

Universal Semantic Communication

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The Meaning of Bits



- Is this perfect communication?
- What if Alice is trying to send instructions?
 - Aka, an algorithm
 - Does Bob understand the correct algorithm?
 - What if Alice and Bob speak in different (programming) languages?

Part I: Context/Motivation

What? Why?

- Example 1: I have a presentation that used to work well on my last laptop.

- Distance: $\delta(f, g) = \Pr_{x \in D}[f(x) \neq g(x)]$
 $\delta(f, \mathcal{F}) = \min_{g \in \mathcal{F}} \{\delta(f, g)\}$
 $f \approx_{\epsilon} g$ if $\delta(f, g) \leq \epsilon$.
- Definition:
 \mathcal{F} is (q, α) -locally testable if

- I transferred the file to my new laptop and it looks like this.

- Distance: $\pm(f, g) = \Pr_{x \in D}[f(x) \neq g(x)]$
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- ... but the bits are intact!

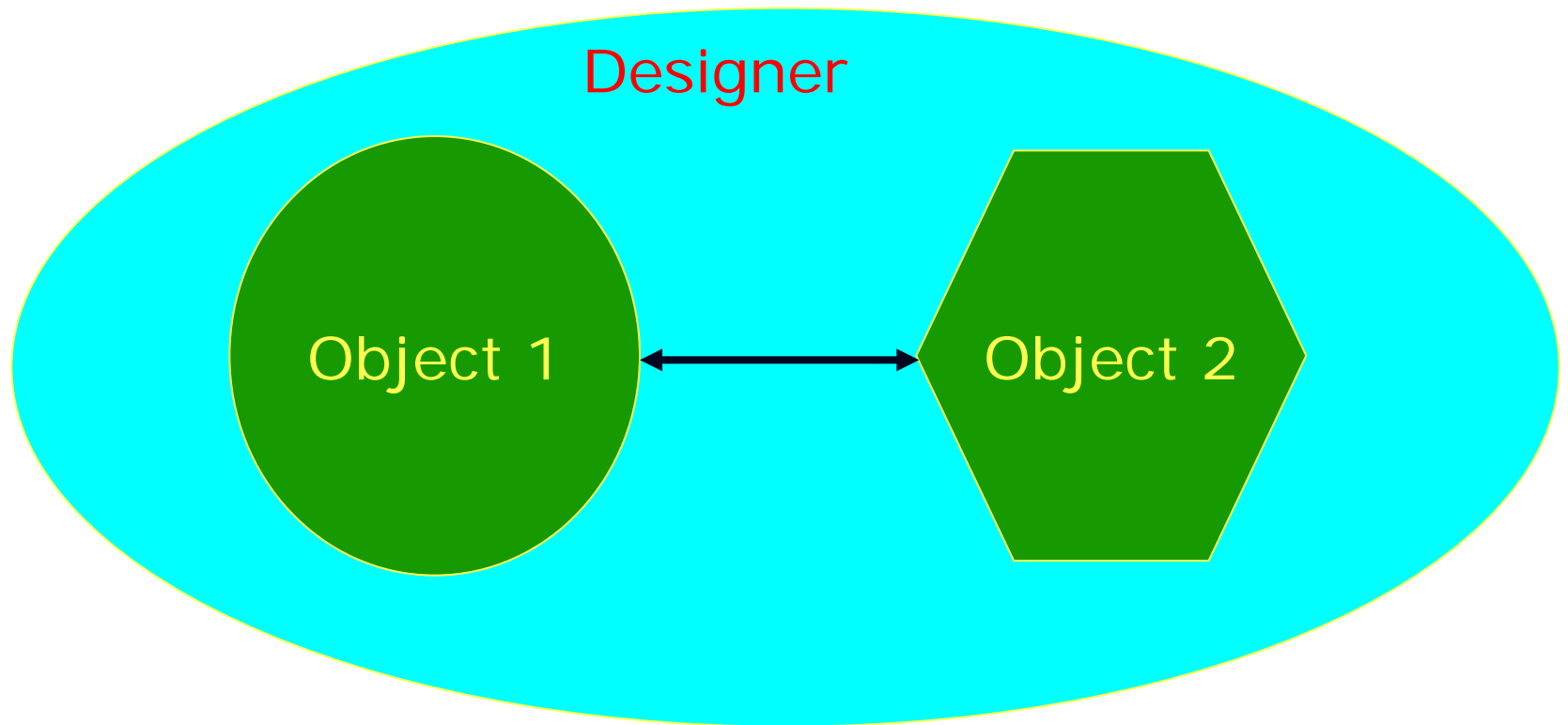
What? Why?

