: **iteratively assigns** pixels to **K clusters** based on **intensity/color similarity**. **Advantages**: simple, fast. **Disadvantages**: needs **predefined K**, sensitive to **initialization**.

Mean Shift: finds **density modes** in feature space, **no parameter K needed**. **Advantages**: **automatic cluster number**, **robust**. **Disadvantages**: **computationally expensive**, sensitive to **bandwidth parameter**."

4. *解释区域生长算法(Region Growing)的基本原理和步骤，并讨论它的优缺点。*
   Explain the basic principles and steps of Region Growing algorithm, and discuss its advantages and disadvantages.

Region Growing: "Starts from **seed points**, **iteratively adds** similar neighboring pixels. **Criteria**: **intensity similarity**, **texture**, etc. **Advantages**: intuitive, considers **spatial information**. **Disadvantages**: sensitive to **seed selection**, **noise**."

广度优先搜索

5. *解释图像分割中的TPR(True Positive Rate)和FPR(False Positive Rate)是什么，如何计算它们?*
   Explain what are TPR (True Positive Rate) and FPR (False Positive Rate) in image segmentation and how to calculate them?

TPR and FPR: "**TPR** = **TP/(TP+FN)**, measures **sensitivity**. **FPR** = **FP/(FP+TN)**, measures **false alarm rate**. Used in **ROC analysis** for **performance evaluation**."

6. *Explain how to evaluate segmentation quality when ground truth is not available. 解释在没有ground truth的情况下如何评估分割质量。*

Without Ground Truth: "Evaluate using **consistency measures**: **compactness**, **separation**, **region uniformity**. Also consider **application-specific criteria** and **human visual assessment**."

非重点:

1. 描述分水岭分割算法(Watershed Segmentation)的原理，并解释它为什么容易产生过分割的问题。
   Describe the principle of Watershed Segmentation algorithm and explain why it tends to produce over-segmentation.

Watershed: "Treats image as **topographic surface**, finds **catchment basins**. **Over-segmentation** due to **local minima**."

2. 在图像分割中，什么是过分割(Over-segmentation)和欠分割(Under-segmentation)？如何平衡这两种情况？
   What are over-segmentation and under-segmentation in image segmentation? How to balance between these two situations?

Over/Under-segmentation: "Balance between **too many regions** (over) and **too few regions** (under) using **merge/split criteria**."

3. 描述Mean Shift算法中核函数(Kernel Function)的作用，以及如何选择合适的带宽参数(Bandwidth Parameter)。
   Describe the role of Kernel Function in Mean Shift algorithm and how to choose appropriate Bandwidth Parameter.

Mean Shift Kernel: "**Kernel function** determines **weight** of neighbors, **bandwidth** controls **scale of analysis**."

4. 什么是归一化切割(Normalized Cuts)？它与最小切割(Minimum Cuts)相比有什么优势？
   What is Normalized Cuts? What advantages does it have compared to Minimum Cuts?

Normalized Cuts: "Considers both **within-cluster similarity** and **between-cluster dissimilarity**. **Better balanced** than minimum cuts."

5. *描述基于图的分割方法(Graph-based Segmentation)的基本原理，以及它与其他分割方法的主要区别。*
   Describe the basic principles of Graph-based Segmentation and its main differences from other segmentation methods.

Graph-based Segmentation: "Treats image as **graph**: pixels are **nodes**, similarities are **edges**. Uses **graph cuts** to minimize **energy function**. Different from traditional methods by considering **global information**."

基于第三周的内容(图像变换)

重点:

1. **解释线性灰度变换中α和β参数的作用，它们如何影响图像的视觉效果？**
   Explain the roles of parameters α and β in linear gray-level transformation, how do they affect the visual appearance of images?

Linear Grayscale Transform Parameters: "In formula **f(x) = αx + β**, **α controls contrast**: **α>1** increases contrast, **α<1** decreases contrast. **β controls brightness**: **positive β** makes image brighter, **negative β** makes darker. Must ensure output remains in **valid range [0,255]**. Important to consider **histogram stretching** effects."

