Presentations

- Logistics
  - Think about what you want to do
  - Thursday we'll informally sign up, see if we can reach consensus.
- Topics
  - Linear representations of classes
  - Non-linear representations of classes
  - Psychology of view-based recognition
  - Descriptors
  - Neuroscience
  - Skeletons
  - Constellation methods
  - HMMs
  - Adaboost
  - Others???

How do Categories Work?

Philosophy, Cognitive Science

- What can we learn from them?
  - Problem Definition
    - What is a category?
    - What phenomena do people display when they categorize?
  - Ideas for algorithms
    - Representations, how they affect learnability
- What will be relevant to vision engineers?
  - May be willing to focus on simple categories
  - May be less interested in odd exceptions
  - But may want to mimic human categorization when we build systems that interact with people.

Philosophy and Categories

- Categories are central to key questions in philosophy.
  - How do we know things.
    - Example, Plato's theory of knowledge
  - What do statements *mean.*
    - Example: statements should be reducible to logic, with primitives verifiable by senses.
    - How then can we express categories with logic?
    - Wittgenstein

Basic Questions

- What is a category? (*class, concept*)
  - A set of objects/things? What sets are valid?
  - A probability distribution?
- What determines what belongs to a category?
  - With a category comes the ability to judge in principle whether new things are part of it. How does this work?
  - Are categories in the world or in our head?
- How do we determine categories computationally?
  - How do we represent and use prior knowledge?
  - How do we cope with partial information? ….

Visual Categories

- Papers don’t talk much about specifically visual, but we want to consider this.
- Only some categories do we expect to perceive visually.
  - Yes: Red.
    - This is nothing but visual.
  - Probably yes: Chair, desk, maple.
    - Structure is important to what they are.
  - Maybe: Measles.
    - Vision is diagnostic, but not integral to what it is.
  - Very tough: game, convince.

Visual Categories

- We don’t ask: “Is this a chair?”, we ask: “Does this look like a chair?”
- Viewing conditions (eg., pose, lighting) affect an object’s appearance.

The Papers

- Women, Fire and Dangerous Things by Lakoff, Chapters 1 and 2.
- S. Laurence and E. Margolis, ``Concepts and Cognitive Science'', in *Concepts* edited by E. Margolis and S. Laurence, MIT Press.
- L. Wittgenstein, *Philosophical Investigations,* sections 65-78.

What do we need to account for?

- Representational adequacy
- Categorization
- Acquisition
- Compositionality
- Internal Structure
  - Prototype effects
- Analytic inference (important for vision?)
- Stability (important for vision?)

Our plan

- Focus on two chief approaches
- First, classical theory
- Discuss prototype effects
- Prototype theory

We'll focus first on:

- Classical theory – a category is definable.
  - Certain properties are present or absent. Example: a chair has a seat. A briefcase has a handle.
  - Eventually, these bottom-out in something verifiable by senses.
  - Category membership is binary.
  - Intuitive: we think things have definitions.
  - Held with little question for ~2,000 years.
  - Initial focus of AI, cognitive science: eg., Schank, Hayes, expert systems, anthropology.

Representational power? (Plato's problem).

- Precise definitions are actually quite difficult.
  - Wittgenstein's example *game* started this. "Don't think but look".
  - Knowledge as justified true belief.
    - *The story of the tennis match.*
  - Paint
    - X covers Y with paint (exploding paint factory).
    - Plus x is an agent (I kick over paint bucket).
    - It's intentional. (Michaelangelo painting mural).
    - Intention is to cover with paint (dip brush in paint).
  - This might be an issue of representational power, or just that definitions are hard to uncover.

Question

- Do we care about this? Maybe these problems only occur for categories more complex than those we can hope to identify with vision.

Question

- Even if we can’t always use them, don’t definitions sometimes seem useful? If we want to find soccer games where Sweden beat Norway, Sweden should have scored more goals.

