

NSWI166 Introduction to recommender systems and user preferences

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8/12 Challenge Response Framework
A general Framework for modeling and evaluation of model-quality

Nástin obsahu

- Dosavadní přehled témat – vše pro zákazníka
- Společný jmenovatel – modelování reality
- Další příklady modelování reality
- Potřeba abstraktního rámce pro modelování reality a vyhodnocení kvality modelu
 - Challenge - Response Framework, situations, reductions
- Model kvality e-shopu, +++

Motivation + L. Peska

NF
Valuing
Manifesting universal values and valuing people

Possible

NT
Visioning
Putting people with ideas to an optimistic future



ENFJ Teacher Smooth talking charmers. Very inspiring & motivational. Often cheer. People pleasers & persuaders. Great salespeople. Very relationship-oriented. Like to motivate groups.	INFJ Counselor Work is to inspire others to achieve great things. Great awareness of human possibilities. Serious academicians. Often professors at other universities to a religious order.	INTJ Mastermind If they say they are going to do something, they do it. Likely to be corporate leaders, scientists. Believe everything has room for improvement. Support planners and necessities of systems.	ENTJ Field Marshall Very leadership-oriented. Likely to be top executives, business persons. Big on success. Influencing, ineffective. Take charge people. Can be over-whelming to less outgoing types.
ENFP Champion Second only to ESTPs for fun. Want lives filled with excitement and romance. Very enthusiastic and creative. Often teachers, artists, writers. Great need for diversity and change.	INFP Healer Noble servants aiding society, different from ISFPs. They try to be like John Lennon. Often psychologists or counsellors. Want to save the whales and rainforest.	INTP Architect Dissect analysts of problems to be solved. Often physicists, scientists. Most sort of types. Critical thinkers.	ENTP Inventor Want one exciting challenge after another. Love to problem-solve. Good at analysis, compare themselves full of ingenuity and ideas. Often involved in computer, systems analysis, design.
ESFP Performer Number one in fun and enthusiasm. Always invite ESTPs to your party. The most generous of all types. Warm, friendly, vibrant people. Excellent at customer service.	ISFP Composer Quietly harmonious with world. Very observing, benevolent. Inclined toward work with people in need. Work for social problems of the immediate such as homeless, stopping hunger.	ISTP Operator Naturally to try anything once. Flashed with the rush of life. Self-disciplined. A love of facts and the utility of the other. Inclined toward mechanical devices, can take apart & reassemble anything.	ESTP Promoter Excitement seekers. Never had more alive than when talking. Like. Great negotiators on the front end. Excellent entrepreneurial & entrepreneurial capabilities if someone else follows through.
ESFJ Provider Hosts & business. Generousness of this type makes them excellent at entertaining, coordinating. May be teachers, nurses. Very conscious of appearances, should should's.	ISFJ Protector A high sense of duty. Guardians of family tradition. Often found in traditional helping professions including nursing, elementary education, etc.	ISTJ Inspector Diers of what should be done. Masters at completing practical details and adding finishing touches. Get it done people. Super administrators. Duty bound & obligated, often military.	ESTJ Supervisor Administrative, systematic of strength in community. Legal matters, parents, employees. Often promoted to management positions. Dependable, consistent, straightforward.

Personal

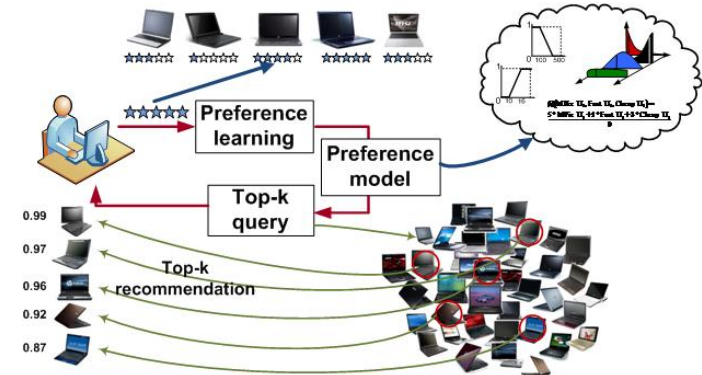
Logical

SF
Relating
Including and building trustworthiness

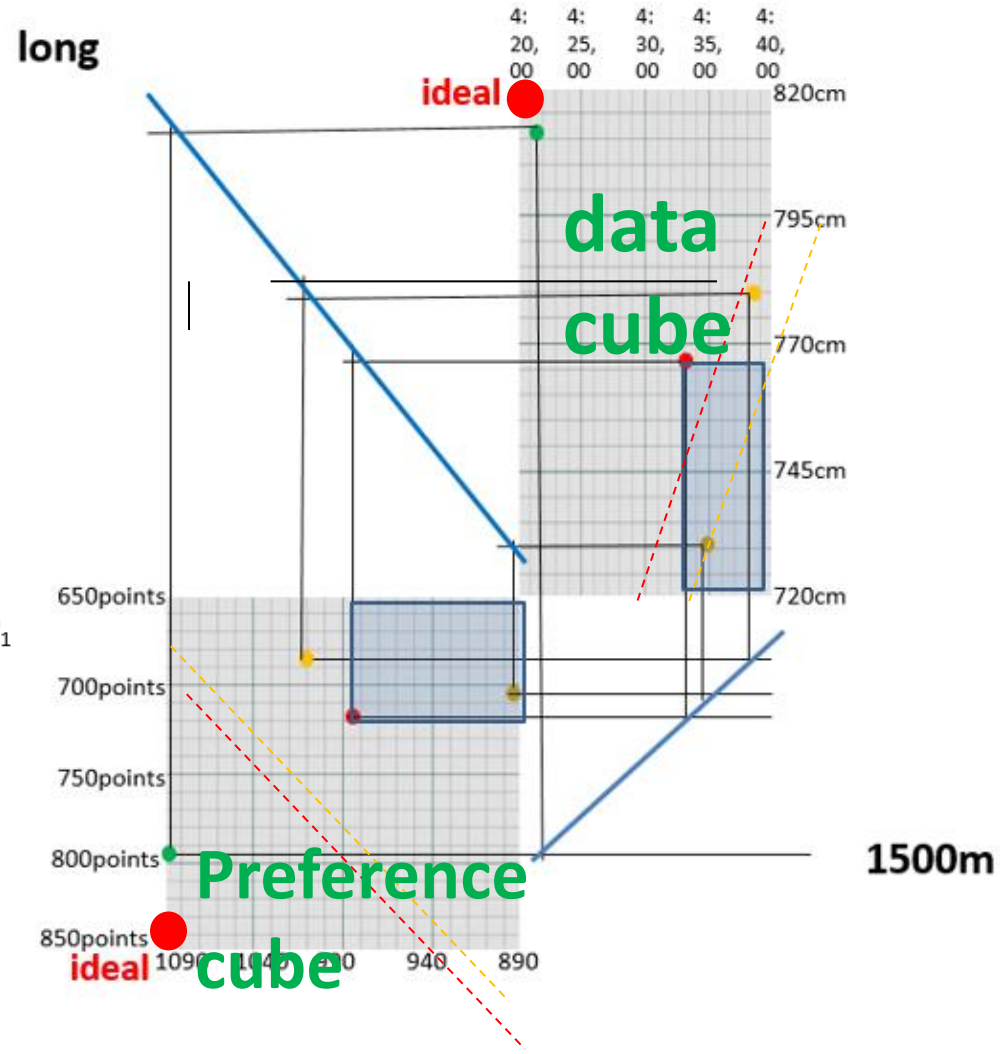
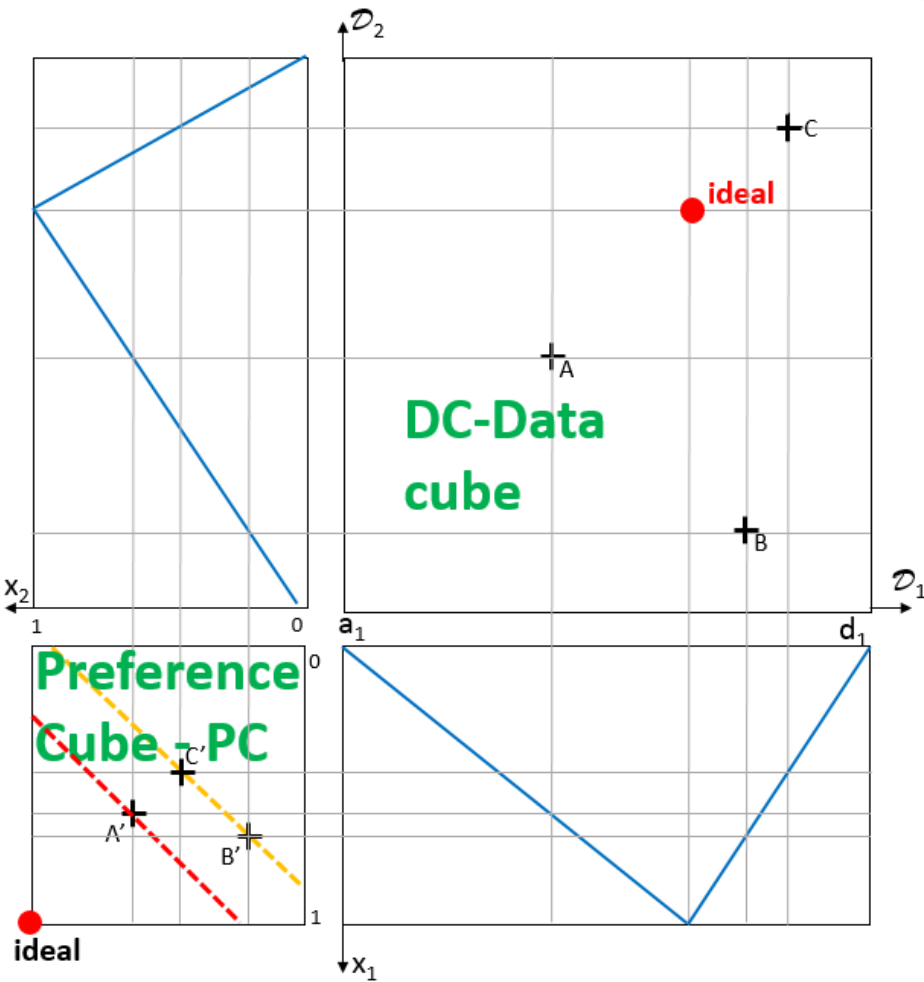
Present

ST
Directing
Action from a strategic perspective

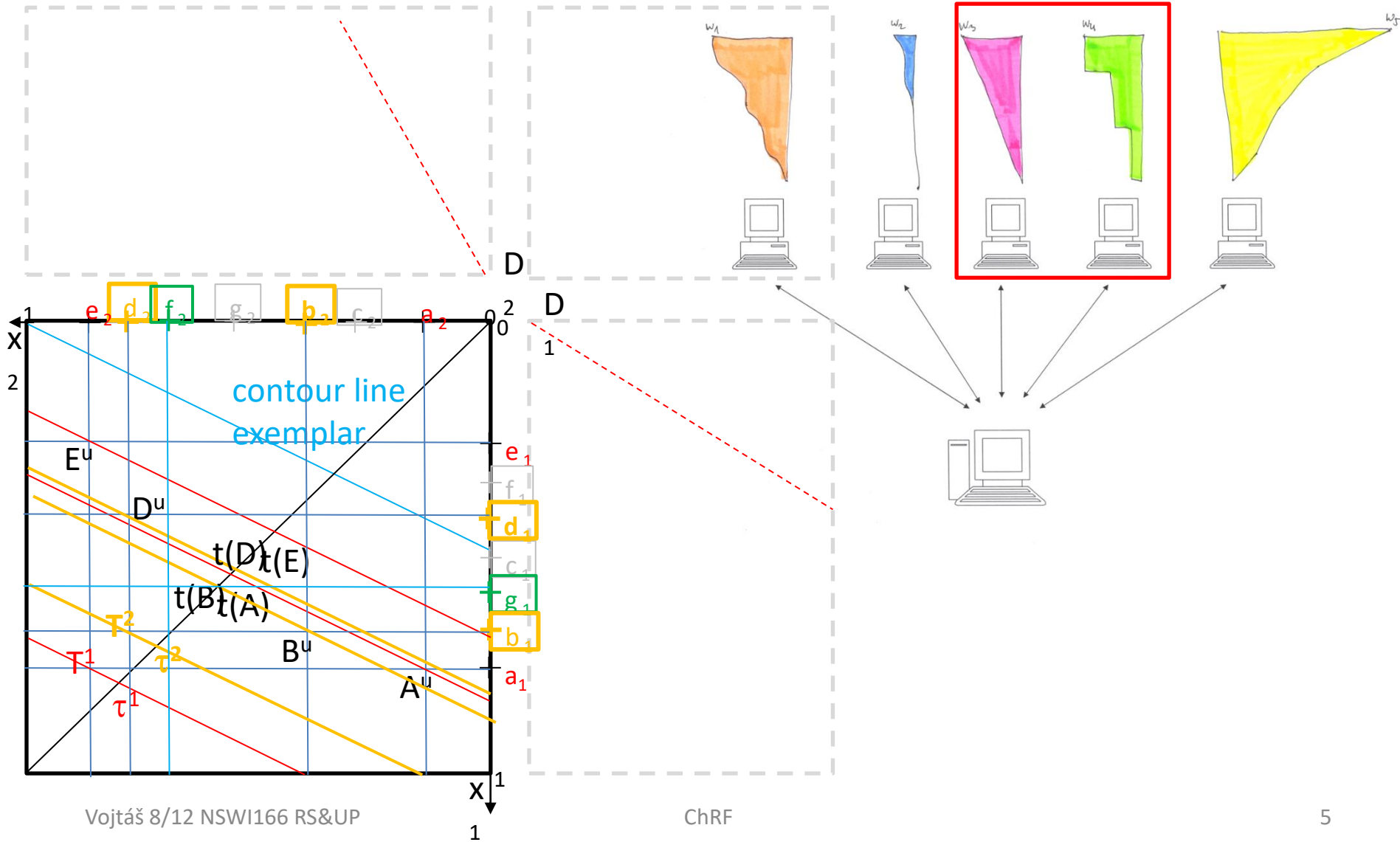
Feedback values:
Dwell time: 16.8 sec
Mouse moving time: 1.8 sec
Travelled distance: 2009px



