# Vector Semantics: Lecture 6

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# Space and time

- We have very well-established mathematical theories of space, ranging from the "most natural" 3d Euclidean space to more sophisticated ones (Riemannian space-time being the one physicists like most)
- The real line $\mathbb{R}$ offers a similarly well-established theory of continuous time, and $\mathbb{Z}$ offers same for discrete time
- Here we will develop something *worse*, something that is considerably less useful for physics
- So why do it? Because the *naive* theory is the one implicit in language use
- "The fact that as a computational device the standard theory is superior to the naive theory is no more a reason to abandon study of the naive theory than the superiority of eukaryotes is reason to abandon study of prokaryotes" (Gyenis and Kornai, 2019)

# Space

- Remember Esau = `seller`; Jacob = `buyer`; birthright = `goods`; bowl of lentils = `consideration/thing of value`
- Spatial language is typecast to one of two schemas, {`place`} and {`bound`}
- There are several lexical entries related to these, beginning with
  *up* `fel sursum A after(at position), vertical(position er_ gen)`
  *down* `le deorsum D vertical(gen er_)`
  *vertical* `fu2ggo3leges verticalis N direction, has top, has middle, has bottom, earth pull in direction`
  *fall* `zuhan cado U move, after(down)`
- A great deal of the definition technology is heavily used here, we delay discussing several aspects such as comparative `er_`