- Example 2: I would like to print some document on some printer.
 - You can do it.
 - I have same permissions as you.
 - But I don't have the printer installed.
- I have the information ... I don't know how to translate to printer's language.

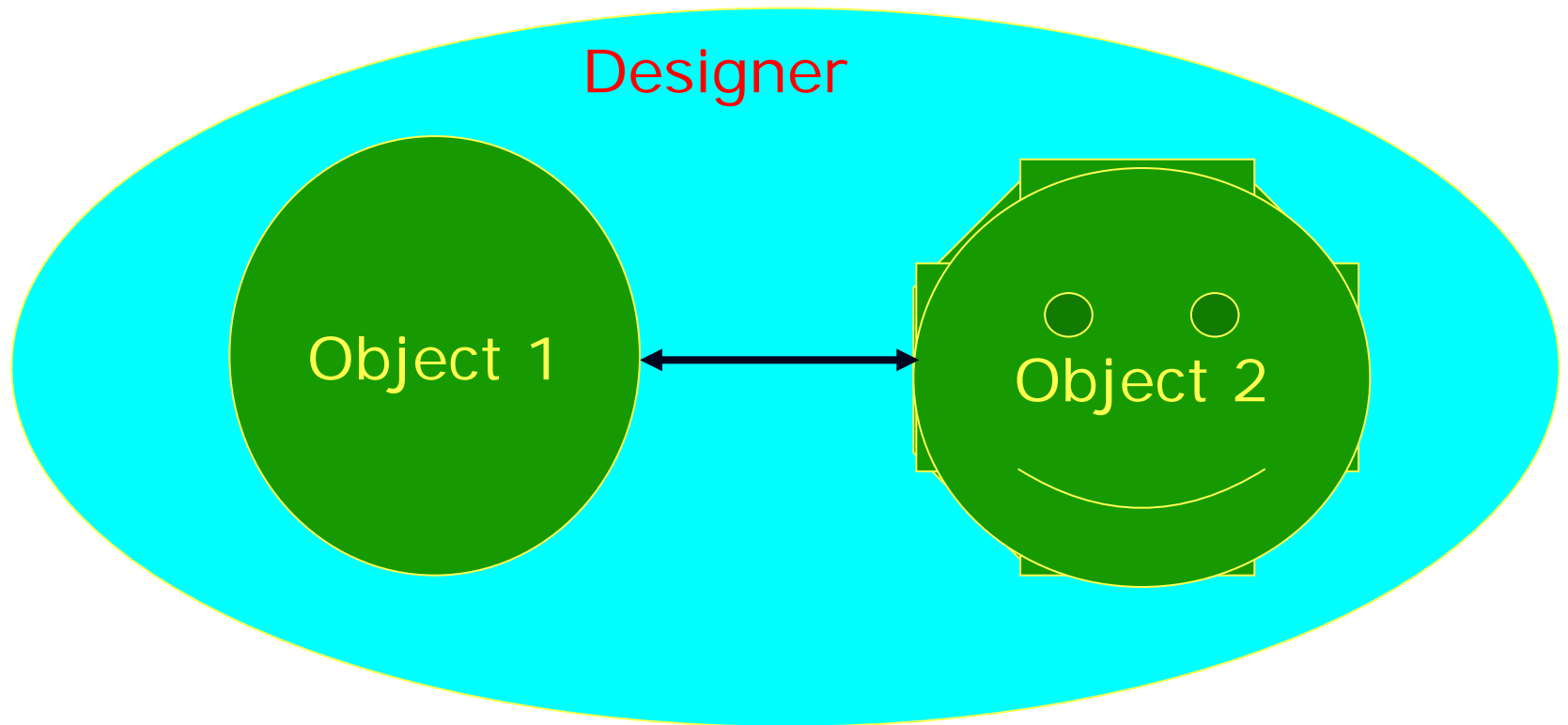
Motivation: Better Computing

- Computers are constantly communicating.
- Networked computers use common languages:
 - Interaction between computers (getting your computer onto internet).
 - Interaction between pieces of software.
 - Interaction between software, data and devices.
- Getting two computing environments to “talk” to each other is getting problematic:
 - time consuming, unreliable, insecure.
- Can we communicate more like humans do?