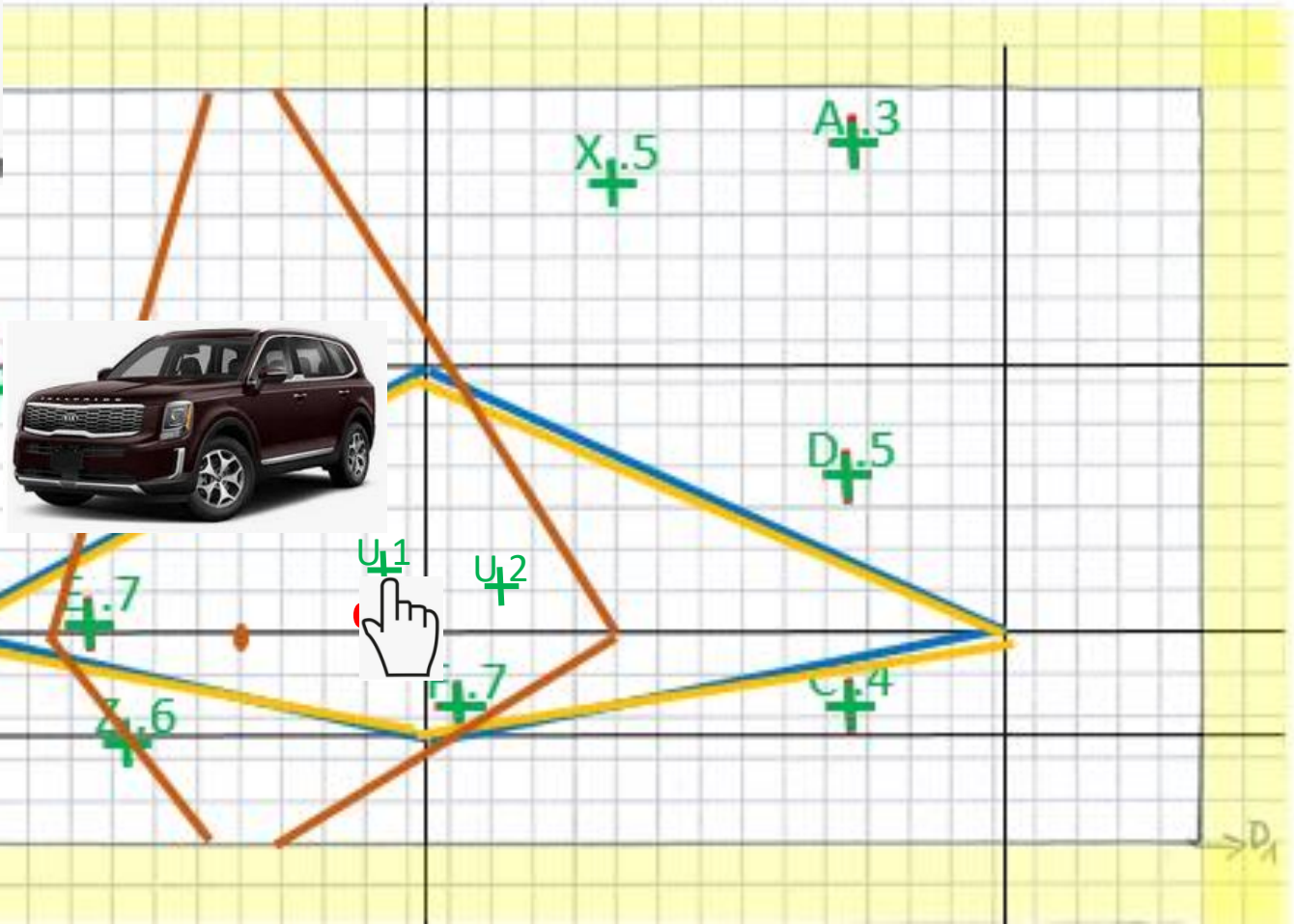
Topic 1 (5/12). Representation



Topic 2 (6/12). Efficient top-k querying



Topic 3 (7/12). Customer's preference learning



all

Vojtáš 8/12 NSWI166 RS&UP

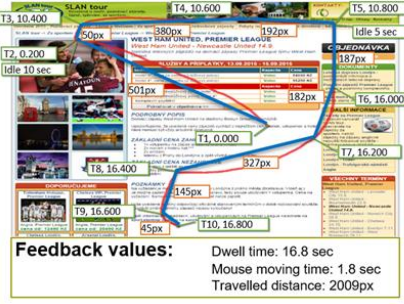
ChRF



Your best
seen

ideal

NF Valuing Manufacturing universal values and valuing people	Possible				NT Visioning Putting people and ideas in an optimistic future
ENFJ Teacher	INFJ Counselor	INTJ Mastermind	ENTJ Field Marshall		
ENFP Champion	INFP Healer	INTP Architect	ENTP Inventor		
ESFP Performer	ISFP Composer	ISTP Operator	ESTP Promoter	Logical	
ESFJ Provider	ISFJ Protector	ISTJ Inspector	ESTJ Supervisor		
SF Relating Including and building trustworthiness	Present				ST Directing Action from a strategic perspective



Google design thinking



Empathy



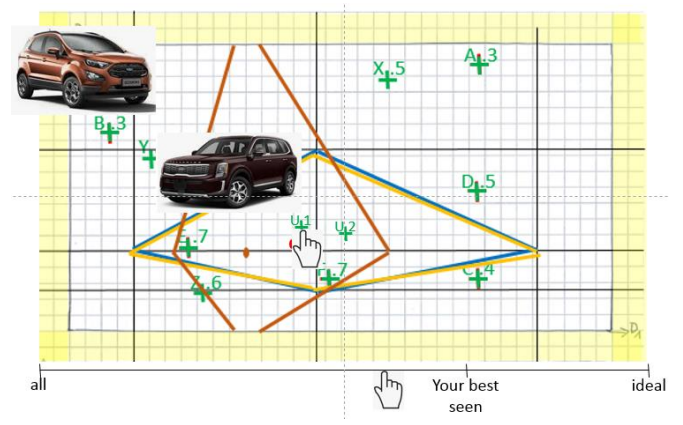
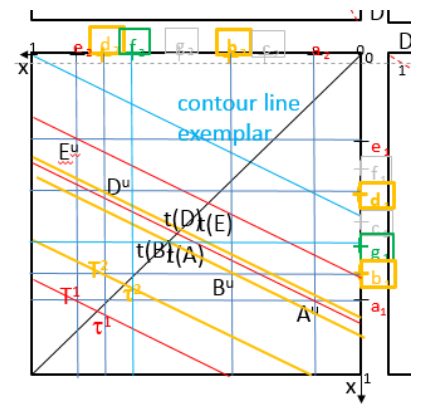
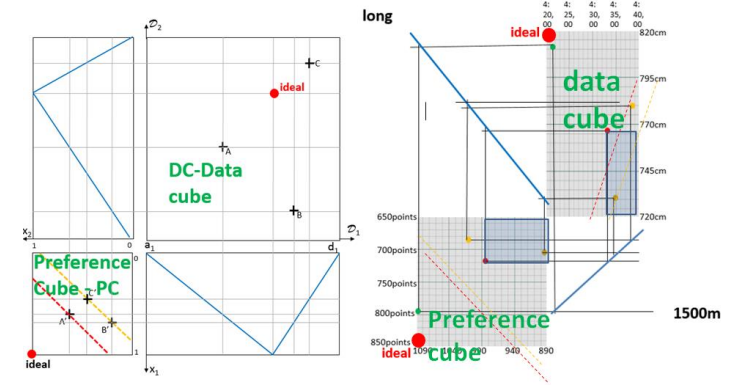
Expansive thinking



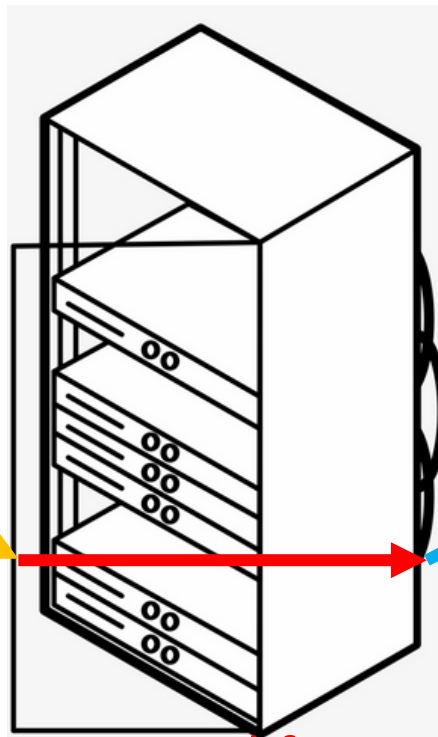
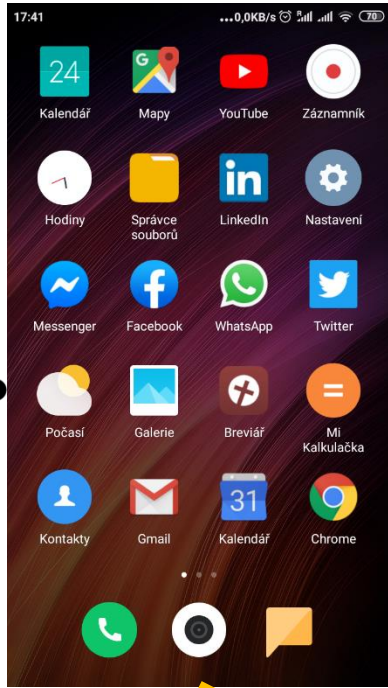
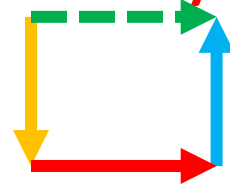
Experimentation

or Lean Startup methodology?

FROM REALITY TO MODEL



Weather forecast – reality to model reduction

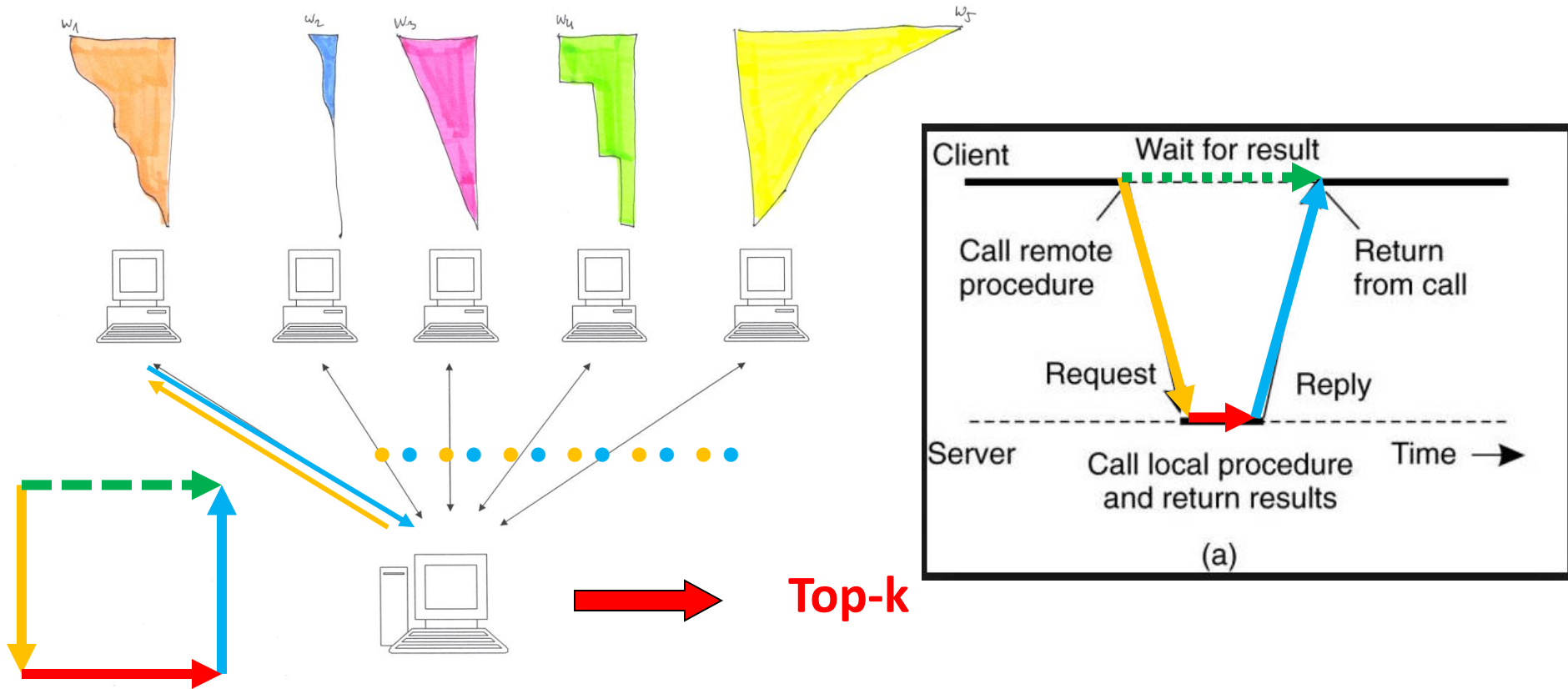


Computed forecast

Problem instance:
Prague, August 9th
2019, reduction

Computed solution
visual intuitive
transformation /
translation

Client-server / middleware – web service, ...



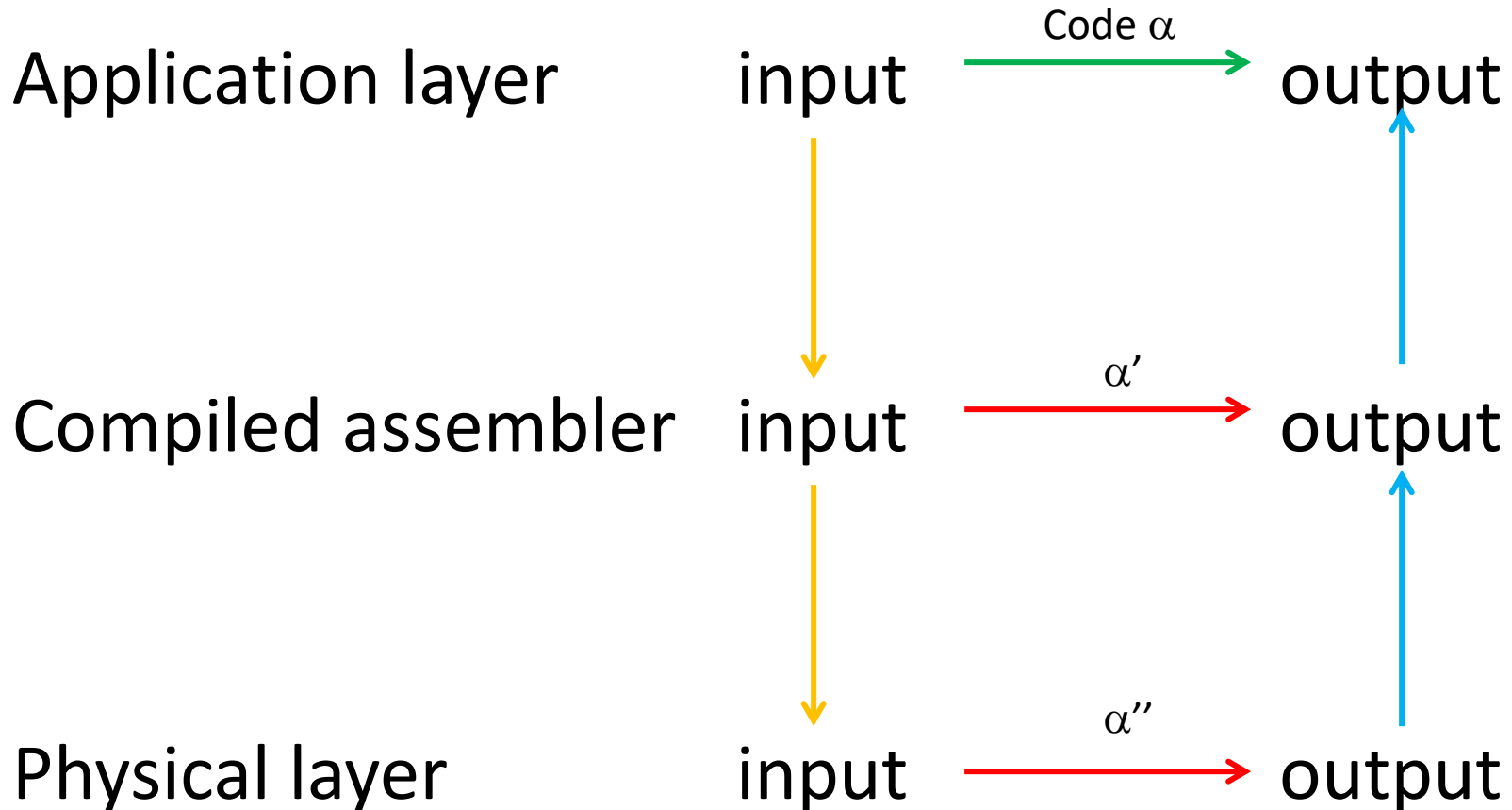
What is the challenge? User expects top-k relevant answers.
Client can finish computation.