# The naive picture of space

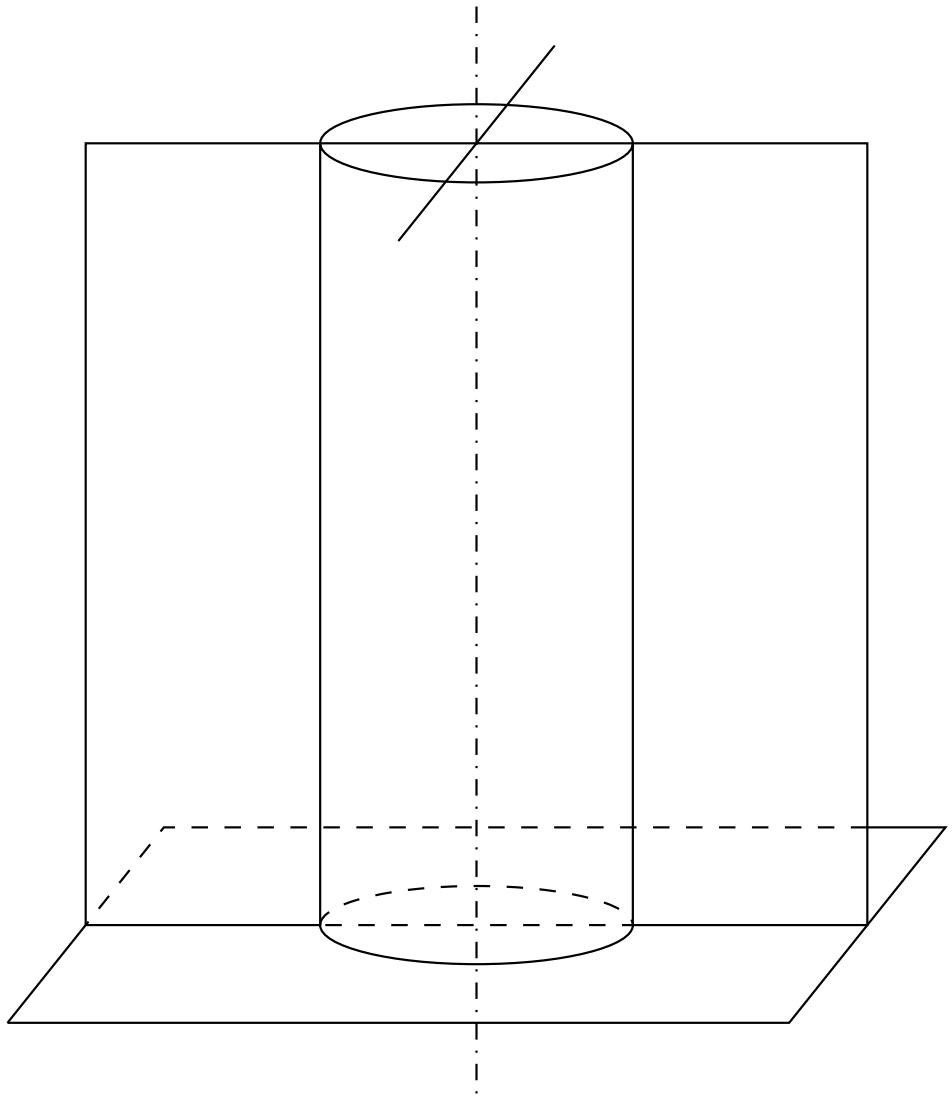


Figure: Egocentric coordinates

# A robot

**Figure 1**

FIGURE 1. Spatial relations between objects can be obtained in different ways. Consider the instruction to the robot: "Take the cup to the left of the fruit bowl to water the plant." Prior embodied experiences are needed for grounding the instruction in the real world. From its camera image, the robot can infer that there are cups **on** the table, but it needs to resolve "`to the left` of the fruit bowl" to use the correct cup. To infer that the plant, which is not in the robot's field of view, is **on** the windowsill, the robot can use prior knowledge, e.g., retrieved from a knowledge base, since it is a typical location for a plant.

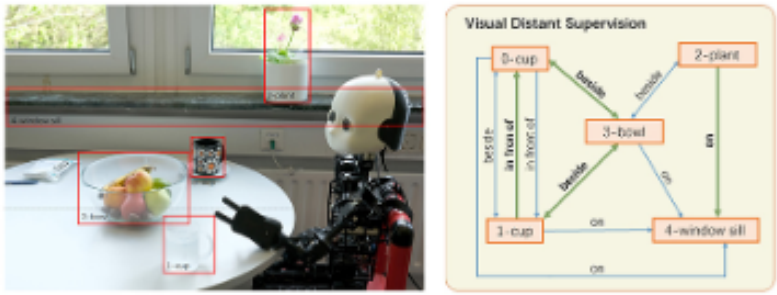



FIGURE 8. Visual distant supervision (Yao et al., 2021) retrieves plausible relations between the detected objects (only a selection of bounding boxes and relations is shown). Correct relation labels are highlighted in bold and green thick arrows.