Classical Paradigm for Protocol Design



New paradigm



Bits vs. their meaning

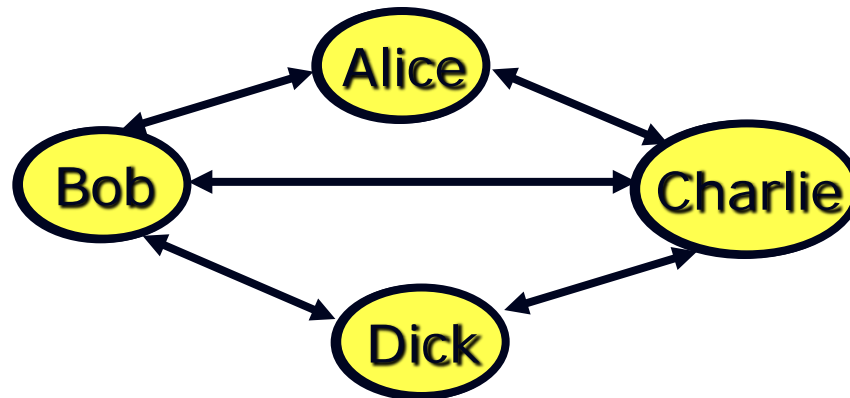
- Say, Alice and Bob know different programming languages. Alice wishes to send an algorithm A to Bob.
 - A = sequence of bits ... (relative to prog. language)
- **Bad News:** Can't be done
 - For every Bob, there exist algorithms A and A' , and Alices, Alice and Alice', such that Alice sending A is indistinguishable (to Bob) from Alice' sending A'
- **Good News:** Need not be done.
 - From Bob's perspective, if A and A' are indistinguishable, then they are equally useful to him.
- What should be communicated? Why?

Aside: Why communicate?

- Classical "Theory of Computing"



- Issues: Time/Space on DFA? Turing machines?
- Modern theory:



- Issues: Reliability, Security, Privacy, Agreement?
- If communication is so problematic, then why not "Not do it"?

Motivations for Communication

- Communicating is painful. There must be some compensating gain.
- What is Bob's Goal?
 - "Control": Wants to alter the state of the environment.
 - "Intellectual": Wants to glean knowledge (about universe/environment).
- Claim: By studying the goals, can enable Bob to overcome linguistic differences (and achieve goal).

Part II: Computational Motivation

Computational Goal for Bob

- Why does Bob want to learn algorithm?
 - Presumably to compute some function f
(A is expected to compute this function.)
 - Lets focus on the function f .
- Setting:
 - Bob is prob. poly time bounded.
 - Alice is computationally unbounded, does not speak same language as Bob, but is "helpful".
 - What kind of functions f ?
 - E.g., uncomputable, PSPACE, NP, P?

Results in Computational Setting

- Feasibility Theorem:
 - Polytime Bob (User) can use Alice's (server's) help to decide languages in PSPACE (using interactive proofs)
- Key definition:
 - **Helpful Server:** Should be able to help some User, starting from any state of mind.
- Infeasibility theorem:
 - Sufficiently diverse class of helpful servers are as bad as malicious servers.
- Contrast with IP:
 - If User is willing to make finitely many mistakes, then can solve every unary decidable language

Principal Criticisms

- Solution is no good: Enumerates "interpreters".
 - This is too slow.
 - Approach distinguishes **right/wrong**; does not solve search problem.
 - Search problem needs new definitions to allow better efficiency.
- Problem is not the right one.
 - Computation is not the goal of communication. Who wants to talk to a PSPACE-complete server?



Next part of talk

Part III: Generic Goals

Generic Communication [Goldreich, J., S.]