How can we meet the challenge?

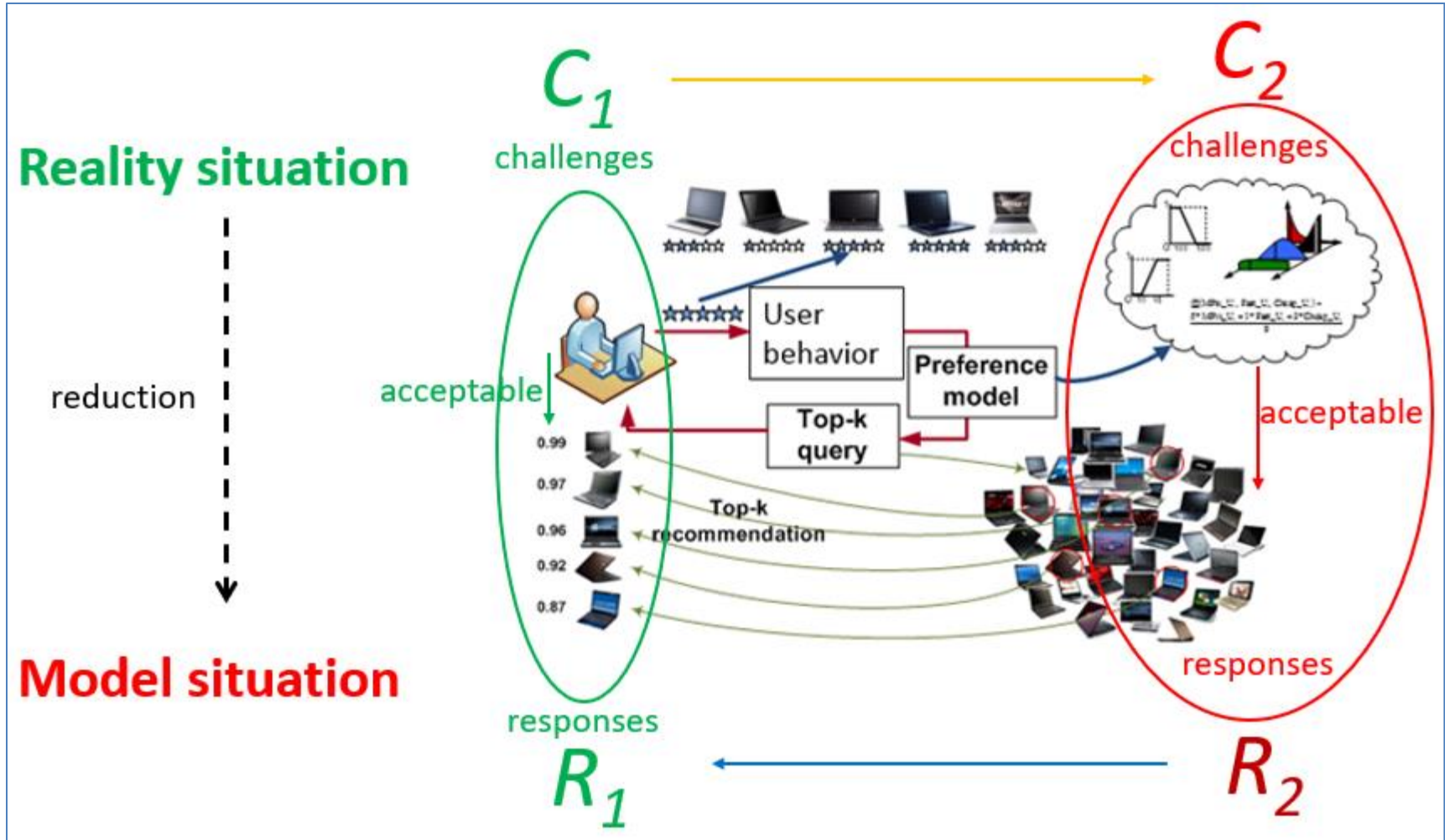
Asking for/providing/accepting-using response

Reality \rightarrow model, process, ...

One needs help \rightarrow the other will provide assistance



Recommendation as reality to model reduction



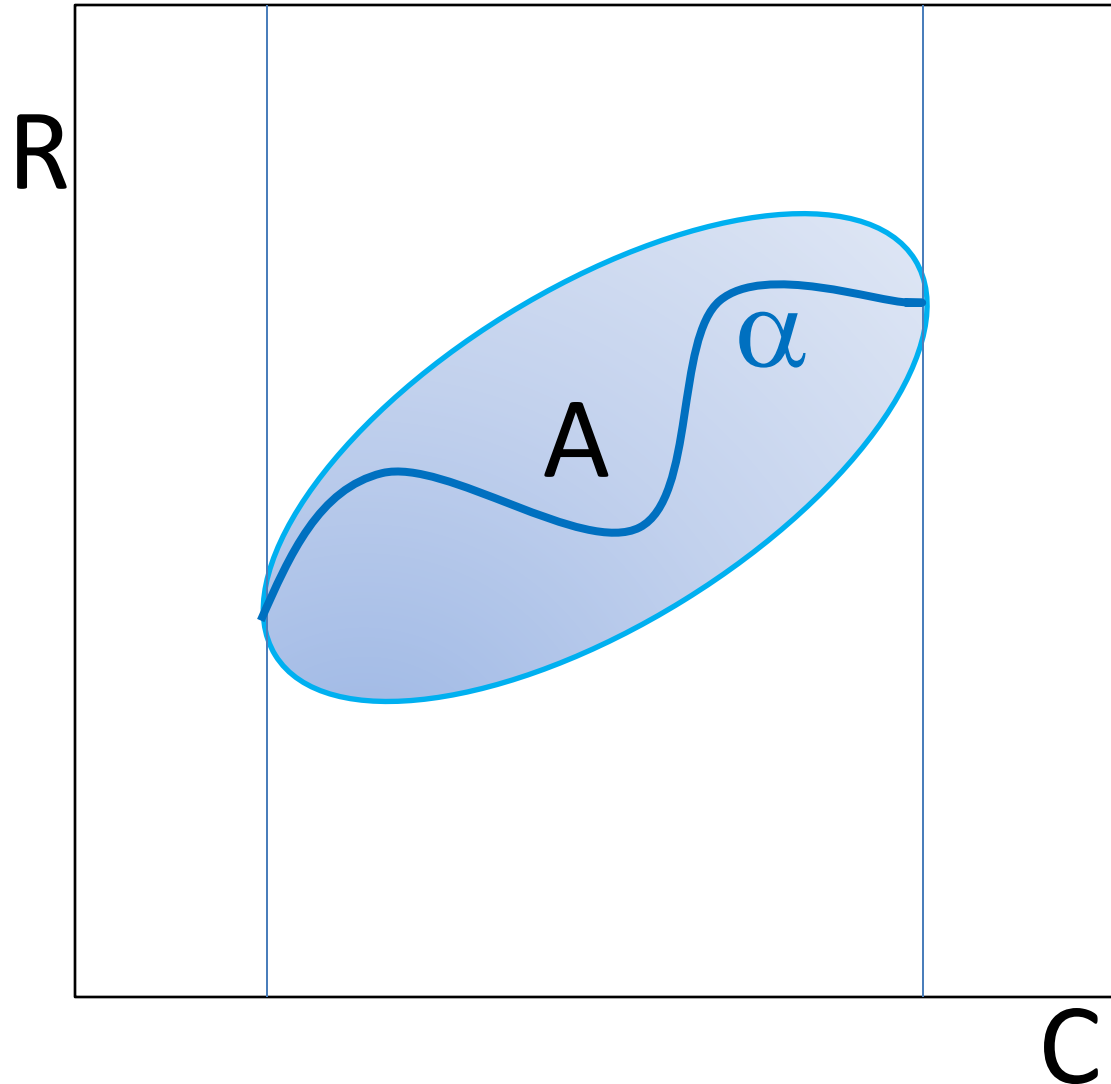
Challenge-Response situation ChRS

Let us have a set **C** of **challenges** and a set **R** **responses**.

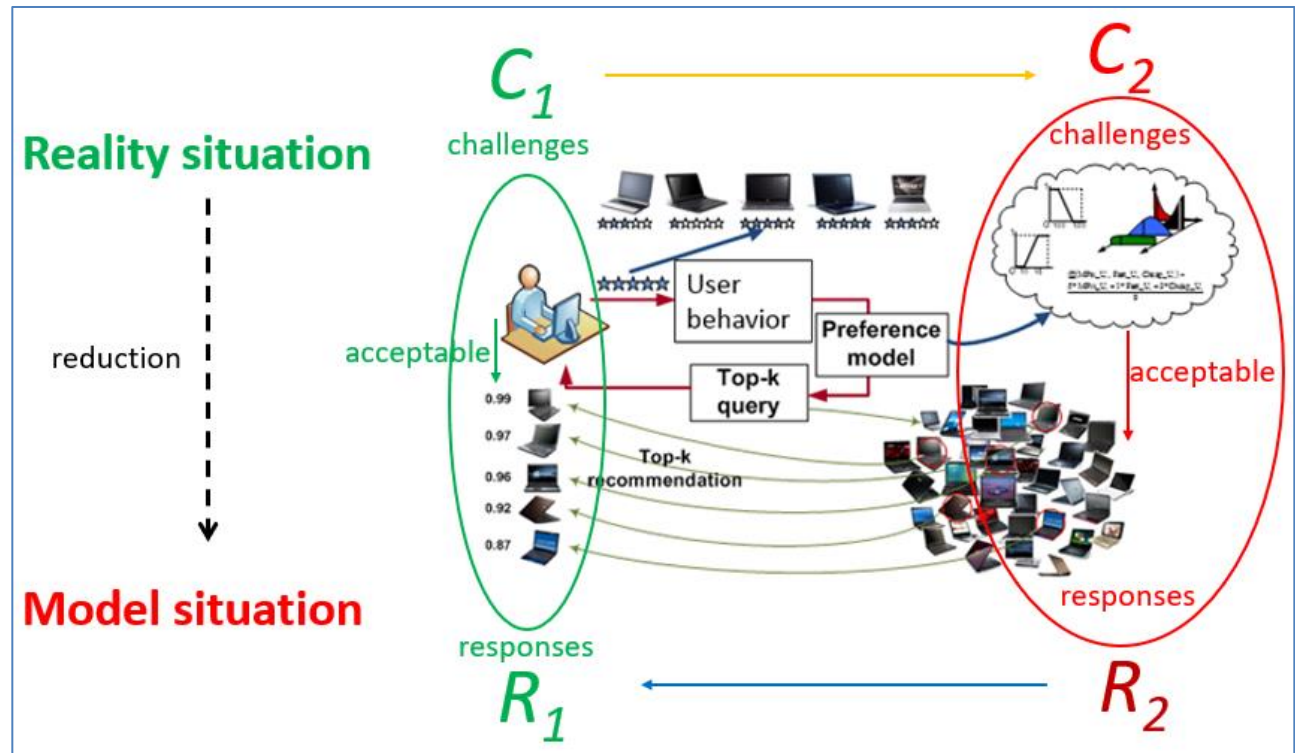
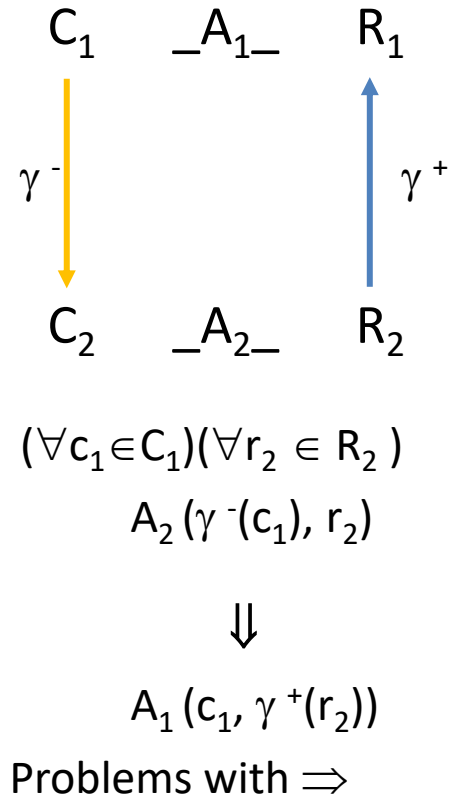
A binary relation $A \subseteq C \times R$ represents **acceptability** of a specific response r to a specific challenge c , denoted $A(c, r)$.