Figures from Lee et al., 2022, but idea goes back to Winograd, 1972

# The block world

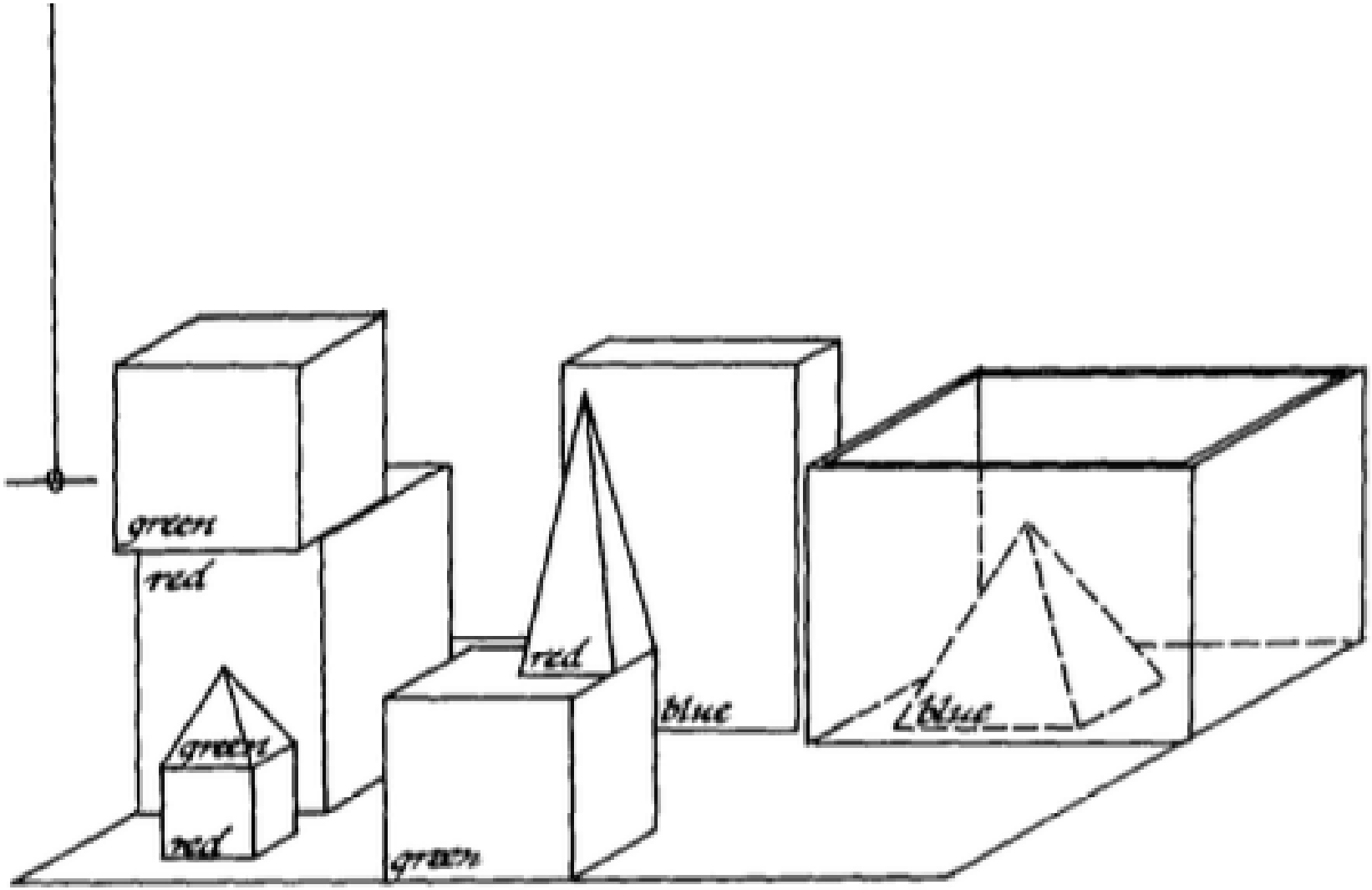



Fig. 3. "Pick up a big red block."

# What do we need here?

- We need some *pattern recognition* to find the big red block
- This was downplayed by Winograd, because it's very hard, but current SOTA models (starting with YOLO9000) work remarkably well
- We need some detection/inference of spatial relations like (ball ON block)
- We need quite a bit of grammar to get *big red block*
- We need to figure out what ON means
- The dictionary tells you that ON means `at, =agt touch =pat, <high(=agt er_ =pat)>`
- OK, so what does *at* mean?
- `=agt has place, =pat[place], ‘‘at __’’ mark_ place`

