Perception

"I hear and I forget. I see and I believe. I do and I understand."
Confucius (551 – 479 BC)

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Perception is a process that uses sensory information to recognize things.
Such things include objects, events and actions.

Contents

- Perception is the recognition process
  - What, Where and When
- Relative properties / Features
- Gestalt grouping principles
- Same versus similar things
- Obscured and ambiguous things
- Objects versus patterns
- Expected, predicted and unexpected

In this chapter I explain some principles of perception that are important for developing a functional / mechanistic model for Adaptron.

There is space and time based pattern recognition.

You need to extract the patterns from the readings measured by your senses.

An important principle is that everything is relative.

There are no absolutes when it comes to perception.

This presentation introduces the Gestalt laws of grouping, and other principles of perception such as: obscured things and ambiguity.

Perception

- The process of recognizing things
  - Objects and events
    - Types of things or instances of things
    - Based on their properties
  - What they are
  - Where they are (spatial)
  - When they occur (temporal)
- Recognition is identification
  - Requires memory

Notice the subtle definition of things.

Things consist of objects that exist in space and events that exist in time.

And you can recognize types (classes) as well as specific instances of things.

Obviously you have to measure some properties of a thing to recognize it.

You cannot identify something unless you have seen it before – so you have to represent it somehow in memory.

Everything is relative

- Absolute property values are not useful for recognition
- Relative property values provide the basis for identifying objects

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The loudness of a sound in not useful in telling you what the sound is.

The brightness of an object does not help you recognize what it is.

It's the relative values of an object's properties that allows you to identify it.

This is either a very small pencil or a very large watch. Size is relative.

Relative Properties / Features

- Relative properties are combined to identify things
- Relative spatial features - examples
  - Intensity $\rightarrow$ Contrast
  - Number $\rightarrow$ Relative quantity
  - Size $\rightarrow$ Shape
  - Distance $\rightarrow$ Separation
- Relative temporal features - example
  - Timing $\rightarrow$ Duration

Spatial = simultaneous = parallel recognition. Temporal = Time based recognition.

The ratio of two intensities (brightness, volume, pressure etc.) gives you contrast.

The ratio of two sizes gives you shape. (Widths in one dimension)

All four spatial features are the same in the temporal dimension, we just have different names for them.

Repetition gives you relative quantity.

The difference between two times gives you duration.

The ratio of two durations gives you relative timing.

Gestalt Grouping Principles [1] [2]

- Proximity
- Similarity
- Continuity
- Common fate
- Closure

In the 1930's and 1940's the Gestalt grouping principles were formulated.
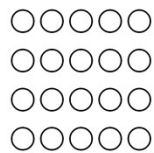
They provide some useful mechanistic principles for understanding the processes of perception.

The principles identify some rules which apply for how we associate things.

In the two dimensional example the grouping is obvious.

Items in the rows are the first grouping and then there is a group of rows.

The one dimensional example illustrates a simpler version of the principle.

If each circle is numbered starting with number one on the left and number 12 on the right the groups are:

1 is an object O1, 2 & 3 form O2, 4 & 5 form O3, 6 & 7 also form an O3, 8, 9 & 10 form an object O4 and 11 & 12 form an object O2. The next grouping G1 is formed from the two O3s (4 & 5 and 6 & 7) because they are beside each other and are the same object. Note that the two O2s are not grouped because they have other objects between them. Also note one does not group the O2 with the first O3 at 4 & 5 even though it is closer than the second O3 at 6 & 7.
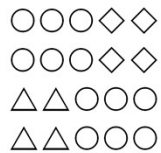
This process could be automated by having parallel / simultaneous waves of searching for identical objects that emanate from each circle. This would then identify the Os. Then when all these O matches are found do the same process using the Os as the sources and form the Gs. And as long as new groups are formed and the same ones are found next to each other then keep doing this at higher and higher levels of complexity.

Note that this principle also applies to events (the temporal dimension). We group a series of repeated noises based on the duration between them.

Law of Similarity

- Group the same or similar things together
  - In two dimensions

    $$\bigcirc\bigcirc\bigcirc\diamondsuit\diamondsuit$$
    $$\bigcirc\bigcirc\bigcirc\diamondsuit\diamondsuit$$
    $$\triangle\triangle\bigcirc\bigcirc\bigcirc$$
    $$\triangle\triangle\bigcirc\bigcirc\bigcirc$$

  - In one dimension

  $\bigcirc \quad \bigcirc\triangle \quad \triangle \quad \diamondsuit \quad\quad \diamondsuit \quad \triangle \quad \triangle\triangle\triangle \quad \diamondsuit\triangle$

  - Also applies to the temporal dimension

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One of the most important properties for the proximity principle to work is that the things need to be the same.
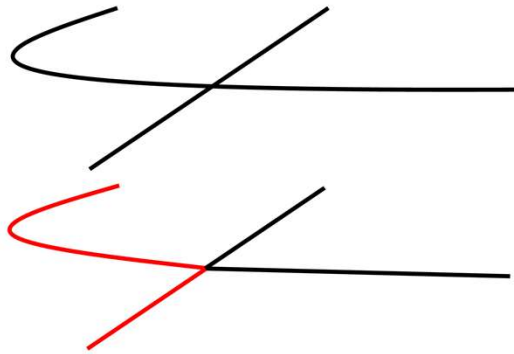
And this property results in the similarity principle which overrides the proximity principle in the previous examples.