Eventually A can be a program, process, then denoted α ,

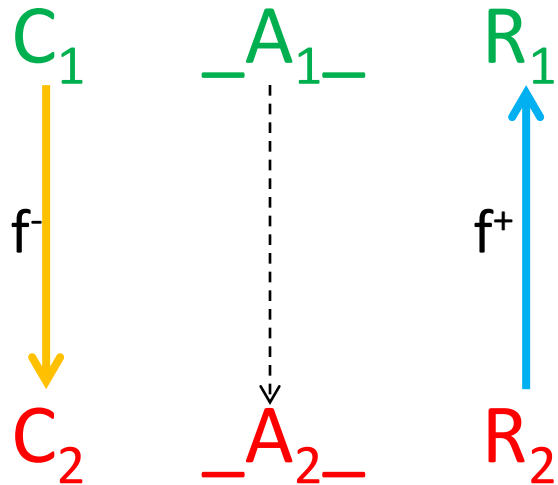
- α can represent either
- an optimal response, or
 - an algorithm



ChRF Challenge-Response Framework



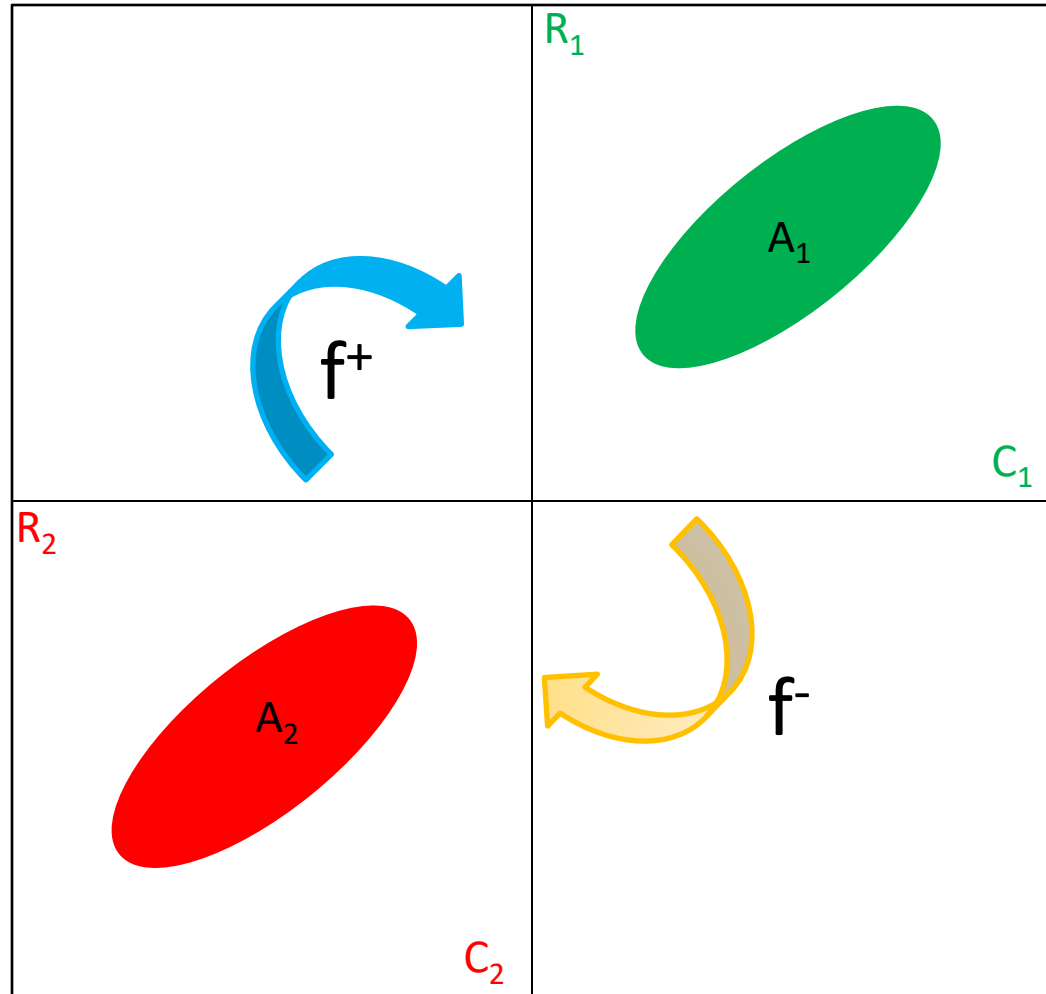
Challenge-Response reduction ChRR



$(\forall c_1 \in C_1)(\forall r_2 \in R_2)$
IF $A_2(f^-(c_1), r_2)$

Then

$A_1(c_1, f^+(r_2))$



ChRF = ChRS + ChRR formally

Challenge Response Situation **ChRS** $S = (C, R, A)$ consists of a set C of challenges, set of responses R and an acceptability relation $A \subseteq C \times R$ (can be preferential, probabilistic, ...)

For an $c \in C, r \in R$ we read $A(c, r)$ as “ r is an acceptable response (in some degree) for challenge c ”, or also “response r meets challenge c ”

Challenge Response Reduction **ChRR** of a situation $S_1 = (C_1, R_1, A_1)$ to a situation $S_2 = (C_2, R_2, A_2)$ consists of a pair of functions (f^-, f^+) such that

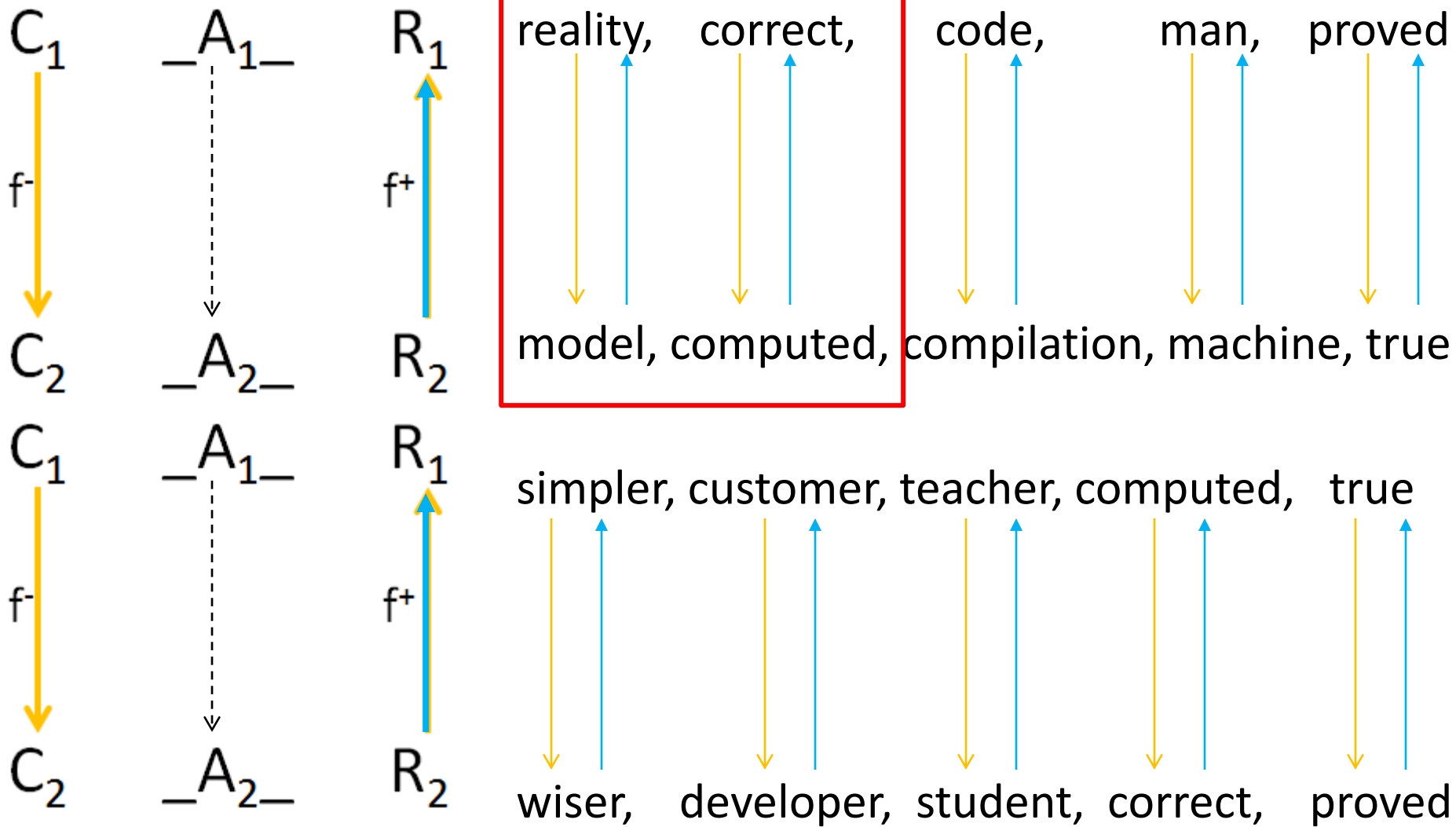
$$f^-: C_1 \rightarrow C_2,$$

$f^+: R_2 \rightarrow R_1$, such that following holds:

$$(\forall c_1 \in C_1)(\forall r_2 \in R_2)(A_2(f^-(c_1), r_2) \Rightarrow A_1(c_1, f^+(r_2))) \quad (*)$$

We will deal later with mathematical problem of “ $0 \rightarrow *$ ”, so far, we can understand it procedurally

Various CRR instances

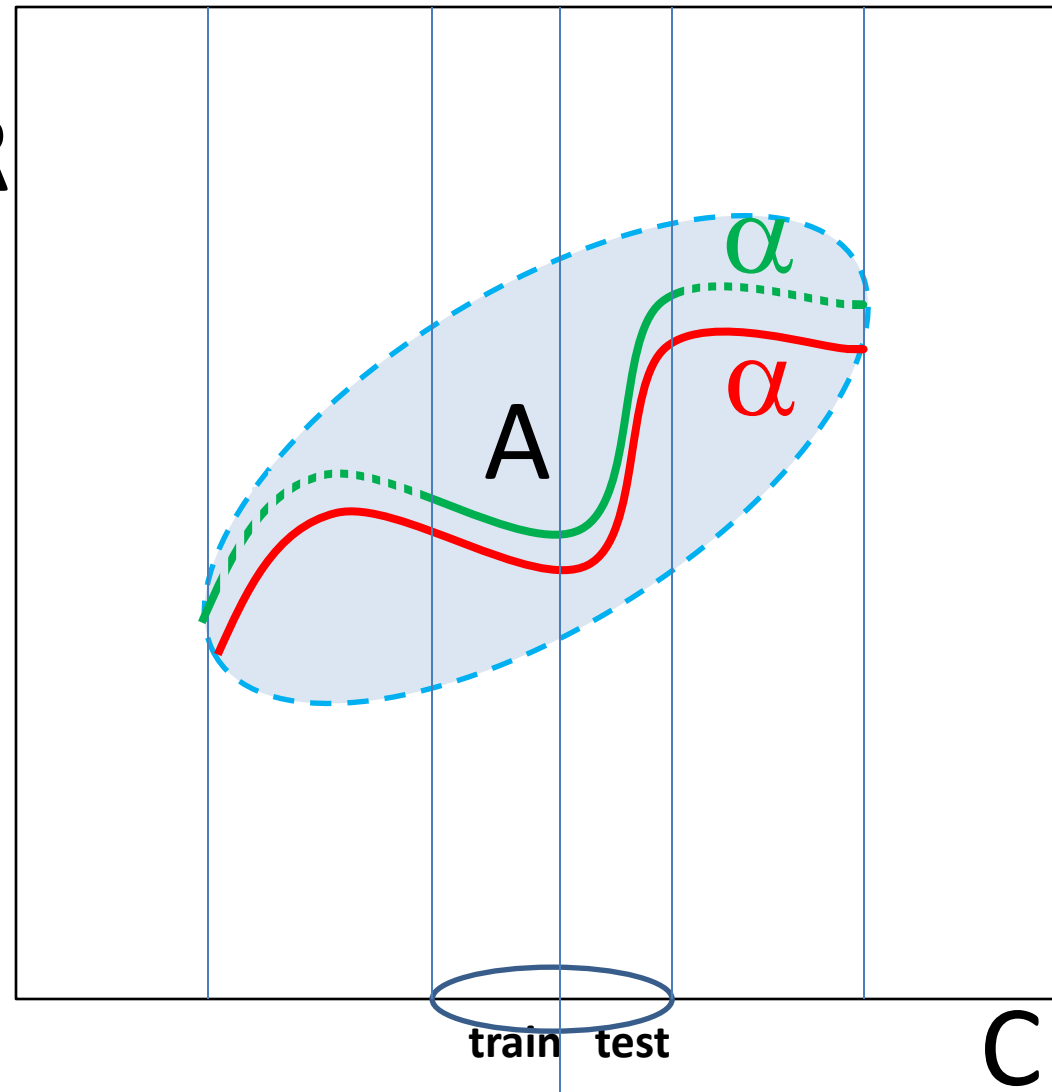


Partial Challenge-Response situation for learning

In learning set of challenges C (vector of independent variables \underline{x}) and the set of responses R (dependent variable y) are not known in total – we know only train and test data (role of extra element α will be discussed later).

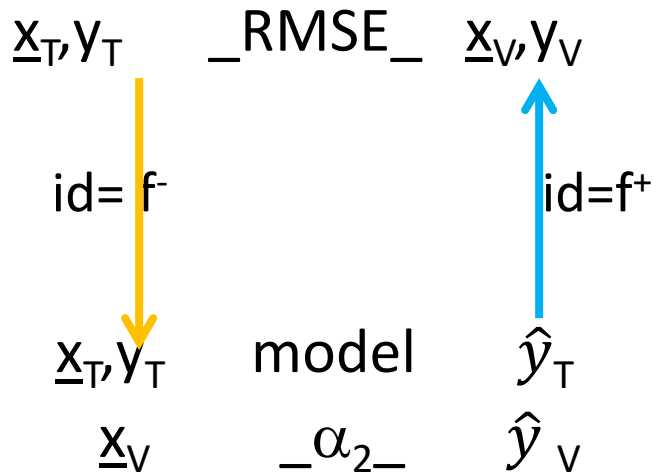
Binary acceptability relation $A \subseteq C \times R$ (selector α) is also known only on train+test).

The task is to find α , as good as possible



Learning from data (\underline{x}, y) gives (\underline{x}, \hat{y})