2. **详细描述gamma校正的原理和目的。为什么我们需要在图像处理中使用gamma校正？**
   Describe in detail the principle and purpose of gamma correction. Why do we need gamma correction in image processing?

公式：$f(x) = Ax^{\gamma}$，其中 $A = 255^{1-\gamma}$ 确保输出在 [0,255]。

Gamma Correction: "Formula is **f(x) = x^γ**. Used to **compensate for display device nonlinearity** and **human perception**. When **γ<1**, enhances **dark regions**. When **γ>1**, enhances **bright regions**. Typical values: **γ=2.2** for **CRT displays**, **γ=1/2.2** for **pre-correction**. Essential for **consistent appearance** across devices."

3. **什么是仿射变换(Affine Transformation)？请写出其数学表达式并解释各个参数的含义。**
   What is Affine Transformation? Please write down its mathematical expression and explain the meaning of each parameter.

Affine Transformation: "**Mathematical form**:

```
Copy[x'] = [a b] [x] + [tx]
[y'] = [c d] [y] + [ty]
```

- **齐次坐标表示**:
  $$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} a & b & t_x \\ c & d & t_y \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$
- **具体变换**：平移(Translation)缩放(Scaling)旋转(Rotation)错切(Shear)
  - **平移**：t_x, t_y 控制位移。
  - **缩放**：矩阵对角线元素控制缩放比例（如 $a = 2, d = 2$ 放大两倍）。
  - **旋转**：θ 为旋转角度，矩阵形式为 $\cos\theta, \sin\theta, -\sin\theta, \cos\theta$。
  - **剪切**：非对角线元素控制变形方向（如 $b = 0.5$ 水平剪切）。

Preserves **parallel lines**. Combines **rotation** (parameters **a,b,c,d**), **scaling**, **translation** (parameters **tx,ty**), and **shear**. Can represent with **3×3 homogeneous matrix**."

4. *解释直方图均衡化(Histogram Equalization)的数学原理，并描述其实现步骤。*
   Explain the mathematical principle of histogram equalization and describe its implementation steps.

Histogram Equalization: "**Goal**: make histogram **uniform**. Steps: compute **cumulative histogram**, **normalize** to [0,255], use as **lookup table**. Improves **global contrast**, but may **amplify noise**."

1. 计算原始图像的灰度直方图 $h(v)$。
2. 计算累积分布函数（CDF）：$cdf(v) = \sum_{k=0}^{v} h(k)$。
3. 映射函数：$h_{\text{eq}}(v) = \text{round}\left(\frac{cdf(v) - cdf_{\min}}{MN - cdf_{\min}} \times (L-1)\right)$，其中 $L = 256$。

4. *解释图像融合(Image Morphing)的基本原理和步骤。*
   Explain the basic principles and steps of image morphing.

Image Morphing: "Combines **shape interpolation** and **cross-dissolve**. Requires **feature correspondence**, **warp generation**, **blending**. Used for **special effects**, **animations**."

非重点:

1. 比较最近邻插值、双线性插值和双三次插值的区别和各自的优缺点。
   Compare the differences between nearest neighbor, bilinear and bicubic interpolation, and their respective advantages and disadvantages.

Interpolation Methods: "**Nearest neighbor**: fastest but **blocky**. **Bilinear**: uses **4 neighbors**, better quality. **Bicubic**: uses **16 neighbors**, best quality but **slowest**."

Bilinear: $I(x', y') = \sum_{i=0}^{1} \sum_{j=0}^{1} I(x_i, y_j) \cdot (1 - |x' - x_i|) \cdot (1 - |y' - y_j|)$

2. 解释为什么在进行几何变换时我们通常使用逆变换(Inverse Transformation)而不是正向变换?
   Explain why we usually use inverse transformation rather than forward transformation when performing geometric transformations?

   Inverse Transform: "Use **inverse mapping** to avoid **holes** and **overlaps**. For each output pixel, find corresponding input position. More **computationally efficient** than forward mapping."

