Model Answer: Computer Vision, Question 2.   2001

1. Infering depth properties and 3D surface properties from image information. An image is a two-dimensional optical projection, but the world we wish to make sense of visually is three-dimensional. In this respect, vision is *"inverse optics:"* we need to invert the 3D $\longrightarrow$ 2D projection in order to recover world properties (object properties in space); but the 2D $\longrightarrow$ 3D inversion of such a projection is, strictly speaking, mathematically impossible. This violates Hadamard's 2nd criterion.

2. Infering object colours in an illuminant-invariant manner. The wavelength mixture reaching a video camera (or the eye) is the convolution of the wavelength composition of the illuminant (which may be multiple, extended, or a point source; narrowband or broadband; etc.) with the spectral reflectances of objects. We wish to infer the latter, i.e. object pigment properties, but in order to deconvolve the two processes we would need to know exactly the properties of the illuminant. Usually we don't have that information. This violates Hadamard's 1st criterion.

3. infering structure from motion, shading, texture, shadows, and interpreting the mutual occlusions of objects as well their self-occlusions as they rotate in depth. The solutions to such problems do not depend continuously on the data, which violates Hadamard's 3rd criterion; and they may not be unique, which violates Hadamard's 2nd criterion.

Most of the problems we need to solve in vision are *ill-posed,* in Hadamard's sense that a *well-posed* problem must have the following set of properties:

- its solution exists;

- its solution is unique;

- its solution depends continuously on the data.

In many respects, computer vision is an "AI-complete" problem: building general-purpose vision machines would entail, or require, solutions to most of the general goals of artificial intelligence. But the intractable problems can be made tractable if metaphysical priors such as "objects cannot just disappear; they more likely occlude each other;" or "objects which seem to be deforming are probably just rotating in depth;" or "head-like objects are usually found on top of body-like objects, so integrate both kinds of evidence together;" etc. can resolve the violation of one or more of Hadamard's three criteria. Bayesian priors provide one means to do this, since the learning (or specification) of metaphysical principles ("truths about the nature of the world") can steer the integration of evidence appropriately, making an intractable problem soluble.