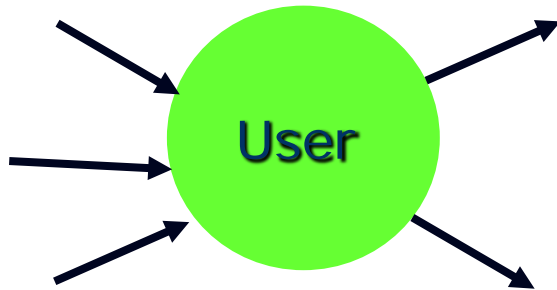
- Still has goals. Goals more diverse.
 - Should be studied; defined formally.
- Major types:
 - Control, e.g.
 - Laptop wants to print on printer.
 - Buy something on Amazon.
 - Sensing/Informational:
 - Computing some (hard) function.
 - Learning/Teaching.
 - Coming to this talk.
 - Mix of the two.

Universal Semantics in Generic Setting?

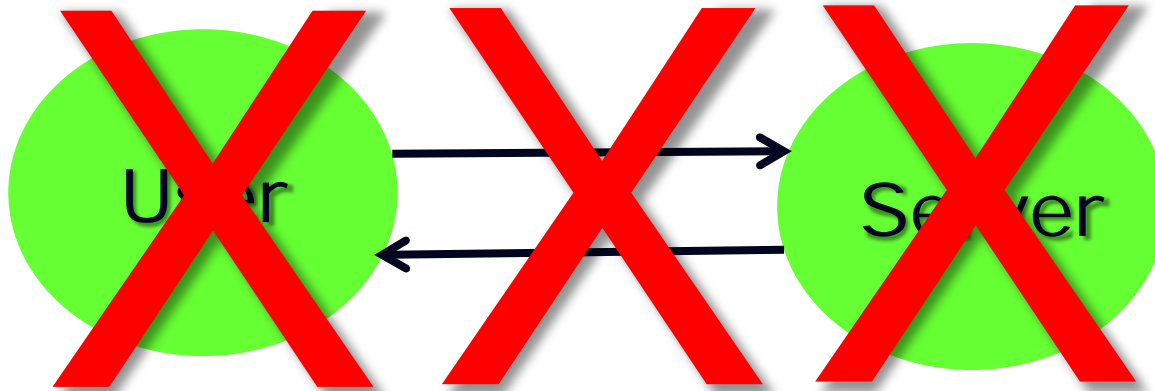
- Can we still achieve goal without knowing common language?
 - Seems feasible ...
 - If user can detect whether goal is being achieved (or progress is being made).
 - Just need to define
 - Sensing Progress?
 - Helpful + Universal?
 - ...
 - Goal?
 - User?

Modelling User/Interacting agents

- (standard AI model)
- User has state and input/output wires.
 - Defined by the map from current state and input signals to new state and output signals.



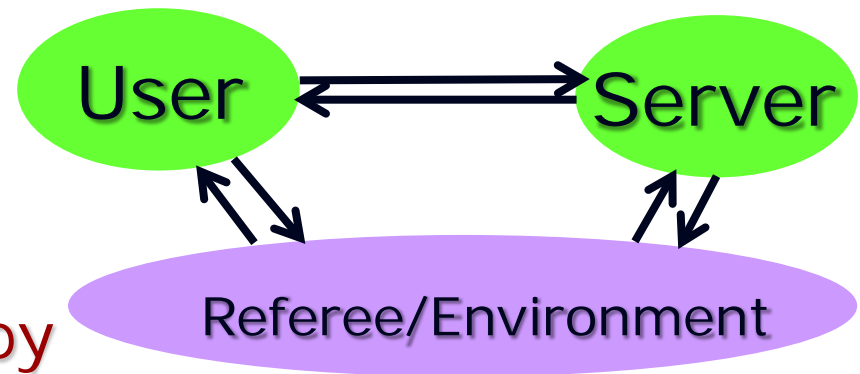
Generic Goal?



- Goal = function of ?
 - User? – But user wishes to change actions to achieve universality!
 - Server? – But server also may change behaviour to be helpful!
 - Transcript of interaction? – How do we account for the many different languages?