3. Describe the relationship between forward and inverse warping, and their respective advantages. 描述正向和反向变形之间的关系及其各自的优势。

Forward vs Inverse Warping: "**Forward**: maps source to target, has **hole problems**. **Inverse**: maps target to source, **ensures coverage**."

4. 在齐次坐标系统中，为什么要使用3×3矩阵来表示二维变换？有什么优势?
   Why do we use 3×3 matrices to represent 2D transformations in homogeneous coordinate system? What are the advantages?

Homogeneous Coordinates: "**3×3 matrices** allow **unified representation** of all transformations including **translation**."

基于第四周的内容(图像滤波)

重点:

1. **详细解释高斯滤波器的数学公式，实现高斯核有什么需要注意的？为什么它是可分离的(Separable)?**
   Explain in detail the mathematical formulation of Gaussian filter, what are the things to be kept in mind to implement Gaussian kernel? Why is it separable (Separable)?

Gaussian Filter and Separability: "**Gaussian filter** formula: $G(x,y) = (1/2\pi\sigma^2)\exp(-(x^2+y^2)/2\sigma^2)$. Key implementation points:

- **Kernel size** should be **~3σ** for sufficient accuracy
- Need to **normalize kernel** to sum to 1
- **σ controls smoothing** degree **Separable** because 2D Gaussian = **product** of two 1D Gaussians: $G(x,y) = G(x)G(y)$. This reduces complexity from **$O(n^2)$** to **$O(2n)$**."

2. **描述空间域滤波和频率域滤波的区别。使用卷积定理(Convolution Theorem)解释它们的关系。**
   Describe the differences between spatial domain filtering and frequency domain filtering. Explain their relationship using the Convolution Theorem.

Spatial vs Frequency Domain: "**Spatial domain**: direct **convolution** with kernel. **Frequency domain**: multiply with **filter's Fourier transform**. **核心**：时域卷积等价于频域乘积。
$\mathcal{F}\{f * g\} = \mathcal{F}\{f\} \cdot \mathcal{F}\{g\}$.

离散傅里叶变换（DFT）：

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \cdot e^{-j2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)}$$

Advantages: frequency domain more efficient for **large kernels**, spatial domain better for **small kernels**."

3. **解释线性滤波，给出数学公式和常见线性滤波器的区别和各自的特点。**

Explain linear filtering, giving mathematical formulae and the differences between common linear filters and their respective characteristics.

Linear Filtering: "**Mathematical form**: g(x,y) = ∑∑h(i,j)f(x-i,y-j) Common filters:

- **Mean filter**: uniform weights, strong smoothing
- **Gaussian**: weighted average, preserves edges better
- **Sobel**: directional derivatives, edge detection Properties: **superposition**, **shift invariance**."
    - **均值滤波器（Mean Filter）**：
        - **核**：所有元素权重相等，例如3×3均值核：
          $$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}$$
        - **效果**：平滑图像，抑制高频噪声，但可能导致边缘模糊。
    - **高斯滤波器（Gaussian Filter）**：
        - **核设计**：权重由高斯函数生成，距离中心越远权重越小。
          $G(x,y) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right)$
        - **特点**：可分离（二维高斯核可分解为两个一维核），计算高效。
        - **应用**：平滑图像的同时保留边缘（因权重衰减）。
    - **锐化滤波器（Sharpening Filter）**：
        - **原理**：增强高频分量（边缘）。
        - **常见核**：拉普拉斯核（突出二阶导数）：
          $$\begin{bmatrix}0 & -1 & 0\\ -1 & 4 & -1\\ 0 & -1 & 0\end{bmatrix}$$
        - **公式**：$I' = I + \alpha \cdot (K * I)$，其中 α 控制锐化强度。

  平滑（低通）用于去噪，锐化（高通）用于增强边缘。

4. *解释拉普拉斯高斯算子(LoG)，高斯导数等数学公式。*

Explain mathematical formulas like Laplace Gaussian operator, Gaussian derivative etc.