Now the grouping is based only on adjacent same things (next to each other) with no intervening things.

A process that does this must first identify things that are the same and only then apply a proximity analysis.

This principle only works in two or more dimensions.

We naturally see the first pattern as being a straight line crossing diagonally over a curved line rather than the red and black objects shown below.

In the bottom example the recognition of the two objects is caused by adding the colour property to make them different objects.

In the top example you had a choice of how to interpret the pattern and the two simpler lines crossing each other was the easier interpretation.

When it comes to events this process is similar to picking out certain voices in a crowded room.

Law of Continuity

- Group same things that continue
  - In one dimension
  - The same as the law of similarity

  □□□□□□□□□□□□□□□

  □□□□□□□□□□□□□□

In one dimension the continuity principle is the same as the law of similarity.

Group the same things together.

As soon as they become different because of a colour difference, the grouping changes.

Law of Common Fate

- Group things together that change in unison
  - Things must maintain the same relationship
  - Changes attract attention

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[The boxes move when in Slide Show mode]

Change attracts attention to those things that have changed.

When a number of objects change in unison they form a group.

The change may be a change in position or a change in colour, size, rotation or some other property.

But the objects must retain their relationship to each other.

As soon as one moves in a different direction or changes at a different speed, as in the motion of the 5th square, it no longer belongs to the group of the 2nd, 3rd and 4th square.

This grouping principle relies on change and therefore only applies when a series of images or experiences are being processed.

It does not help identify an object in a single image.

We group events together provided they maintain the same timing relationship.

Different events that are coincidental (occur at the same time) we tend to attribute to a common cause.

Events that directly follow each other are often seen as related.

Law of Closure

- Complete things based on the simplest familiar pattern
  - Predict partly missing objects
    - Maximu
 - Predict a national anthem after the first few notes

We naturally tend to identify complete things even though we are provided with only a subset of a known / familiar thing.

However the subset needs to contain sufficient detail to unambiguously predict/identify the known thing.

We always will identify the least complex familiar thing first.

Law of Closure

- Past experience is required
  - Simplest familiar patterns are recognized first
  - *minimum* or *minimum*
  - A diamond is the simplest prediction of the obscured figure
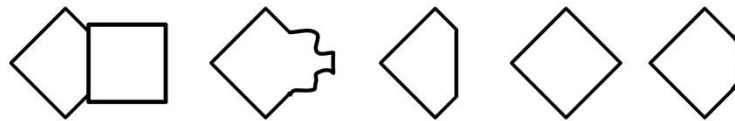
This principles relies on past experiences.

The two colours in the word "minimum" make it more complex than the all black version of the word.

These principles suggests a process in which things are created from less complex things and

less complex things get reused in forming more complex ones.

Same versus Similar Things

- Things are the same
  - They have all the same relative properties / features.
- Things are similar
  - They have a subset of relative properties / features that are the same
  - They are the same type of thing

One of the underlying mechanisms to make the Gestalt principles work is the ability to identify when two things are the same or different.

In some of the examples I used different shapes to illustrate the principle.

In others I added colour to make the objects different.

Two things are identical only if all their relative properties are the same.

Similar things share a subset of their relative properties.

Types of things have a common subset of relative properties.

All country flags are rectangular.

Dogs have 4 legs.

Cars have wheels.

Obscured Things

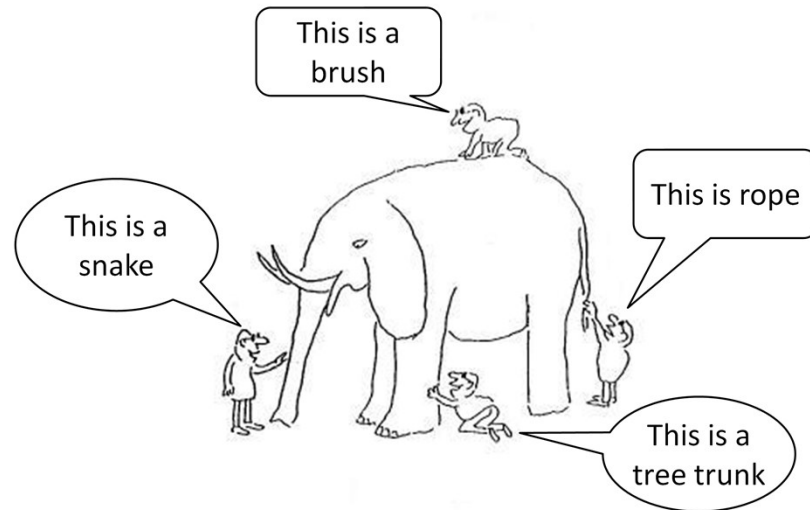- A thing can be identified even though only a subset of its relative properties / features can be perceived

You see the tail, hind legs and back of an animal behind a tree.