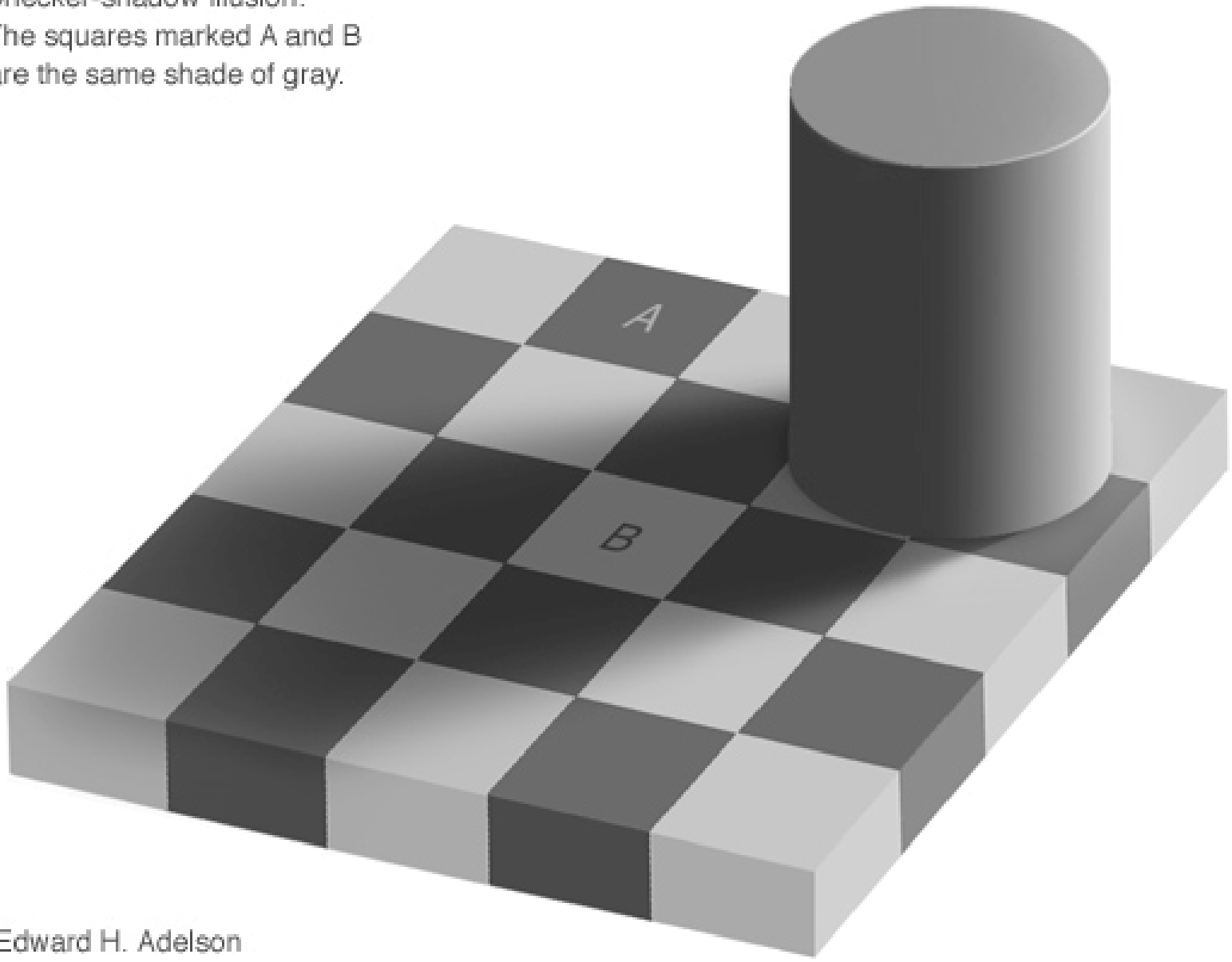
Acquisition/Categorization

- Seems straightforward
- Acquisition: especially easy to hard code these.
- Still, issues in finding good algorithms, in choosing best features.

Visual Categorization

- Are there visual analogs to these?
  - Visual categories may be simpler(?)
  - But definitions in terms of visual properties are harder.
    - Even if I can define a chair as something one person can sit in, this is far from a visual definition. Classical theory assumes ultimately there's a visual definition, but doesn't usually try to work it all out.
    - Even very simple visual properties are hard. Try to define "gray".

Checker-shadow illusion:
The squares marked A and B
are the same shade of gray.



Edward H. Adelson

Prototype Structure of Classes

- Berlin and Kay – focal color stable across cultures.
- Rosch – converging evidence of prototypes.
  - Direct rating: (robin over chicken)
  - Reaction time:
  - Production of examples
  - …

Prototypes and Classical view

- Mysterious why definitional categories would have prototypes.

Prototype theory

- Not really a theory, ie., not too specific.
- Category is based on statistical occurrence of features
- Example of a specific prototype theory: a statistical model based on properties.
  - Gaussian distribution;
  - Weighted combination of properties: eg., Bird Properties: flies, sings, lays eggs, is small, nests in trees, eats insects. All are true of a robin, but maybe only some need to be true (eg., a chicken) This could be a linear separator eg., an SVM.
- Wittgenstein: Family resemblance, rope.
  - This could be a manifold representation.

Representational power?

- Prototype theory
  - In its vaguest form, has arbitrary power.
  - In simpler form, more powerful than definitions, but is it powerful enough?
  - But still faces problem of feature selection, and reducing these to sensory inputs.