LoG and Derivatives: "**LoG**: $\nabla^2 G = (x^2+y^2-2\sigma^2)/\sigma^4 \cdot \exp(-(x^2+y^2)/2\sigma^2)$ **First derivative**: $\partial G/\partial x = -x/\sigma^2 \cdot G(x,y)$ Used for **edge detection**, **blob detection**."

5. *什么是幅度谱(Magnitude Spectrum)和相位谱(Phase Spectrum)？它们各自包含了图像的什么信息？*
   What are Magnitude Spectrum and Phase Spectrum? What information about the image do they contain respectively?

Magnitude/Phase Spectra: "**Magnitude**: |F(u,v)| shows **frequency components' strength Phase**: arg(F(u,v)) contains **structural information Magnitude** affects **energy distribution**, **phase** crucial for **feature locations**."

6. *详细描述卷积操作的数学原理和实现步骤。如何处理图像边界？*
   Describe in detail the mathematical principles and implementation steps of convolution operation. How to handle image boundaries?

   Convolution Implementation: "Steps: **kernel flipping**, **sliding window multiplication**, **summation**

   - **相关（Correlation）**：
     - **公式**: $I'(x,y) = \sum_{i=-a}^{a} \sum_{j=-b}^{b} K(i,j) \cdot I(x+i,y+j)$
     - **特点**：核直接与图像区域逐点相乘后求和，结果可能包含旋转。
   - **卷积（Convolution）**：
     - **公式**: $I'(x,y) = \sum_{i=-a}^{a} \sum_{j=-b}^{b} K(i,j) \cdot I(x-i,y-j)$
     - **特点**：核旋转180度后执行相关操作。
     - **意义**：卷积定理表明，时域卷积等价于频域乘积。

非重点：

1. 详细解释不同类型的频域滤波器（低通、高通、带通、带阻）的特点和应用场景。
   Explain in detail the characteristics and application scenarios of different types of frequency domain filters (low-pass, high-pass, band-pass, band-stop).

Frequency Domain Filters: "**Low-pass**: smoothing, **high-pass**: edges, **band-pass/stop**: select frequency ranges."

2. 比较均值滤波器和高斯滤波器的区别。为什么高斯滤波器通常更受欢迎？
   Compare the differences between mean filter and Gaussian filter. Why is Gaussian filter usually more popular?

Mean vs Gaussian: "**Gaussian** preferred due to **isotropic smoothing**, **no ringing**, **separability**."

3. 解释中值滤波(Median Filter)的工作原理。它在什么情况下比线性滤波效果更好？
   Explain the working principle of median filter. In what situations does it perform better than linear filtering?

Median Filter: "**Non-linear**, sorts values in window. Better for **impulse noise**, preserves **edges**."

基于第五周的内容(边缘检测和图像金字塔)

重点：

1. **详细解释混叠(Aliasing)现象是什么，为什么会发生？如何防止混叠？**
   Explain in detail what is aliasing, why does it occur, and how to prevent it?

Aliasing: "**Aliasing** occurs when **sampling frequency** is too low compared to **signal frequency**. Manifests as **jagged edges** in images, **moiré patterns** in textures. Prevention requires:

- **Pre-filtering** with **low-pass filter** (usually **Gaussian**)
- **Sampling above Nyquist rate** (2× highest frequency)
- Using **anti-aliasing techniques** like **multisampling, Jittering, Stratified sampling**"

2. **解释高斯金字塔(Gaussian Pyramid)的构建过程。为什么在降采样前需要进行高斯模糊?**
   Explain the construction process of Gaussian Pyramid. Why do we need Gaussian blur before downsampling?

Gaussian Pyramid: "**Construction process**:

Apply **Gaussian blur** (typically σ=1)

Downsample by factor of 2

Repeat for each level **Gaussian blur needed** because:

- Prevents **aliasing** in downsampling
- Ensures **smooth transition** between levels
- Removes **high-frequency** components"

3. **详细描述Canny边缘检测器的完整步骤及每一步的目的，为什么需要使用双阈值(Double Thresholding)和滞后技术(Hysteresis)?**
   Describe the complete steps of Canny edge detector and the purpose of each step. Why do we need double thresholding and hysteresis?