# Finally, we are at the {place} schema

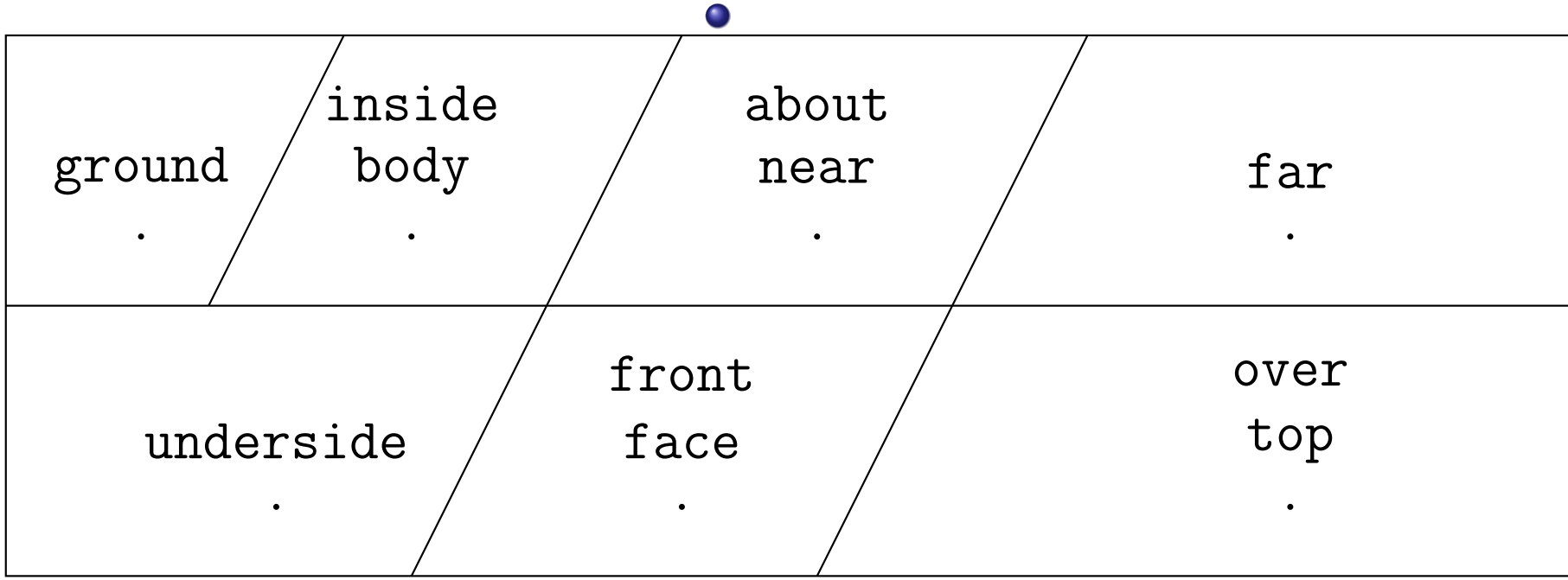
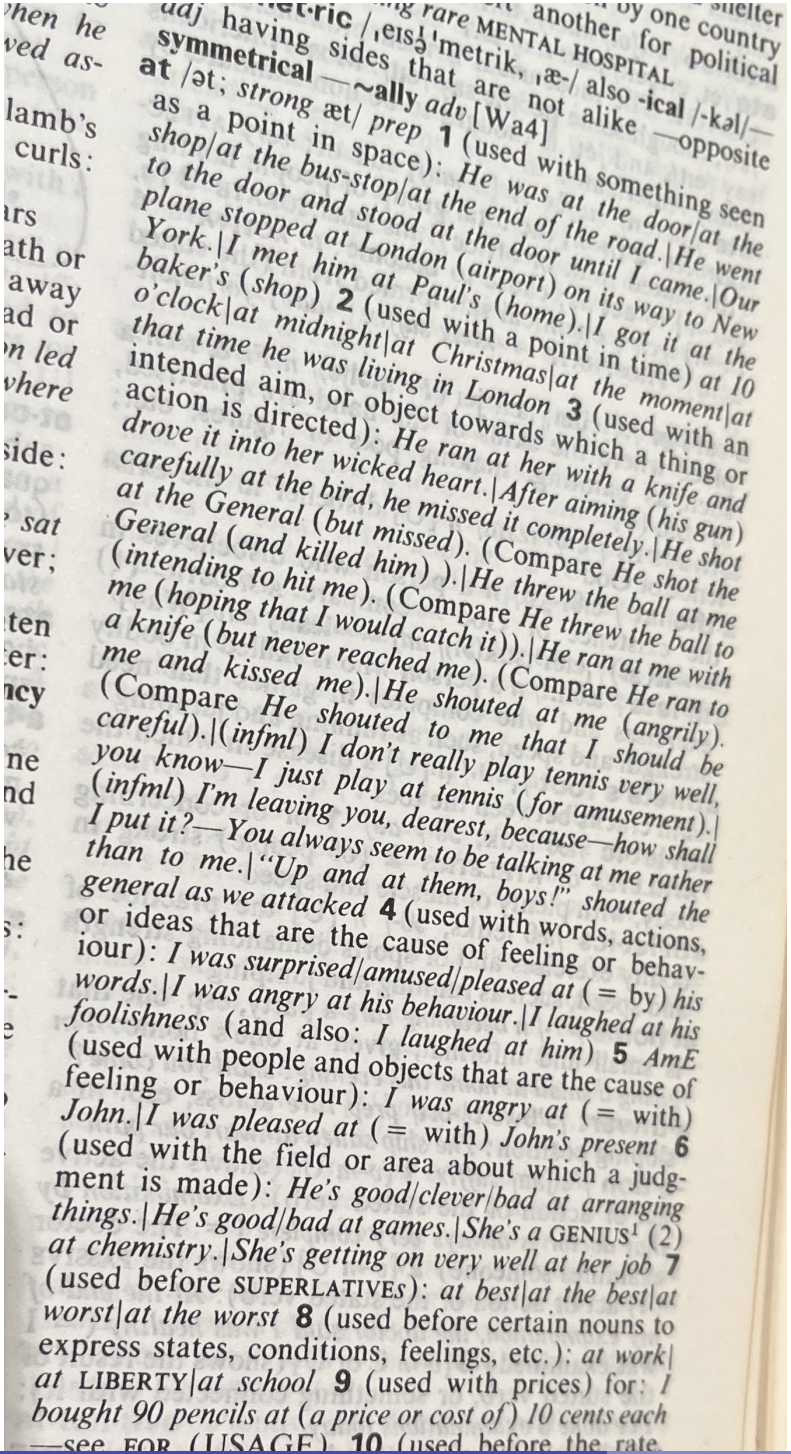