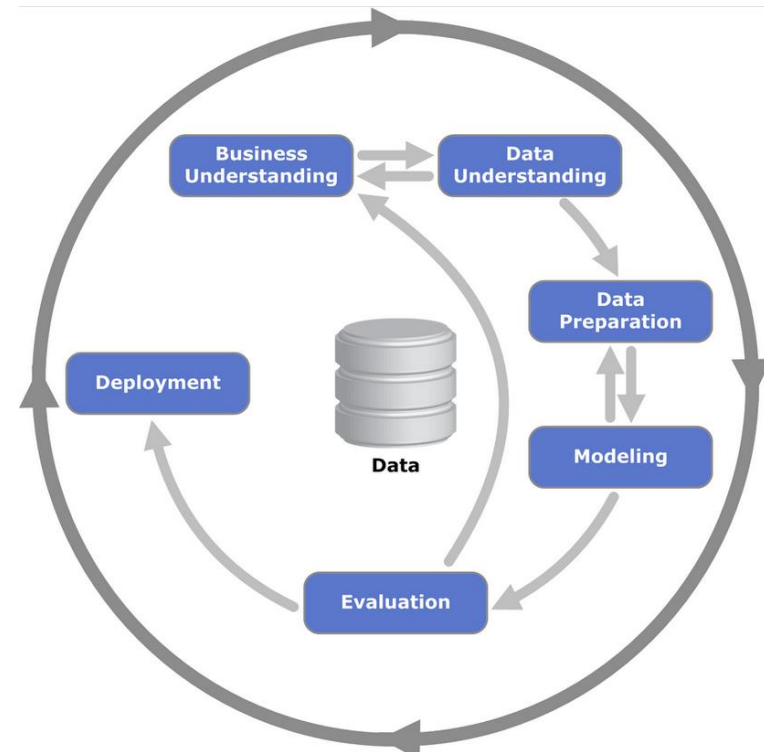
T-train, V-validate



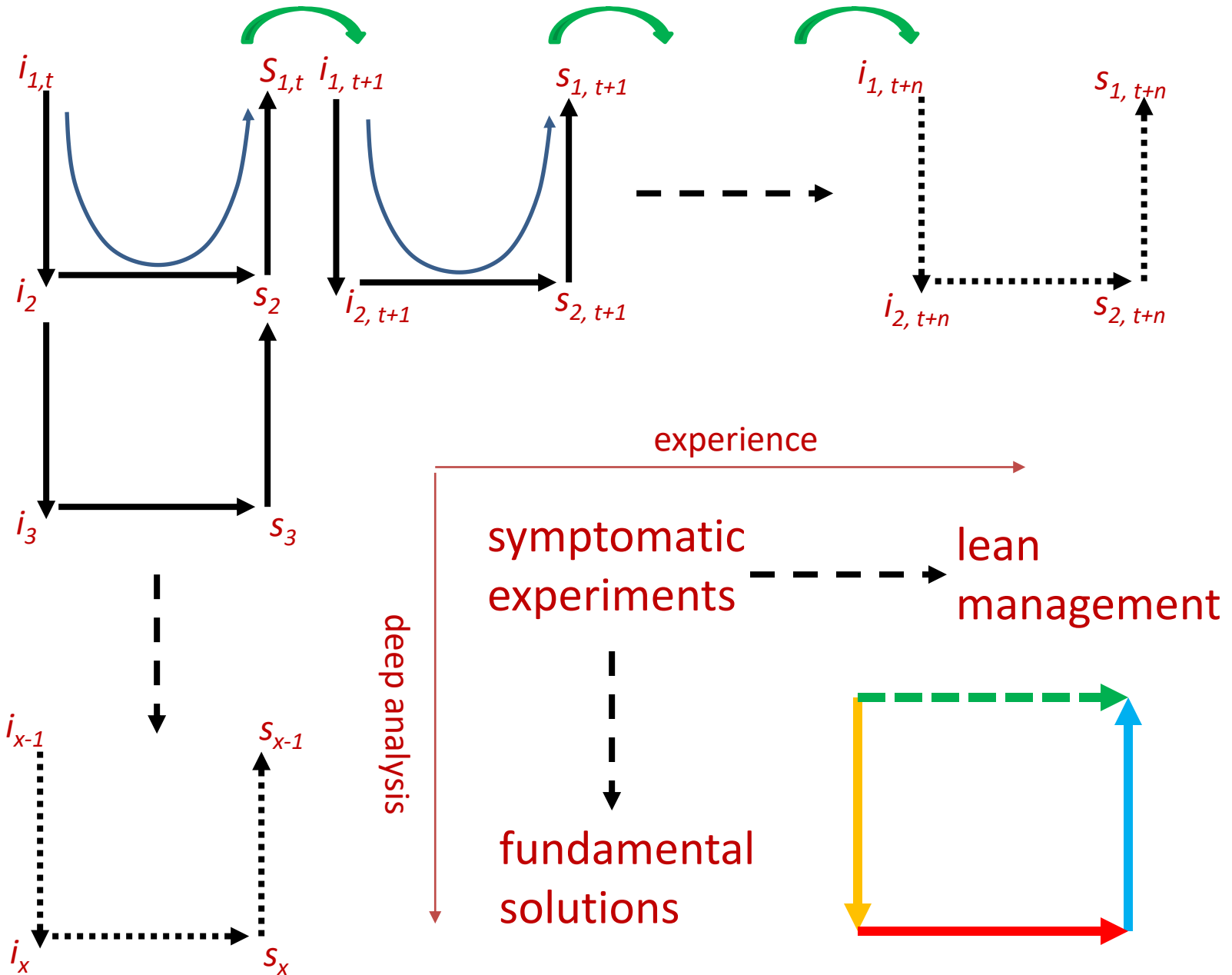
Whenever cross validation gives satisfactory results, then

$\alpha_2(\underline{x}_{\text{valid}}) = \hat{y}_{\text{valid}}$ is sent to be compared with y_{valid} . $\text{RMSE}(y_{\text{valid}}, \hat{y}_{\text{valid}})$ can be considered the truth degree of this ChRR

Complex model
CRISP-DM



Learning and management strategies

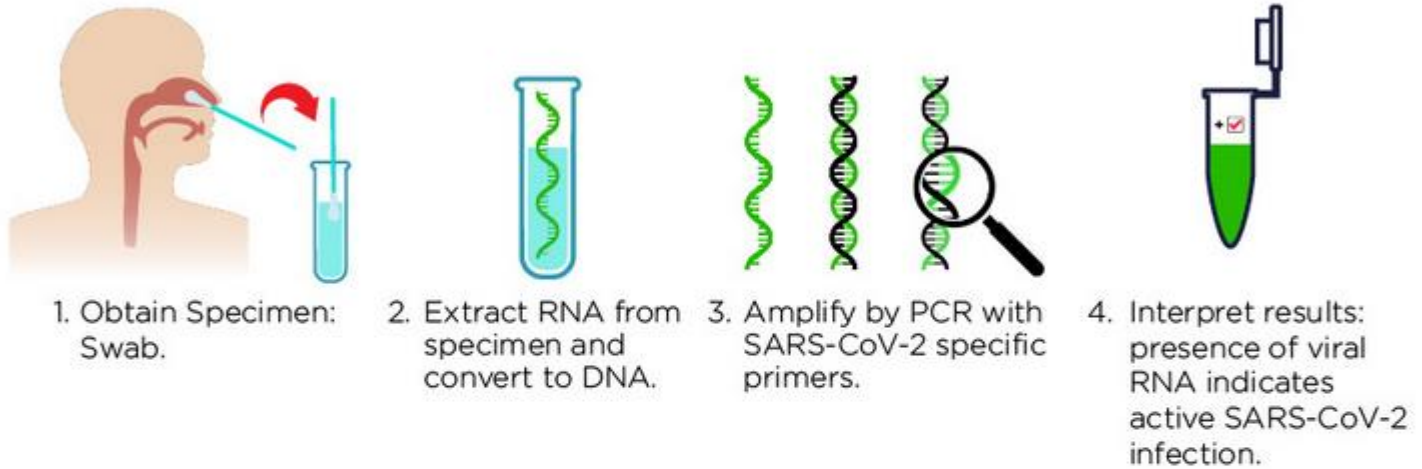


Comparison of COVID-19 Molecular and Antibody Tests

What is reality?
Some tests represent reality

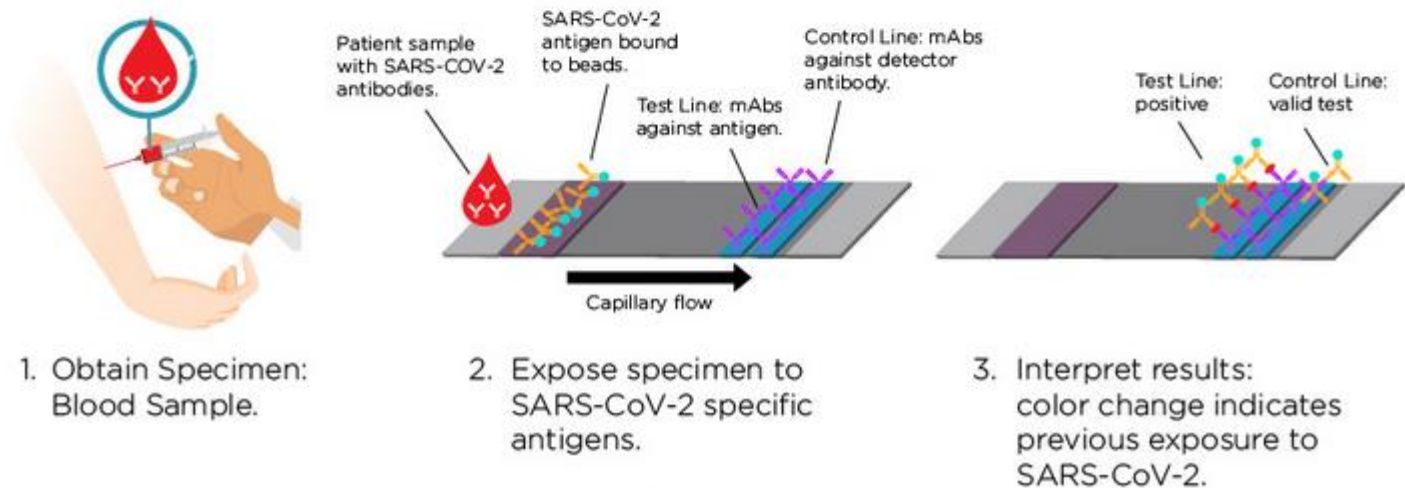
Molecular Tests (Nucleic Acid Detection)

Diagnose active SARS-CoV-2 infections

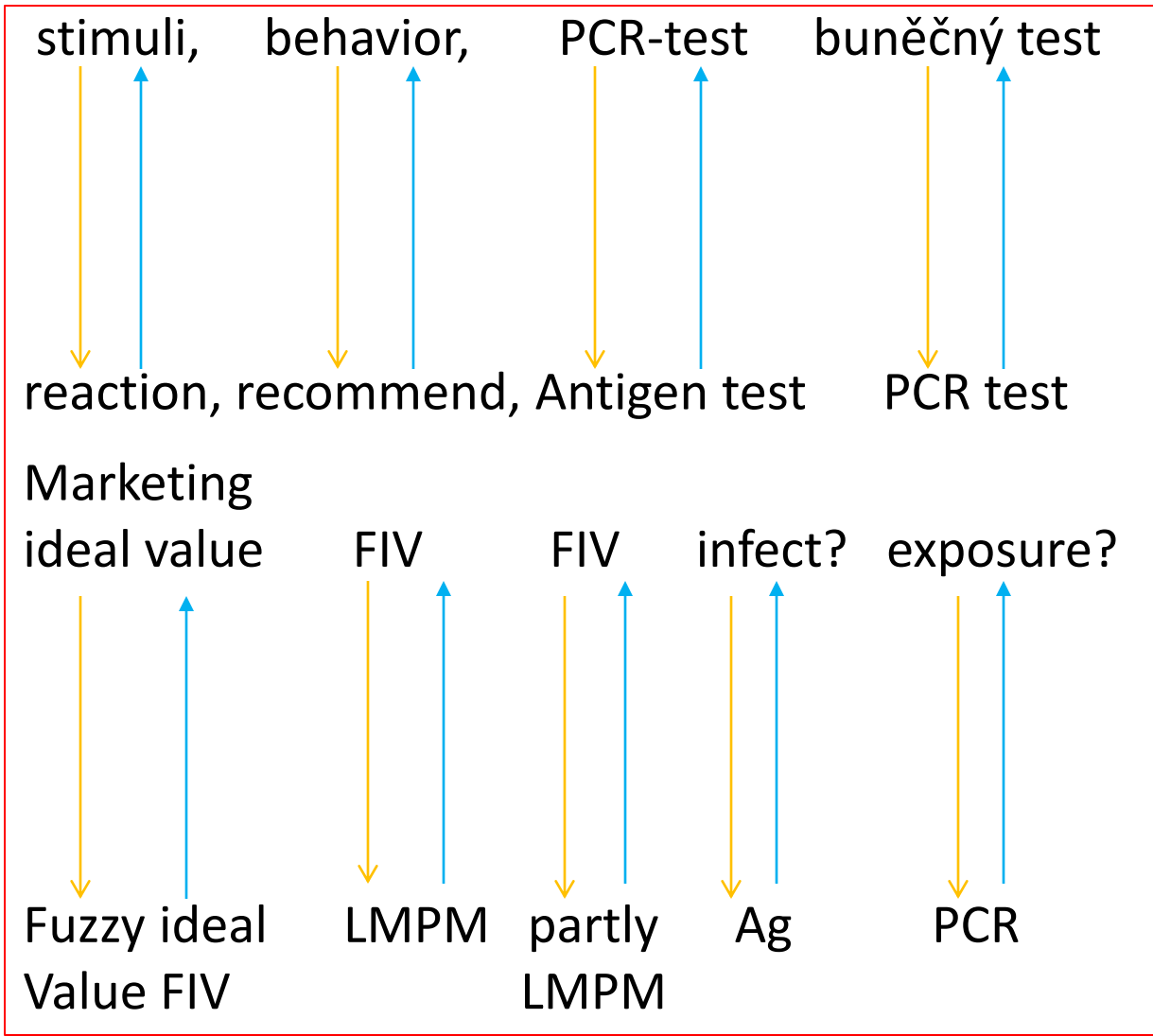
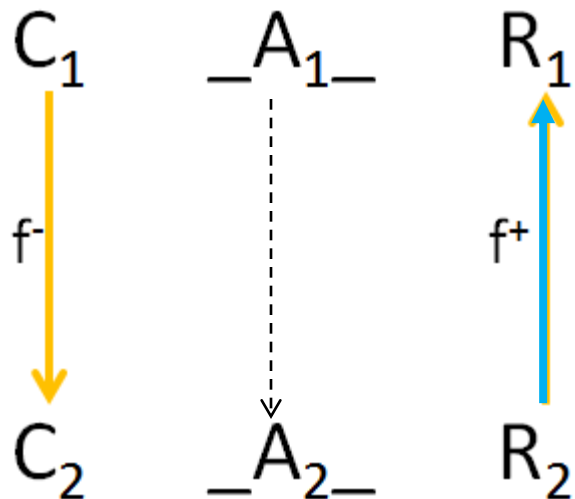


Antibody Tests (Serology)