Canny Edge Detection: "**Complete steps**:

1. **Gaussian smoothing** to reduce noise
2. Compute **gradients** using **Sobel**
3. **Non-maximum suppression** for thin edges
4. **Double thresholding** and **hysteresis**

Double thresholding needed because:

- **High threshold**: find **strong edges**
- **Low threshold**: find **weak edges Hysteresis** connects weak edges to strong ones if they're **connected**, reducing **false edges**"

4. *详细描述拉普拉斯金字塔(Laplacian Pyramid)的构建过程及其应用。它与高斯金字塔有什么关系?*
   Describe in detail the construction process and applications of Laplacian Pyramid. What is its relationship with Gaussian Pyramid?

Laplacian Pyramid: "**Construction**: **difference** between Gaussian level and **upsampled** next level.

构建步骤：高斯金字塔相邻层之差（保留高频细节）。

公式： $L_k = G_k - \mathrm{UpSample}(G_{k+1})$

Applications: image compression, blending **Relationship**: can **perfectly reconstruct** Gaussian pyramid"

5. *比较一阶导数（如Sobel, Prewitt）和二阶导数（如Laplacian）边缘检测算子的区别。*
   Compare the differences between first-order derivative (like Sobel, Prewitt) and second-order derivative (like Laplacian) edge detection operators.

First vs Second Derivatives: "**First-order** (Sobel, Prewitt):

- Detect **edge strength** and **direction**
- **Less sensitive** to noise
- Give **thick edges**

Second-order (Laplacian):

- Detect **zero crossings**
- **More sensitive** to noise
- Give **thin edges**"

6. 金字塔混合（Pyramid Blending）
   - **算法流程**：
     1. **构建拉普拉斯金字塔**：分别对两幅图像生成多尺度高频细节。
     2. **构建高斯金字塔**：生成混合区域的权重图（如渐变蒙版）。
     3. **逐层混合**：按权重合并对应层的拉普拉斯金字塔。
     4. **重建图像**：从混合后的拉普拉斯金字塔逆变换得到最终图像。
   - **公式**： $LS(i,j) = GR(i,j) \cdot LA(i,j) + (1 - GR(i,j)) \cdot LB(i,j)$

非重点：

1. 描述奈奎斯特采样定理(Nyquist Sampling Theorem)的内容及其在图像处理中的重要性。
   Describe the Nyquist Sampling Theorem and its importance in image processing.

Nyquist Theorem: "**Sampling frequency** must be **≥2× highest frequency** to avoid aliasing"

2. 解释非最大值抑制(Non-maximum Suppression)的目的和实现方法。
   Explain the purpose and implementation method of non-maximum suppression.

Non-maximum Suppression: "Keep only **local maxima** in gradient direction for **thin edges**"

3. 描述多分辨率分析(Multiresolution Analysis)的概念及其在图像处理中的应用。
   Describe the concept of multiresolution analysis and its applications in image processing.

   Multiresolution Analysis: "Analyze images at **multiple scales** using **pyramid structures**"
4. 解释为什么在图像缩小时需要预滤波(Pre-filtering)，而放大时不需要？
   Explain why we need pre-filtering when downsampling images but not when upsampling?

   Pre-filtering Need: "Downsampling needs pre-filter to **prevent aliasing**, upsampling doesn't risk aliasing"
5. 描述不同类型的边缘（阶跃边缘、坡状边缘、屋顶边缘等）及其特点。
   Describe different types of edges (step edge, ramp edge, roof edge, etc.) and their characteristics.

   Edge Types: "**Step**: sudden change, **Ramp**: gradual change, **Roof**: peak/valley pattern“.

基于第六周的内容(特征点检测)

重点：

1. **详细解释Harris角点检测器的数学原理，特别是自相关矩阵(Auto-correlation Matrix)的构建和分析。**
   Explain in detail the mathematical principles of Harris corner detector, especially the construction and analysis of auto-correlation matrix.