Based on the colour pattern you recognize it as your pet cat "Ginger".

You see a tail behind a tree with the same colour pattern and you recognize it as a cat tail but not necessarily Ginger.

You see the tip of a tail behind a tree and you recognize it as an animal tail, it could be a dog or cat.

Four men with sunglasses only see a small subset of the whole. Each has insufficient properties to identify it.

But combine this information with where they saw these things and you might be able to identify an elephant.

General to Specific

- Too few properties
  - Ambiguous identification
- More properties
  - Might allow for identification of its type
- Sufficient subset of properties
  - Identify it's instance

As you combine properties you go from the more general to the more specific.

Using the flag example. A rectangular shape with no colours does not indicate it is a flag.

It might be a book. It might be a computer monitor.

Put 3 rectangles on top of each other and you might identify it as a flag (its type). Or it might be a pile of 3 books.

Colour the rectangles and you know for sure it is a flag of a specific country.

[Bolivia, Sierra Leone, Lithuania, Netherlands, Germany, Yemen]

A type of object may be independent of its parts.

A square is a pattern of parts that occur in straight lines.

A square is a combination of properties.

And you can recognize this combination of properties on any sense that can capture its 2 dimensional structure.

You can recognize it when you see it, if it is traced on your back and if someone moves your hand in a square.

Objects versus Patterns
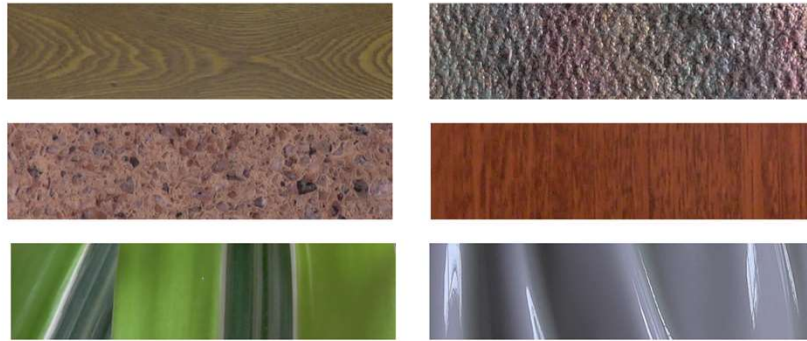
- Objects are made up of objects (parts)

Objects are made up of parts.

Parts are also objects that can be further decomposed into sub-parts ad infinitum.

Patterns are not objects. A pattern is made up of objects.

Patterns can have low spectral frequency.

This is when the intensity changes gradually over a distance such as in a blurred image.

Objects versus Patterns

- An object is a pattern of parts
- The parts of an object retain their relationship as it moves
  - All its parts move in unison
  - Gestalt common fate principle
- Objects have an outer edges
  - The pattern at the edge changes as the object moves in front of another pattern.

The parts of an object stay in the same relationship to each other while the object moves.

As soon as the parts move independently then they are separate objects.

At an object's outer edge the relationship between the background and the object is always changing as it moves.

Consider a flag. The edge pattern formed from an edge part and an adjacent background part is always changing.

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Expected

- Familiar things are expected
- It is uninteresting when they occur
- In English words
  - The following are expected after W
    - WA, WD, WE, WH, WI, WL, WO, WS, WU
- Many possible expectations for W

Given W in English words there are many expected next letters. These are all familiar.

They are uninteresting when they occur. It becomes boring if you are paying attention to them.

Predicted

- One expectation results in a prediction
- In English words
  - after the Q there is always a U
  - If you just perceive the Q you can predict the next letter will U
- A, E, I and O would be unexpected
  - It is surprising if they occur
  - The U would be missing or obscured

Given Q in English words there is only one expected next letter – U. [given that we ignore such words as Qatar, Qantas and Qwerty]

Therefore given the Q you can predict the next letter will be U.

If some other letter occurs then you could say the U is obscured.

QE would be unexpected or we have discovered a novel English word.

An E is surprising if you had predicted a U.

Unexpected

- Novel things are unexpected
- It is interesting when they occur
- In English words
  - the following are unexpected after a W
    - WK, WP, WX

Anything unexpected is novel.

It is interesting when they occur. They attract your attention.

References

[1] http://www.scholarpedia.org/article/Gestalt_principles
[2] https://en.wikipedia.org/wiki/Gestalt_psychology

Both Scholarpedia and Wikipedia have good descriptions of the Gestalt grouping principles.