Detect immune response to SARS-CoV-2 exposure

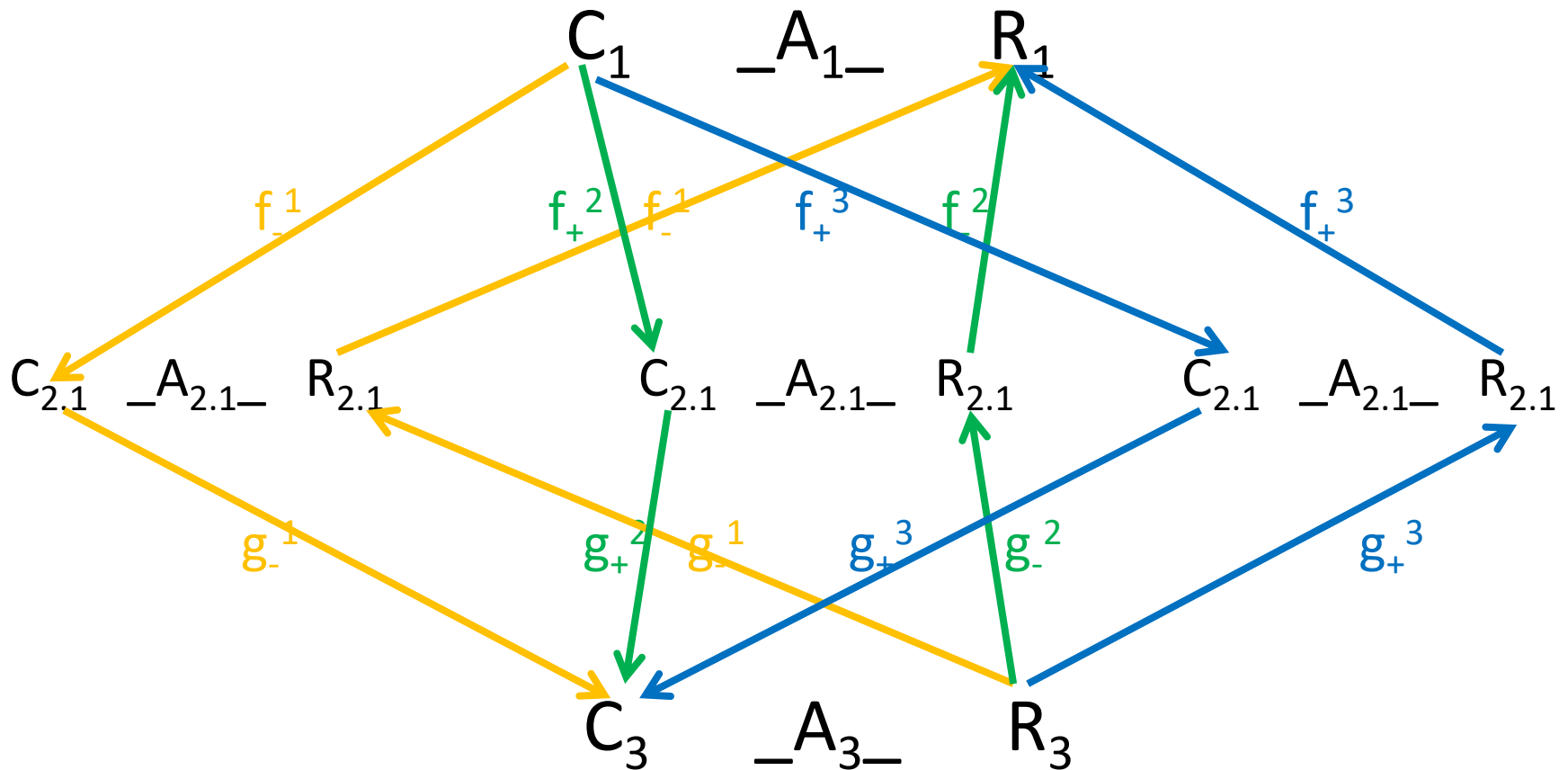


Various CRR instances



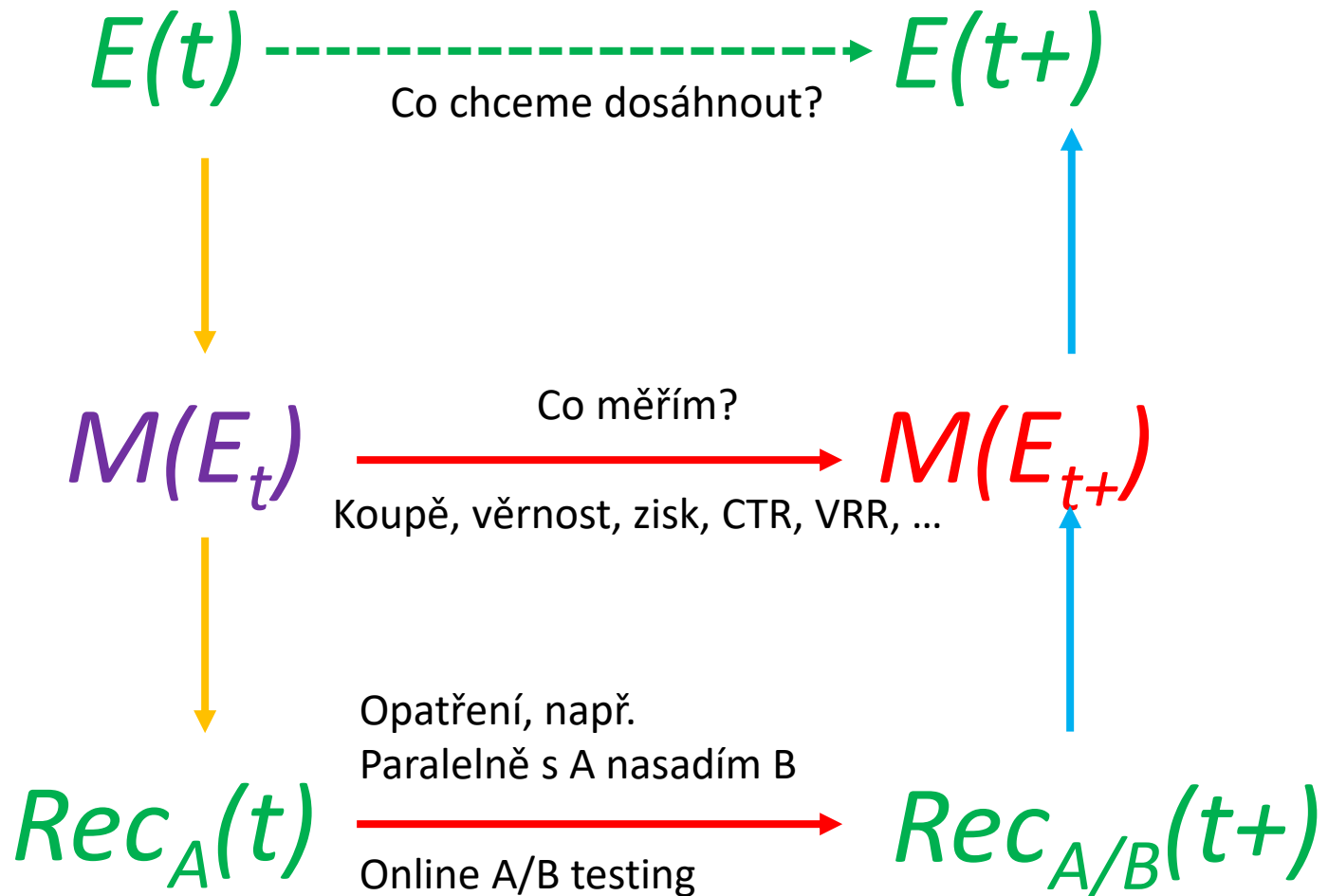
query	answer
Input	output
Item	attributes
object	owner
speech	ascii record
Image	recognition

Cartesian closed category



Upper level - Several models, chose the best / different aspects
 Lower level - ensemble learning, integration/ ?transfer learning

Globální vyhodnocení e-shopu E

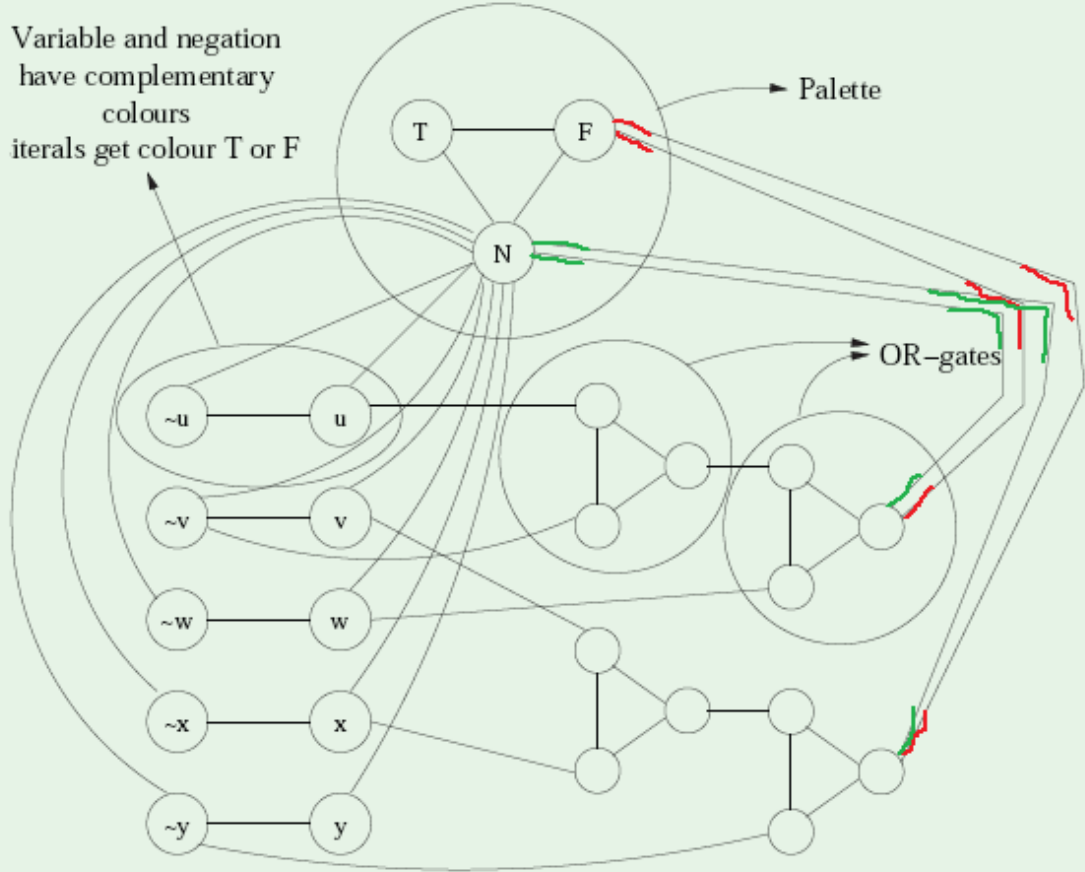


Further material

- 3 SAT reduction to 3 COL
- Mathematical problem of Challenge Response Framework – CRFm
- CRF – situations and reductions
 - Definitions
 - Decision (yes-no) and search problems
 - NAR – no acceptable responses
 - Theorem – one implication suffices
- Metrics

Example

$$\varphi = (u \vee \neg v \vee w) \wedge (v \vee x \vee \neg y)$$



Variable and negation
have complementary
colours
iterals get colour T or F

Palette

OR-gates

Example CRR of 3SAT to 3COL

Start with 3-SAT formula φ with n variables x_1, \dots, x_n and m clauses K_1, \dots, K_m . Create graph G_φ such that

- G_φ is 3-colorable iff φ is satisfiable (decision problem) and
- 3SAT is CR reducible to 3COL, up to this we need to establish truth assignment for x_1, \dots, x_n via colors for some nodes in G .

create triangle with node True, False, Base

for each variable x_i two nodes v_i and \underline{v}_i connected in a triangle with common Base

If graph is 3-colored, either v_i or \underline{v}_i gets the same color as True.

Interpret this as a truth assignment to v_i

For each clause $K_j = (a \vee b \vee c)$, create a small gadget graph

gadget graph connects to nodes corresponding to a, b, c ,

implements OR connect output node of gadget to both False and Base

Correctness of $3SAT^{dec}$ reduction to $3COL^{dec}$

φ is satisfiable implies G_φ is 3-colorable

- if x_i is assigned True, color v_i True and \bar{v}_i False
- for each clause $K_j = (a \vee b \vee c)$ at least one of a, b, c is colored True. OR-gadget for K_j **can be** 3-colored such that output is True.

G_φ is 3-colorable implies φ is satisfiable

- if v_i is colored True then set x_i to be True, this is a legal truth assignment
- consider any clause $K_j = (a \vee b \vee c)$. it cannot be that all a, b, c are False. If so, output of OR-gadget for K_j has to be colored False but output is connected to Base and False!

CRF situations and reductions “0 \rightarrow * is true”

Challenge Response Situation $S = (C, R, A)$ consists of a set C of challenges, set of responses R and an acceptability relation $A \subseteq C \times R$ (can be preferential)

For an $c \in C$, $r \in R$ we read $A(c, r)$ as “ r is an acceptable response (in some degree) for challenge c ”, or also “response r meets challenge c ”

We assume, that each set R contains also a special element “ nar ” representing “there is no acceptable response”. We assume:

$A(c, nar)$ is equivalent to $(\forall r \in R \setminus \{nar\})(\neg A(c, r))$ (* nar)

$R \setminus \{nar\}$ are meaningful responses, “ nar ” is like logical “not” in decision problems

Example CRR of 3SAT to 3COL with “nar”

Assume we have situation $3SAT^{nar}$ ($3SAT^{dec}$ variant with $R_1 = \{\text{true}, \text{false}\}$ is constructed analogously, with same $f(\varphi)$) with

C_1 is the set of all 3CNF clauses,

R_1 is the set of all truth assignments of variables + nar_1 and

$A_1(\varphi, v)$ if $v \models \varphi$, here \models says that in the world v is true (xor nar)

And situation $3COL^{nar}$, where

C_2 is the sets of all graphs $G(V, E)$,

R_2 is the set of all 3-vertex coloring + nar_2 and

$A_2(G, c)$ if c is a proper coloring of vertices of G (xor nar)

CR reduction consists of a pair of functions (f^- , f^+) such that

$f^-(\varphi) = G_\varphi$, see illustration

$f^+(c) = v_c$, also described in illustration

$$(\forall c_1 \in C_1)(\forall r_2 \in R_2)(A_2(f^-(c_1), r_2) \Rightarrow A_1(c_1, f^+(r_2))) \quad (*)$$

Note that $A_2(f^-(c_1), nar_2) \Rightarrow A_1(c_1, nar_1)$ is equivalent to

$\neg A_2(f^-(c_1), nar_2) \Leftarrow \neg A_1(c_1, nar_1)$ and this is equivalent to

$$(\exists r_1 \in R_1 \setminus \{nar_1\})(A_1(c_1, r_1)) \Rightarrow (\exists r_2 \in R_2 \setminus \{nar_2\})(A_2(f^-(c_1), r_2)) \quad (**)$$

Challenge-Response situation “nar”

Let us have a set C of challenges and a set R responses (with an extra element $\text{nar} = \text{“no acceptable response in } R\text{”}$).

a binary acceptability relation $A \subseteq C \times R$ represents search problem (and “yes” decision). A selector

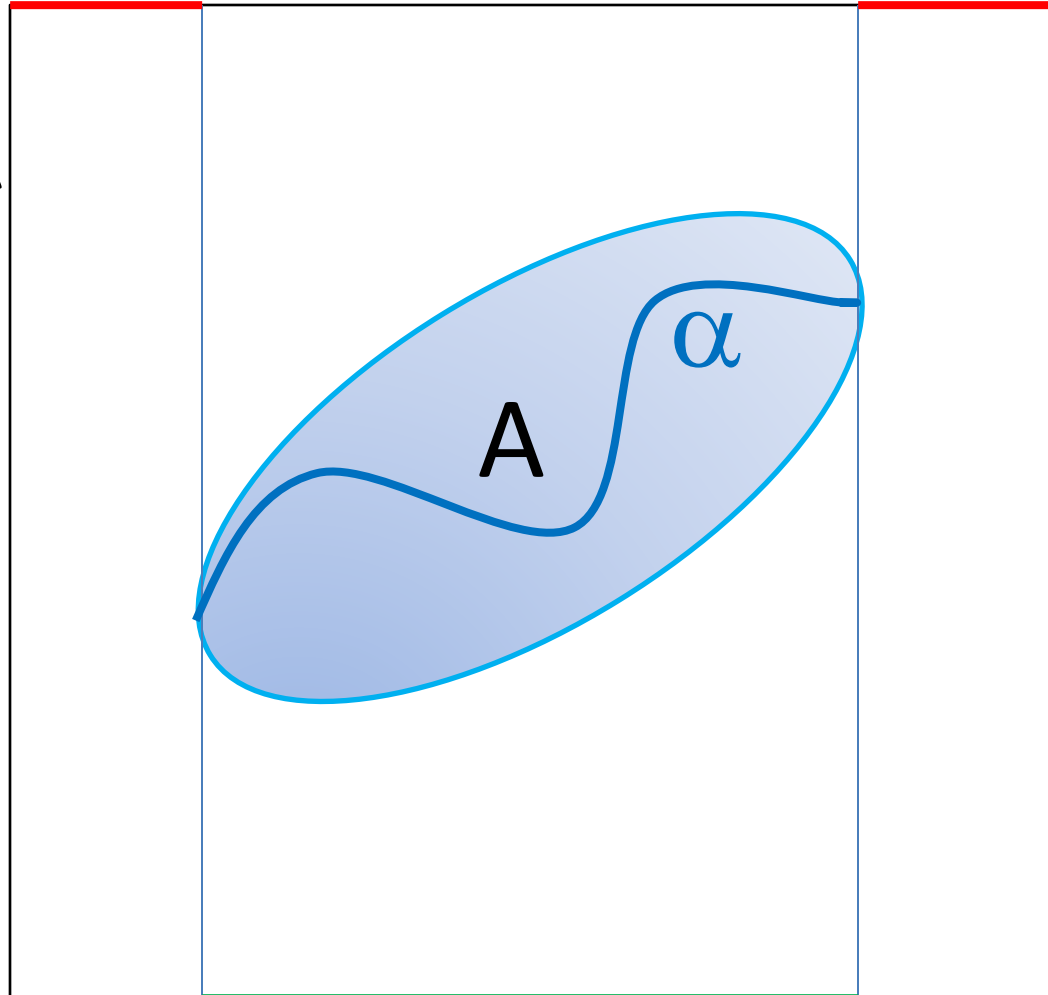
α can represent either

- an optimal response, or
- an algorithm

$\{(c, \text{nar}): c \in C \setminus \text{dom}(A)\}$ fills “no” decision ...and corresponding decision problem