Harris Corner Detector Mathematics: "**Auto-correlation matrix** M is constructed as: M = ∑w(x,y) [**I_x^2 I_xI_y**; **I_xI_y I_y^2**] where **I_x, I_y** are image gradients, **w** is window function. **Corner response** R = **det(M) - k·trace(M)²**

1. **自相关函数**：窗口平移(u, v)后的灰度变化：
   $E(u, v) = \sum_{x,y} w(x, y)[I(x + u, y + v) - I(x, y)]^2$
2. **泰勒展开近似**：
   $$E(u,v) \approx [u \quad v] \cdot M \cdot \begin{bmatrix} u \\ v \end{bmatrix}, \quad M = \sum w(x,y) \begin{bmatrix} I_x^2 & I_xI_y \\ I_xI_y & I_y^2 \end{bmatrix}$$
3. **角点响应函数**：
   $R = \det(M) - k \cdot \text{trace}(M)^2 \quad (k \approx 0.04)$
   $R = \lambda_1\lambda_2 - k(\lambda_1 + \lambda_2)^2$

Key steps:

- Calculate **image gradients**
- Compute **matrix elements**
- Apply **Gaussian window**
- Calculate **corner response**"

2. **基于Harris角点检测器的特征值分析，如何区分角点、边缘和平坦区域?**
   Based on eigenvalue analysis of Harris corner detector, how to distinguish between corners, edges and flat regions?

Harris Eigenvalue Analysis: "Based on **eigenvalues λ_1, λ_2**:

- $\lambda_1 \approx \lambda_2$ 且都大：角点. $\lambda_1 >> \lambda_2$ 或 $\lambda_2 >> \lambda_1$：边缘. $\lambda_1 \approx \lambda_2 \approx 0$：平坦区域
- **Corner**: Both λ_1, λ_2 **large** and **similar**
- **Edge**: One λ **large**, one **small**
- **Flat**: Both λs **small** Mathematically, **corner response** R ≈ $\lambda_1\lambda_2 - k(\lambda_1+\lambda_2)^2$"

3. **描述SIFT(Scale-Invariant Feature Transform)特征检测的完整步骤。为什么SIFT特征具有尺度不变性?**
   Describe the complete steps of SIFT feature detection. Why do SIFT features have scale invariance?

SIFT Detection: "Steps:

1. Build **scale-space pyramid** using **DoG**

   构建高斯金字塔，通过差分高斯（DoG）检测极值。公式：
   $D(x, y, \sigma) = L(x, y, k\sigma) - L(x, y, \sigma)$。
2. Detect **local extrema** across scales
3. **Refine keypoint** locations
4. Assign **orientations**
5. 描述子生成:将16×16窗口分为4×4子块，每块计算8方向梯度直方图，形成128维向量

Scale invariance achieved through:

- **Scale-space** pyramid construction
- **DoG** (Difference of Gaussian) detection
- **Automatic scale selection**"

4. **描述SUSAN和FAST角点检测器的原理和性能差异。**
   Describe the principles and performance differences between SUSAN and FAST corner detectors.

SUSAN vs FAST: "**SUSAN**: Uses **circular mask**, compares with **nucleus**. **USAN area** determines feature type. **FAST**: Examines **16 pixels** on circle, tests for **n contiguous pixels** brighter/darker than center. Performance:

- FAST is **computationally efficient**
- SUSAN more **robust** to noise
- FAST better for **real-time** applications"

算法	计算效率	尺度不变性	抗噪性
Harris	中	无	中
SIFT	低	有	高
FAST	高	无	低

5. *解释Moravec角点检测器的原理及其局限性。Harris检测器如何改进了这些问题?*
   Explain the principle of Moravec corner detector and its limitations. How did Harris detector improve these issues?