Figure: {place}

- For =agt to be AT =pat means that it is the patient (prepositional object) that is = the origin (little standing homunculus) of the schema
- John (is) AT (the) office: office is the 'ground' and John is the 'figure' (as in gestalt psychology)



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**met·ric** /ˌeɪsɪˈmetrɪk, ˌæ-/ also **-ical** /-kəl/— *adj* having sides that are not alike —opposite **symmetrical** —**~ally** *adv* [Wa4]

**at** /ət; *strong* æt/ *prep* **1** (used with something seen as a point in space): *He was at the door|at the shop|at the bus-stop|at the end of the road.|He went to the door and stood at the door until I came.|Our plane stopped at London (airport) on its way to New York.|I met him at Paul's (home).|I got it at the baker's (shop)* **2** (used with a point in time) *at 10 o'clock|at midnight|at Christmas|at the moment|at that time he was living in London* **3** (used with an intended aim, or object towards which a thing or action is directed): *He ran at her with a knife and drove it into her wicked heart.|After aiming (his gun) carefully at the bird, he missed it completely.|He shot at the General (but missed). (Compare He shot the General (and killed him) ).|He threw the ball at me (intending to hit me). (Compare He threw the ball to me (hoping that I would catch it)).|He ran at me with a knife (but never reached me). (Compare He ran to me and kissed me).|He shouted at me (angrily). (Compare He shouted to me that I should be careful).|(infml) I don't really play tennis very well, you know—I just play at tennis (for amusement).|(infml) I'm leaving you, dearest, because—how shall I put it?—You always seem to be talking at me rather than to me.|"Up and at them, boys!" shouted the general as we attacked* **4** (used with words, actions, or ideas that are the cause of feeling or behaviour): *I was surprised/amused/pleased at (= by) his words.|I was angry at his behaviour.|I laughed at his foolishness* (and also: *I laughed at him*) **5** *AmE* (used with people and objects that are the cause of feeling or behaviour): *I was angry at (= with) John.|I was pleased at (= with) John's present* **6** (used with the field or area about which a judgment is made): *He's good/clever/bad at arranging things.|He's good/bad at games.|She's a* GENIUS[1] *(2) at chemistry.|She's getting on very well at her job* **7** (used before SUPERLATIVES): *at best|at the best|at worst|at the worst* **8** (used before certain nouns to express states, conditions, feelings, etc.): *at work|at* LIBERTY*|at school* **9** (used with prices) for: *I bought 90 pencils at (a price or cost of) 10 cents each* —see FOR (USAGE) **10** (used before the rate

# Time, real and fast

- Will use discrete time, but not quite like $\mathbb{Z}$
- We will use separate time *scales* but keep `now` at 0
- **real time** is measured in heartbeats or seconds (s)
- Only one step down, to centisecond (cs) scale: already too fast for subliminal events (Ionescu, 2016), fully eliminates motion picture artifacts like strobing, flicker, and motion blur. Human reaction times are on the order of 10-30 cs. Events need to last several cs for discrimination, events not separated by 2-3 cs cannot be told apart by unaided perception. Normal speech sounds take 7-10 cs
- https://bit.ly/43AhWGH
- Timescales are separated by 2-3 ROoMs

# Time, slow and slower

- One step up from real time is kilosecond (ks) or **quarter hour timescale** on which slow motion, such as that of the sun in the sky, is barely perceptable. It is well suited for describing changes in human perceptions regarding both internal states (hunger, sleepiness, tiredness) and external states (temperature, light, weather), for which the second scale, let alone the centisecond scale, are too detailed.
- Next up is **day scale**, which contains 96 quarter-hour (86.4 ks) time slots. The motion of the sun is evident on this scale
- Next is the **season scale**
- Next up is **generation scale** (also: Metonic cycle, Saros)
- Next up is **aeon scale** (few thousand years)
- These days, we can go zeptosecond ($10^{-21}$ s) to zettasecond ($10^{21}$ s) but we are nowhere near the real limits (Planck time $10^{-42}$ s) Poincaré recurrence $e^{10^{120}}$ Planck units)

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