$\text{nar} = \text{not}$

R



yes

C

CRF situations and reductions “nar”

Challenge Response Reduction of a situation $S_1 = (C_1, R_1, A_1)$ to a situation $S_2 = (C_2, R_2, A_2)$ consists of a pair of functions (f^-, f^+) such that

$$f^-: C_1 \rightarrow C_2,$$

$f^+: R_2 \rightarrow R_1$, such that $f^+(nar_2) = nar_1$, $f^+(r_2) = nar_1$ implies $r_2 = nar_2$ and following holds:

$$(\forall c_1 \in C_1)(\forall r_2 \in R_2)(A_2(f^-(c_1), r_2) \Rightarrow A_1(c_1, f^+(r_2))) \quad (*)$$

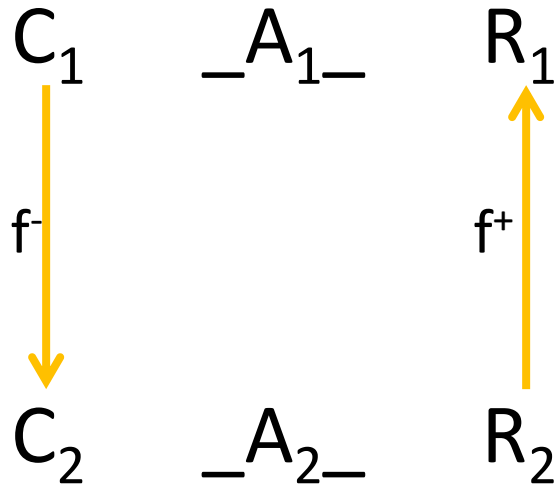
Note that $A_2(f^-(c_1), nar_2) \Rightarrow A_1(c_1, nar_1)$ is equivalent to

$$\neg A_2(f^-(c_1), nar_2) \Leftarrow \neg A_1(c_1, nar_1) \text{ and this to}$$

$$(\exists r_1 \in R_1 \setminus \{nar_1\})(A_1(c_1, r_1)) \Rightarrow (\exists r_2 \in R_2 \setminus \{nar_2\})(A_2(f^-(c_1), r_2))$$

Hence “nar” prevents fake reductions

Challenge-Response reduction “nar”



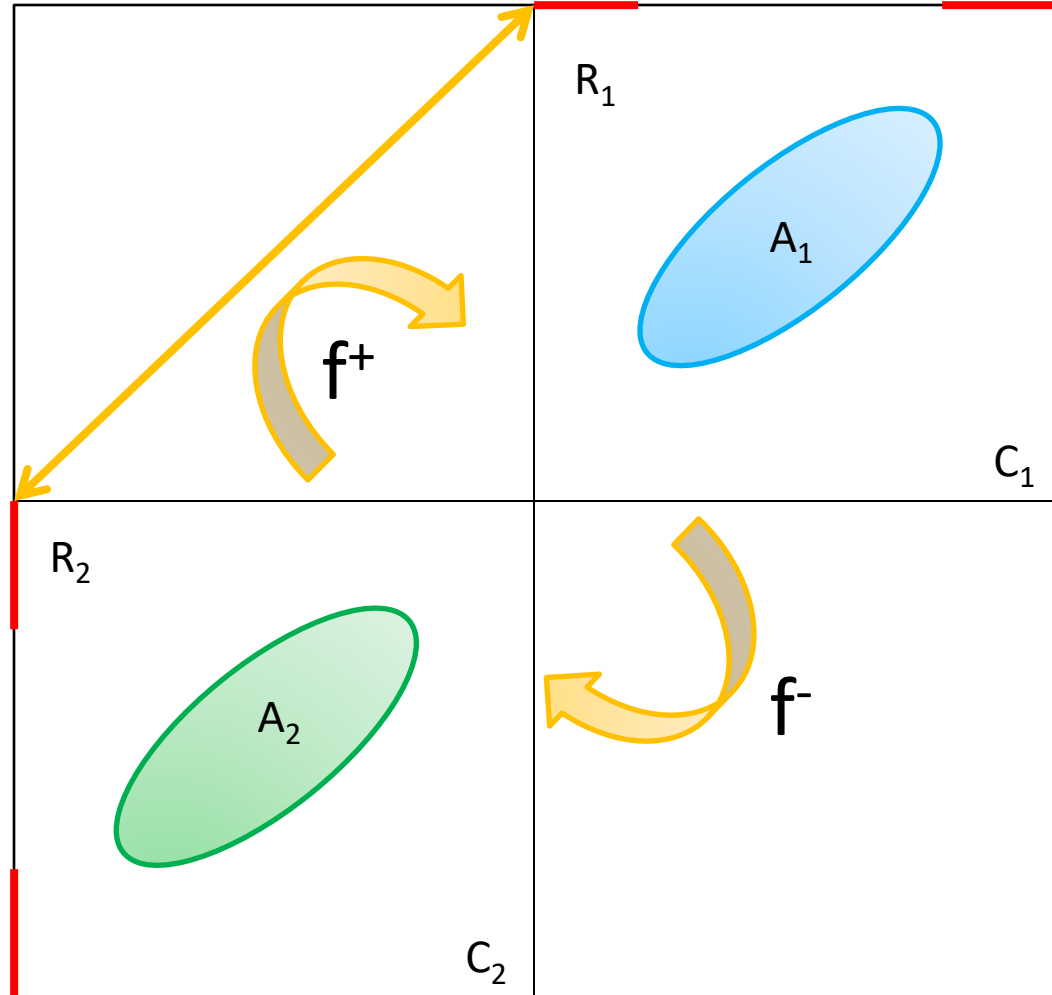
$$(\forall c_1 \in C_1)(\forall r_2 \in R_2)$$

$$A_2(f(c_1), r_2)$$



$$A_1(c_1, f^+(r_2)) \ \&$$

$$f^+(nar_2) = nar_1$$



Correctness of $3SAT^{nar}$ reduction to $3COL^{nar}$

Denote $G_\varphi(V_\varphi, E_\varphi) = f(\varphi)$, assume $A_2(G_\varphi, c)$ and $c: V_\varphi \rightarrow \{\text{True}, \text{False}, \text{Base}\}$, hence $c \neq nar_2$, is a proper 3-coloring. Let us construct $f^+(c)$ as follows: if v_i is colored True then set $f^+(c) = v_c(x_i)$ to be True, this is a legal truth assignment and $v_c \models \varphi$

- consider any clause $K_j = (a \vee b \vee c)$. it cannot be that all a, b, c are False. If so, output of OR-gadget for K_j has to be colored False but output is connected to Base and False!

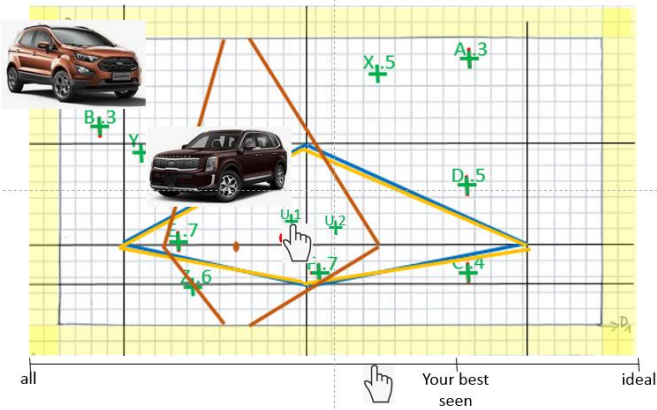
To show $A_2(G_\varphi, nar_2)$ implies $A_1(\varphi, nar_1)$, by (**) it is sufficient to show that if $v \in R_1$ is a truth assignment with $A_1(\varphi, v)$ then there is a c a proper 3-coloring of $G_\varphi = f(\varphi)$, hence $A_2(G_\varphi, c)$

Indeed

- if variable x_i is assigned True by v , color v_i True and \underline{v}_i False by c
- for each clause $K_j = (a \vee b \vee c)$ at least one of a, b, c is colored True. OR-gadget for K_j **can be** 3-colored such that output is True.

Graphical solution and visualization in LMPM

Human visual perception



Analytical layer

input $\xrightarrow{\text{User study}}$ output

input $\xrightarrow{\alpha'}$ output

input $\xrightarrow{\alpha''}$ output

What is the role of “nar” in practical applications?

Database as a mediator by AHV

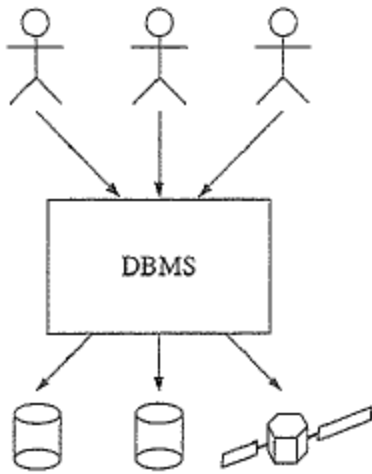
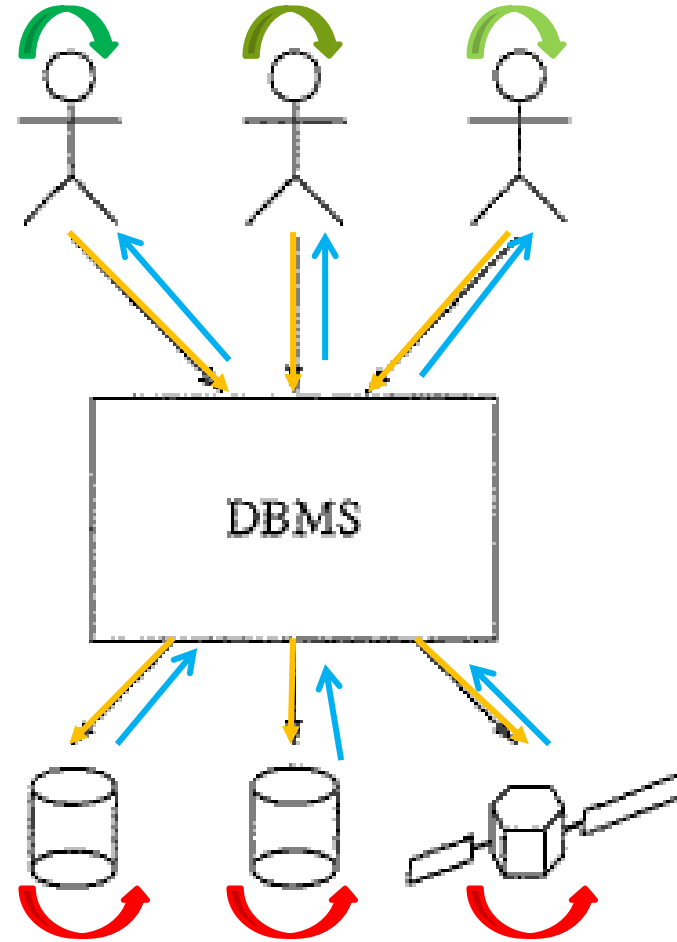


