Structure and Semantics of Arrows in Diagrams

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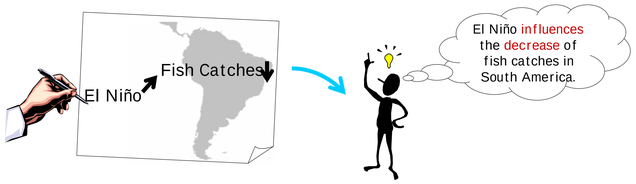
Why Arrows?

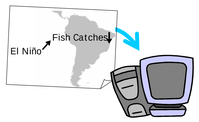
Arrows are a major component of diagrams, with which people communicate spatial and temporal knowledge.



Problem People often use similar-looking arrow symbols for different meanings without explanation. Therefore, diagram readers have to *interpret* the meaning of each arrow symbol.

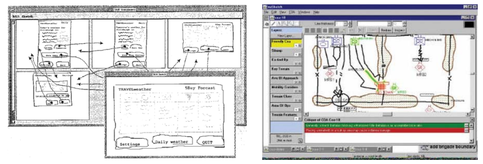
Research Goal

To develop a *computational method* for interpreting the meaning of arrow symbols.



Why a Computational Method?

Because pen-based systems* needs to understand the arrow-containing diagram that people naturally sketches.



However, current pen-based systems restrict the use of arrows or require their users to specify the meaning of every arrow.

** Examples of pen-based systems, which is used for GUI design and military planning.*

Approach

The appearance of an arrow symbol alone does not determine any meaning.

The meaning is established when the arrow symbol originates from, traverses, or points to other components.

We focus on the *structure* that the arrow-related components organizes around the arrow symbol.

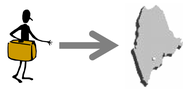
As a first step,
this paper points out arrows' three structural properties that contribute to their interpretations.

Property 1 Component Alignment

Obviously, different alignment of components leads to different interpretations.

Mounting a wheel to a car.

Removing a wheel from a car.

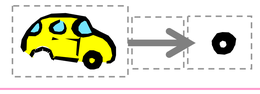


A person *goes to* Maine.

A person *passes through* Maine.

To formalize the alignment of components, we introduce *three component slots* where the components are located.

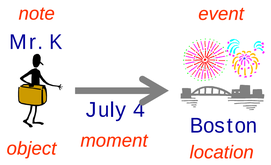
With this idea, an arrow can be described by text



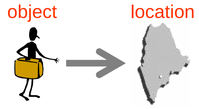
(*car*, –, *wheel*)

Property 2 Component Types

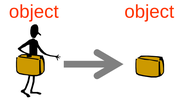
Components may be mentioned by an icon, a text, or a specific position in the background drawing. At a semantic level, however, they are classified into five types: *objects, events, locations, moments, and notes.*



Even if the component alignments are similar, two arrows with different types of components have different types of interpretation.

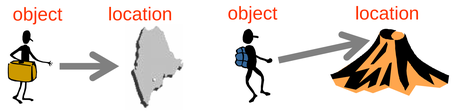


A person *goes to* Maine.



A person *leaves a bag.*

On the other hand, two arrows with identical alignments of component types often lead to the same class of interpretation.

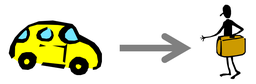


(*object*, – , *location*)

go_to (*object*, *location*)

Property 3 Component Orientations

An object expressed by an icon often shows an *intrinsic orientation* toward which the object usually moves.
This orientation is a key for successful interpretation.



A car approaches a person.

A person moves away from a car.

An object (car, person) is supposed to move only when its intrinsic orientation corresponds to the arrow's direction. Therefore, the following figure is ambiguous.

A car approaches a person or a person moves away from a car.

Then, how can we interpret this figure?

Ongoing Work

Since *five types of components* are located in the *three component slots*, we can distinguish $(5+1)^3 = 216$ types of *simple arrows.*

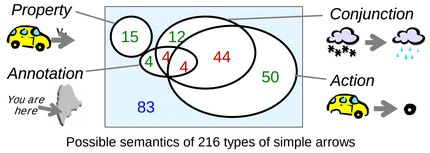
simple arrows := (*c*, *c*, *c*)
c := – | *object* | *event* | *moment* | *location* | *note*

We investigated what semantics each type of simple arrows may illustrate, by

- classifying the arrow-related semantics into four classes (*property*, *annotation*, *conjunction*, and *action*), and
- considering the structural conditions for illustrating each class of semantics.

We found that:

- 15+4+12+50 = 81 types of arrows lead to a unique interpretation.
- 4+4+44 = 52 types of arrows have more than one candidate of interpretations.
- 83 types of arrows are nonsense.



Possible semantics of 216 types of simple arrows

For the 52 types of ambiguous arrows, we are now developing a method for determining the most reliable interpretation, making use of various clues in diagrams, such as the *intrinsic orientations* of objects.