Moravec vs Harris: "**Moravec**: Shifts window in 8 directions, takes **minimum variation**. **Limitations**:

- Only **45-degree** shifts
- **Binary** window function **Harris improvements**:
- **All-direction** analysis
- **Gaussian** window
- **Mathematical** formulation"

6. *Explain the difference between detecting and describing features, and why this separation is important. 解释特征检测和特征描述的区别，以及为什么这种分离很重要。*

Detection vs Description: "**Detection**: Locates **where** features are **Description**: Characterizes **what** features look like **Separation important** because:

- Allows **independent optimization**
- Enables **different combinations**
- Supports **different applications**"

非重点：

1. 描述什么是"好的"特征点，一个好的特征点应该具备哪些性质?
   Describe what is a "good" feature point, and what properties should a good feature point possess?

Good Features: "Need **repeatability**, **distinctiveness**, **locality**, **accuracy**"

- **不变性**：对光照、旋转、尺度、噪声等变化保持稳定。
- **独特性**：不同场景中可重复检测并匹配。

2. 解释什么是尺度空间(Scale Space)，为什么需要在不同尺度下检测特征点?
   Explain what is scale space and why we need to detect feature points at different scales?

Scale Space: "**Gaussian pyramid** enables **scale-invariant** detection"

3. 解释为什么要进行方向赋值(Orientation Assignment)，以及SIFT是如何实现旋转不变性的。
   Explain why we need orientation assignment and how SIFT achieves rotation invariance.

   Orientation Assignment: "Uses **gradient histogram**, enables **rotation invariance**"
4. 比较Harris和SIFT特征检测器的优缺点。在实际应用中如何选择?
   Compare the advantages and disadvantages of Harris and SIFT feature detectors. How to choose in practical applications?

   Harris vs SIFT Choice: "**Harris**: fast, simple. **SIFT**: more robust, scale-invariant"
5. 详细描述SIFT特征描述符的构建过程。为什么使用128维向量?
   Describe in detail the construction process of SIFT feature descriptor. Why use a 128-dimensional vector?

   SIFT Descriptor: "**4×4 grid**, **8 orientations**, hence **128 dimensions**"

基于第七、八周的内容(模板匹配和光流)

重点:

1. **光流定义？详细解释Lucas-Kanade光流算法的三个关键假设，并推导其数学原理(最小二乘解的计算过程)和相关的光流方程。**
   Definition of optical flow? Explain in detail the three key assumptions of the Lucas-Kanade optical flow algorithm and derive its mathematics (the process of calculating the least squares solution) and the associated optical flow equations.

"**Optical flow** is the **apparent motion** of pixels between frames. 矢量 (u, v)

Three key assumptions:

1. **Brightness constancy**: I(x,y,t) = I(x+dx,y+dy,t+dt)
2. **Small motion**: allows **Taylor expansion** $I_x u + I_y v + I_t = 0$
3. **Spatial coherence**: neighboring pixels have **similar motion**

Mathematical derivation:

- From brightness constancy: $\nabla I_k + I_t = 0$
- For window W, minimize: $E = \sum W(I_x \cdot u + I_y \cdot v + I_t)$²
- Least squares solution:

$$\begin{bmatrix} \sum I_x^2 & \sum I_x I_y \\ \sum I_x I_y & \sum I_y^2 \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} = - \begin{bmatrix} \sum I_x I_t \\ \sum I_y I_t \end{bmatrix}$$

解存在的条件：矩阵 $A^T A$ 的特征值 λ_1, λ_2 需足够大（类似Harris角点检测）。

2. **解释为什么在模板匹配中要考虑亮度变化的问题，归一化相关(NCC)的数学公式及其在模板匹配中的作用。为什么要使用归一化相关而不是简单的相关?**
Explain why we need to consider intensity variations in template matching, the mathematical formula of Normalized Cross Correlation (NCC) and its role in template matching. Why use NCC instead of simple correlation?