Generic Goals

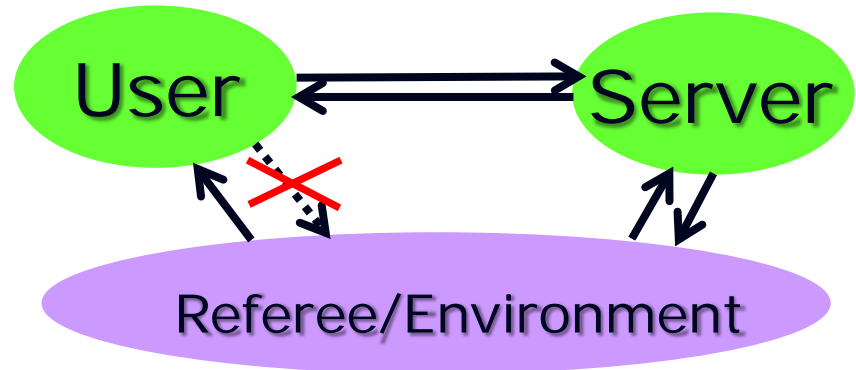
- Key Idea: Introduce 3rd entity: Referee
 - Poses tasks to user.
 - Judges success.



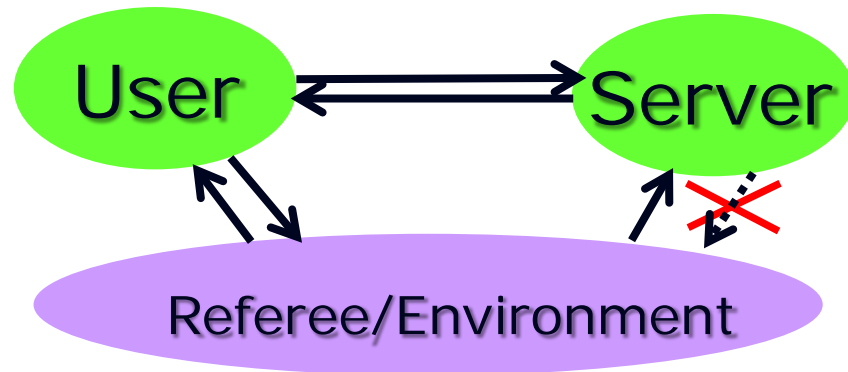
- Generic Goal specified by
 - Referee (just another agent)
 - Boolean Function determining if the state evolution of the referee reflects successful achievement of goal.
 - Class of users/servers.

Generic Goals

- Pure Control



- Pure Informational



Sensing & Universality

- To achieve goal, User should be able to sense progress.
 - I.e., user should be able to compute a function that (possibly with some delay, errors) reflects achievement of goals.
- Generalization of positive result:
 - Generic goals (with technical conditions) universally achievable if \exists sensing function.
- Generalization of negative result:
 - If non-trivial generic goal is achieved with sufficiently rich class of helpful servers, then it is safely achieved with every server.

Conclusions

- Is there a universal communication protocol?
 - No! (All functions vs. PSPACE-computable functions).
 - But can achieve sensible goals universally.
 - But ... diversity of goals may be the barrier to universality.
- Goals of communication.
 - Should be studied more.
 - Suggests good heuristics for protocol design:
 - Server = Helpful?
 - User = Sensing?

Language Learning

- Meaning = end effect of communication.
 - [Dewey 1920s, Wittgenstein 1950s]
- What would make learning more efficient?
 - What assumptions about "language"?
 - How to do encapsulate it as "class" restrictions on users/servers.
 - What learning procedures are efficient?
- Time to get back to meaningful conversation!

References

- Juba & S.
 - ECCC TR07-084: <http://eccc.uni-trier.de/report/2007/084/>

- Goldreich, Juba & S.
 - ECCC TR09-075: <http://eccc.uni-trier.de/report/2009/075/>

Why is the paper so long?

- Attempts to model
 - Infinite sequence of interactions
 - Probabilistic Users
 - Nondeterministic environment/referee
 - Leads to diversity of possible definitions.
- Soon to come:
 - A briefer writeup focussing on one-shot goals.