Categorization/Acquisition

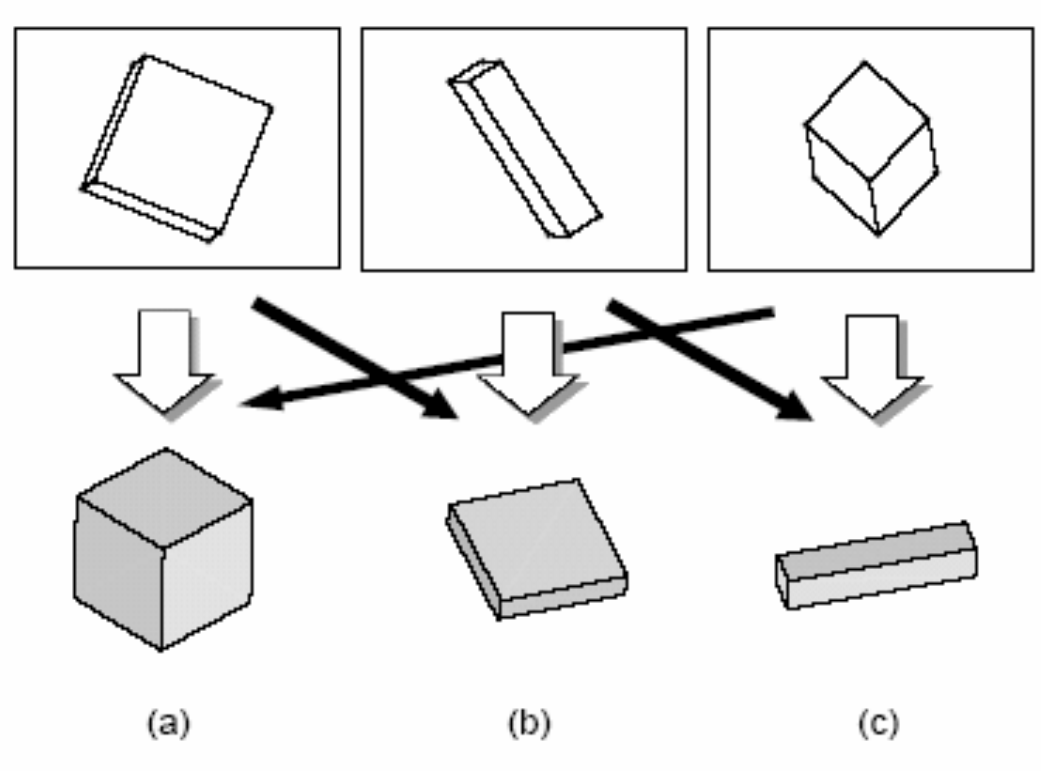
- In principle seems do-able
- But algorithm must be specified.

Prototypes and Prototype Theory

- Natural explanations: prototypes are most probable examples (mode of distribution).
- But this doesn’t explain all prototypes:
  - 8 is a better example of an even number than 34.

Prototypes and Vision

- Prototypes exist in visual terms, (pose).
  - Often these are most informative (in some sense).
  - Many algorithms produce prototype effects, but still, very suggestive.



Other issues

- Acquisition: plausible for both.
- Conceptual fuzziness; similar issues to prototypes (are carpets furniture?)
- Ignorance and error. We can be wrong about properties of a category, or change our mind. So what is essential to a category, if not its properties?
  - Fascinating, but is it relevant to us?

Other Issues

- Compositionality – how do categories combine? Example: pet fish.
  - Classical approach has less problem.
  - Prototypes: not function of constituent prototype.
    - Prototype pet fish isn’t prototype pet or fish.
    - Probabilistic framework might predict this, but striped apple example.
    - Some complex categories don’t have prototypes. (Don Delillo book).

Compositionality and Vision

- This is a great problem.
  - Given algorithm to find yellow things, and to find apples, can I find a yellow apple? A square head?
  - Not worked on much, cause absorbed with simpler problems.

Question

- Do prototype phenomena help to narrow down which algorithms to use?

Dual Theory

- There is a core concept, that may be closer to classical view.
- And an identification procedure, which is pragmatic, probabilistic, based on diagnostic features.
  - Measles defined by virus, recognized by symptoms.
  - Explains how *even* can have prototype.
  - We are then mainly interested in identification procedure.

Questions

- Is this discussion really relevant?
  - Can’t we just use people as oracles and try to replicate them?
- “Don’t think but look”. Is it important to implement theories?
- Is it different to ask: What is a visual category?
- Are categories so complex, that to understand one, you must understand all?
  - Is explaining *gray* vision complete. Rules for *gifts*.
  - Basis of Dreyfus critique, based on Heidegger.

Basic Categories

- Examples:
  - Animal, *dog*, retriever
  - Furniture, *chair*, rocking chair
- Perception: first level with common shape (can average the shapes); single mental image; fast id.
- Function: general motor program
- Communication: shortest most common name. First learned.
- Knowledge: most attributes.

Implications

- Categories are partly constructed, not given by world (eg., genus).
  - What does this say about unsupervised learning?
- Primary level of visual classification.
- Based on part structure?
  - Level where correspondence makes sense.
- Computational mechanisms key in understanding categories.

Key Points

- Definitional approach especially tough,
- but not clear any good description of a category exists.
- Could be they are very complex, intertwined.
- Turning properties into visual input hard.
- Computation key to understanding what category is.

Questions

- Does discussion of acquisition take problem of generalization too lightly?
- How relevant is this work to our task?
- Can computer vision contribute to this discussion?