NCC in Template Matching:
"**Intensity variations** affect matching because of:

- 直接交叉相关对全局亮度敏感，高亮度区域可能误判为高匹配值。(消除亮度偏移影响，仅保留相对亮度变化的匹配信息。)
- **Lighting changes**
- **Camera settings**
- **Surface reflectance**

NCC formula:$\mathrm{NCC}(f,g) = \frac{\sum(f(i,j)-\mu_f)(g(i,j)-\mu_g)}{\sqrt{\sum(f(i,j)-\mu_f)^2} \cdot \sqrt{\sum(g(i,j)-\mu_g)^2}}$

Advantages over simple correlation:

- **Invariant** to linear intensity changes
- **Normalized range** [-1,1]
- More **robust** to lighting changes"

3. **解释孔径问题(Aperture Problem)是什么，以及Lucas-Kanade算法如何解决这个问题?**
Explain what is the Aperture Problem and how does Lucas-Kanade algorithm solve it?

"**Problem**: Can only determine motion **perpendicular** to edge orientation due to **local ambiguity**.

LK solution: - Uses **multiple constraints** from neighborhood - Forms **overdetermined system** - Solves using **least squares** Requires good **texture** in window"

4. *比较模板匹配中的相似度度量方法SSD(Sum of Squared Differences)、相关(CC)和归一化相关(NCC)在模板匹配中的优缺点。*
Compare the advantages and disadvantages of SSD, CC and NCC in template matching.

- **交叉相关（Cross-Correlation）数学公式**:
$C_{fg} = \sum_{(i,j)\in R} f(i,j) \cdot g(i,j)$
其中，f为模板，g为图像局部区域，R为模板窗口。
- **SSD公式**:
$\mathrm{SSD} = \sum_{(i,j)\in R} (f(i,j) - g(i,j))^2$
- **展开形式**:
$\mathrm{SSD} = \sum f^2 + \sum g^2 - 2 \cdot C_{fg}$
可见，SSD最小化等价于交叉相关C_{fg}最大化。
- **SSD**: - Simple computation - Sensitive to intensity changes **CC**: - Better than SSD - Not invariant to scaling **NCC**: - Best robustness - Computationally expensive"

5. *描述多尺度Lucas-Kanade算法的工作原理，它如何处理大位移问题? Describe how multi-resolution Lucas-Kanade algorithm works. How does it handle large displacements?*

"**Process**: 1. Build **image pyramid** 2. Start at **coarsest level** 3. Estimate flow, **propagate** to finer level 4. **Refine** estimation Handles **large displacements** by making them **smaller** at coarse levels"

非重点:

1. 详细解释模板匹配中如何处理尺度和旋转变化的问题。
   Explain in detail how to handle scale and rotation changes in template matching.

"Use **pyramid** for scale, **orientation normalization** for rotation"

2. 解释为什么在图像金字塔中进行模板匹配能提高效率？具体如何实现？
   Explain why performing template matching in image pyramid can improve efficiency? How to implement it specifically?

"Reduces **search space**, uses **coarse-to-fine** strategy"

3. 解释什么是运动场(Motion Field)和光流场(Optical Flow Field)，它们之间有什么区别？
   Explain what are Motion Field and Optical Flow Field, and what are the differences between them?

   "**Motion field**: 3D projection, **Optical flow**: apparent 2D motion"

4. 描述Shi-Tomasi特征跟踪器的工作原理及其与Lucas-Kanade算法的关系。
   Describe the working principle of Shi-Tomasi feature tracker and its relationship with Lucas-Kanade algorithm.

   "Uses **minimum eigenvalue**, improves **feature selection**"

   - **特征选择**：基于Harris角点检测，选择特征值 $\lambda_{\min}$ 较大的点（纹理丰富区域）。
   - **跟踪流程**:
     1. 使用Lucas-Kanade跟踪特征点。
     2. **仿射验证**：将当前帧特征与初始帧进行仿射变换匹配，检测漂移。

5. 详细解释光流估计中的迭代优化过程，为什么需要迭代？如何实现？ Explain the iterative refinement process in optical flow estimation. Why do we need iteration? How to implement it?

   "**Refines** estimation through **multiple passes**"

6. 解释光流估计中的Harris矩阵(ATA)的特征值分析，如何用它来选择好的追踪点？ Explain the eigenvalue analysis of Harris matrix (ATA) in optical flow estimation. How to use it to select good tracking points?

   "**Large eigenvalues** indicate good tracking points"