Figure 1.1: Database as mediator between humans and data



Query _correct_ answer
 ↓ # reduction is correct ↑
 Query _computed_ answer

AHV three levels of DB architecture

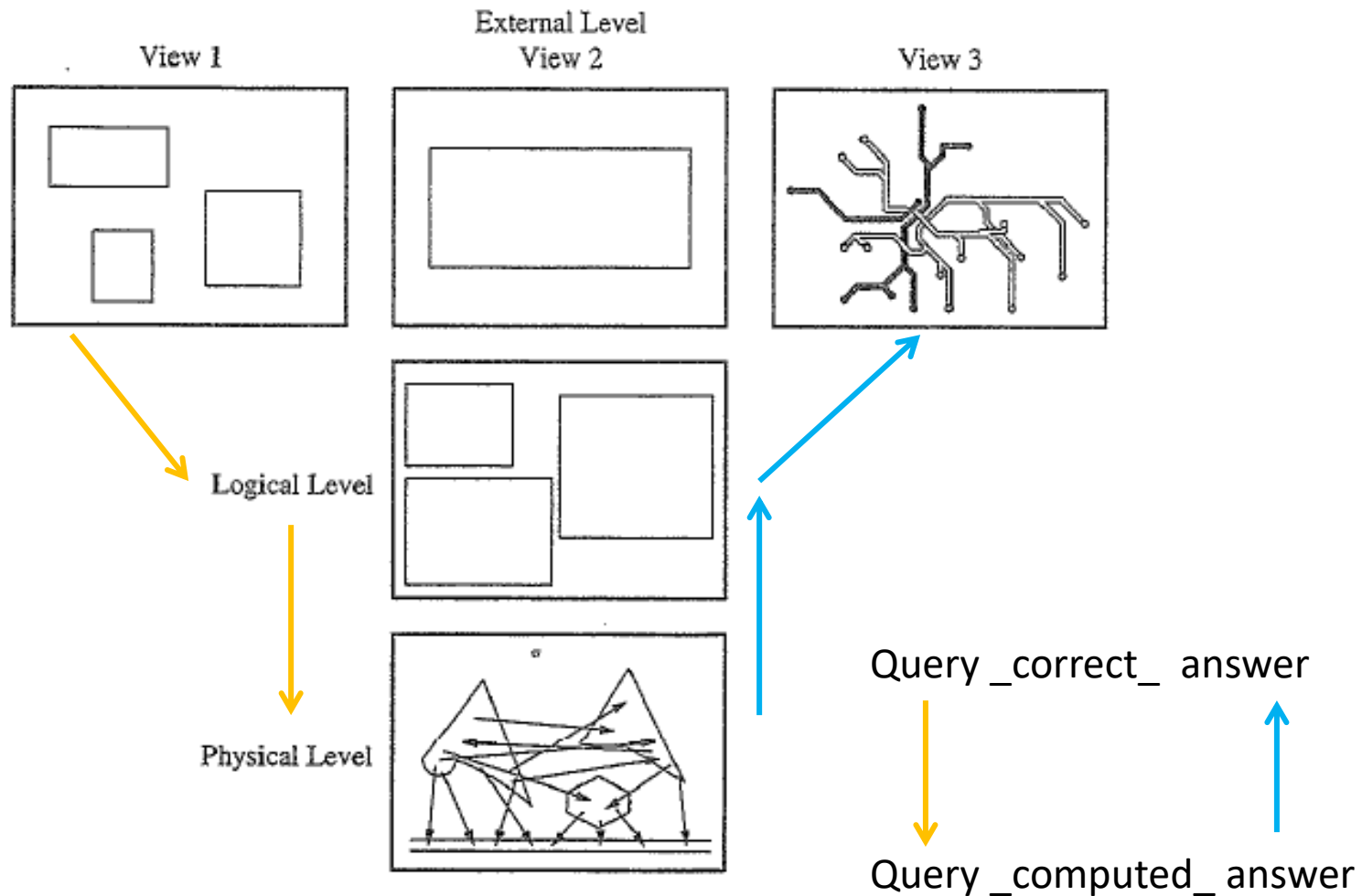
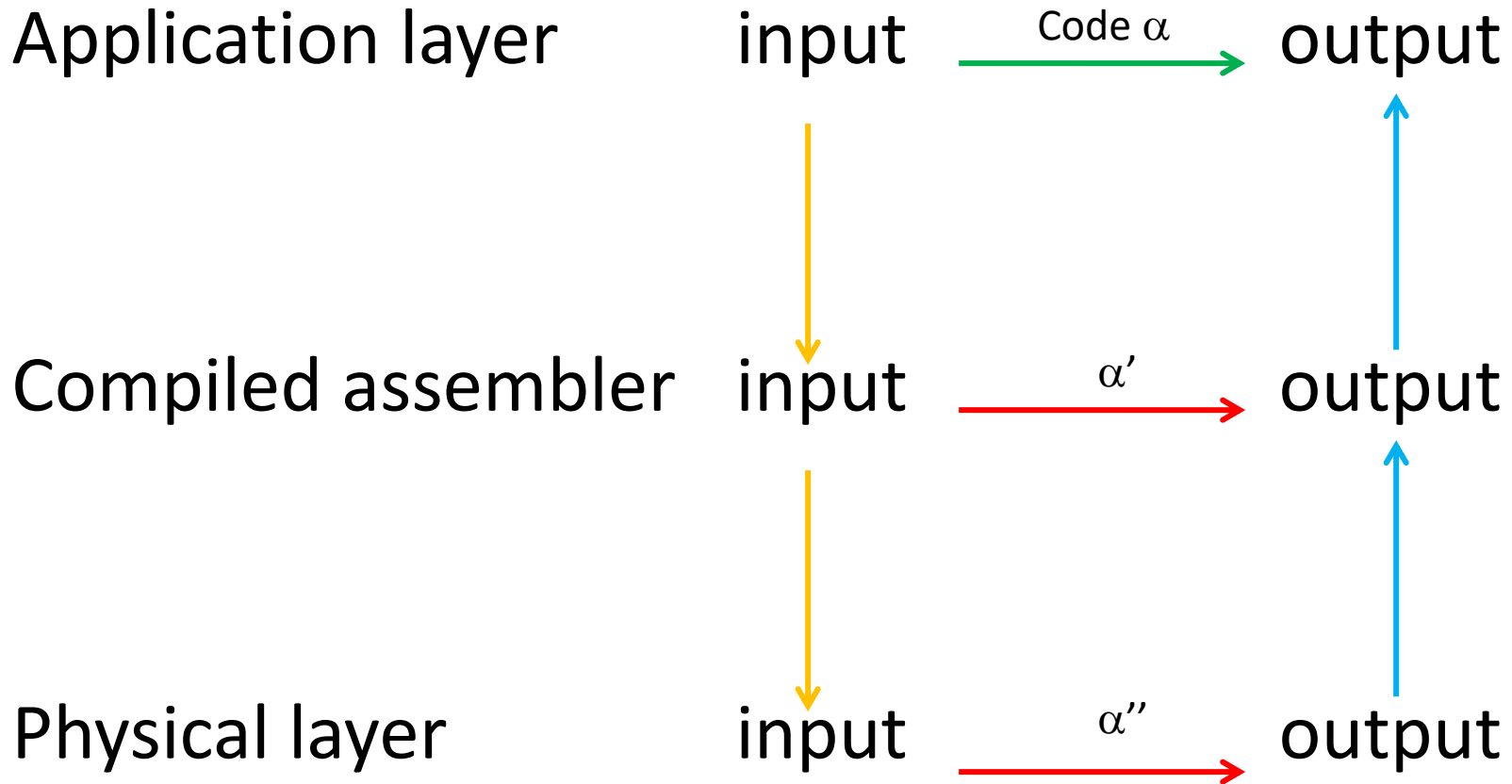


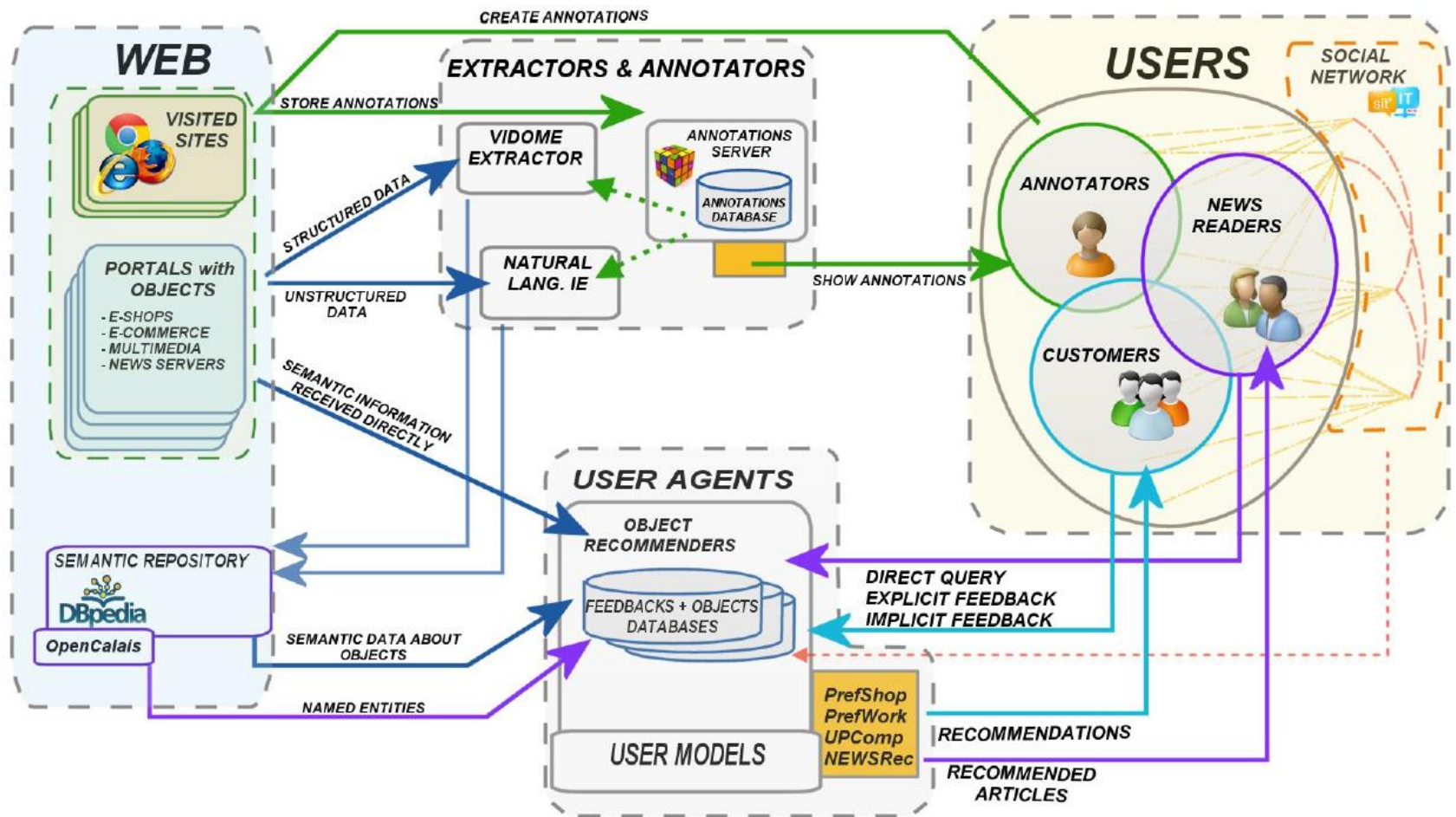
Figure 1.2: Three-level architecture of database systems

Computer architecture



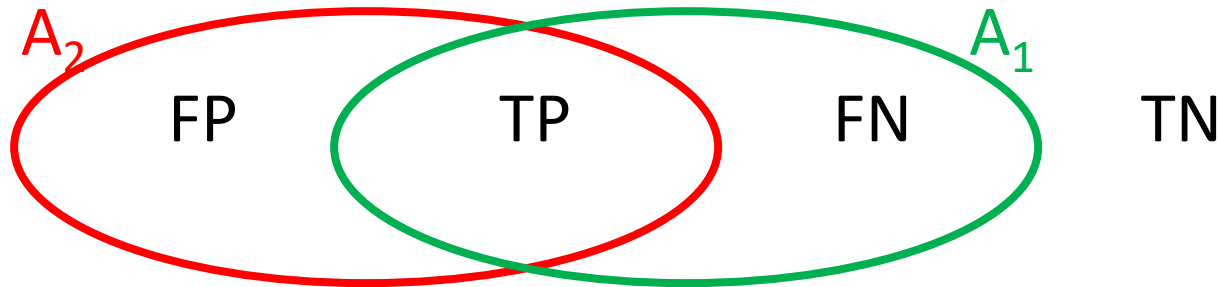
reduction is correct means “if α'' is computed then (implies) α is correct” is a true statement – implication can be true also in case “False implies *” - fake reduction
In computer science we have to be careful – **consequence should have a true witness**

SemPre – aggregated measures - evaluating success of semantization and recommendation



ChRF as a general epistemic reasoning method?

- What is the “truth value” $A_2(r(i_1), s_2) \Rightarrow A_1(i_1, t(s_2))$?
- A_1 - target, hypothesis, event, reality, deployment, \downarrow
 A_2 - source, model, evidence, test, experiment, \downarrow
- A_1 - declarative, correct, semantics, truth, tautology \downarrow
 A_2 - procedural, computed, syntax, proof \downarrow
- Preferential logic; Hájek’s comparative notion of truth; Bayes; Hájek’s observational logic, 4ft, IR; user studies; formal proofs



$$\frac{(A_2, b), (A_1 \leftarrow A_2, r)}{(A_1, C_{\rightarrow}(b, r)}}$$



$$\Pr(A_1 | A_2) = \frac{\Pr(A_2 | A_1) * \Pr(A_1)}{\Pr(A_2)}$$

$$\frac{\# \text{ true positive}}{\# \text{ all}}$$

https://en.wikipedia.org/wiki/Precision_and_recall

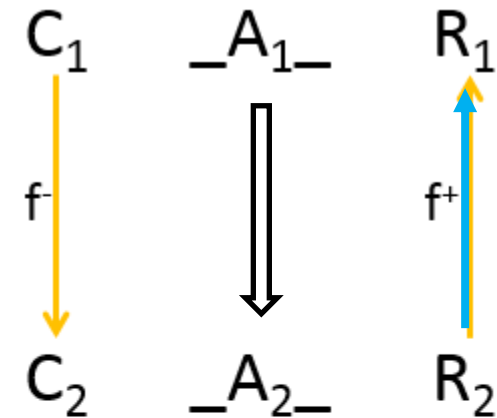
		True condition			
Total population		Condition positive	Condition negative	Prevalence = $\frac{\Sigma \text{Condition positive}}{\Sigma \text{Total population}}$	Accuracy (ACC) = $\frac{\Sigma \text{True positive} + \Sigma \text{True negative}}{\Sigma \text{Total population}}$
Predicted condition	Predicted condition positive	True positive , Power	False positive , Type I error	Positive predictive value (PPV), Precision = $\frac{\Sigma \text{True positive}}{\Sigma \text{Predicted condition positive}}$	False discovery rate (FDR) = $\frac{\Sigma \text{False positive}}{\Sigma \text{Predicted condition positive}}$
	Predicted condition negative	False negative , Type II error	True negative	False omission rate (FOR) = $\frac{\Sigma \text{False negative}}{\Sigma \text{Predicted condition negative}}$	Negative predictive value (NPV) = $\frac{\Sigma \text{True negative}}{\Sigma \text{Predicted condition negative}}$
		True positive rate (TPR), Recall, Sensitivity, probability of detection = $\frac{\Sigma \text{True positive}}{\Sigma \text{Condition positive}}$	False positive rate (FPR), Fall-out, probability of false alarm = $\frac{\Sigma \text{False positive}}{\Sigma \text{Condition negative}}$	Positive likelihood ratio (LR+) = $\frac{\text{TPR}}{\text{FPR}}$	Diagnostic odds ratio (DOR) = $\frac{\text{LR+}}{\text{LR-}}$
		False negative rate (FNR), Miss rate = $\frac{\Sigma \text{False negative}}{\Sigma \text{Condition positive}}$	Specificity (SPC), Selectivity, True negative rate (TNR) = $\frac{\Sigma \text{True negative}}{\Sigma \text{Condition negative}}$	Negative likelihood ratio (LR-) = $\frac{\text{FNR}}{\text{TNR}}$	
				F ₁ score = $2 \cdot \frac{\text{Precision} \cdot \text{Recall}}{\text{Precision} + \text{Recall}}$	

ChRR motivated problems “challenges”

- Specify A_1
- Learn, find, code A_2 , α_2 ,
- Learn, find, code f^- , f^+ , ...
- What is the right “truth value” of $A_1 \Rightarrow A_2$
 - math. logic (fuzzy connectives)
 - probabilistic measures P/R , RMSE, ...
 - offline A/B testing measures, business metric, ...
- U-process 
- Iterative coupling of enriched / recurrent 

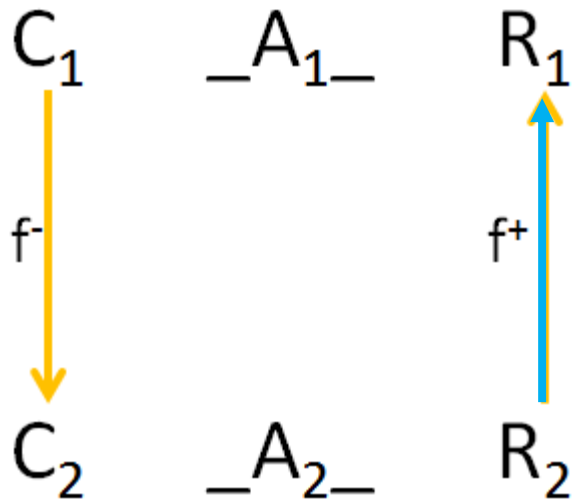
ChRR \rightarrow many valued logic \rightarrow preferential Datalog + Data domain calculi

- Integration of search and decision complexity problems, of deduction and induction
- Only one implication!
- No equivalence! Still correct ...
- No nontrivial fulfillment of \Rightarrow
- Cartesian closed category \Downarrow
- Complexity strength as that of search and decision problem
- Acceptability can be function, algorithm
- Not necessary 100%, various metric

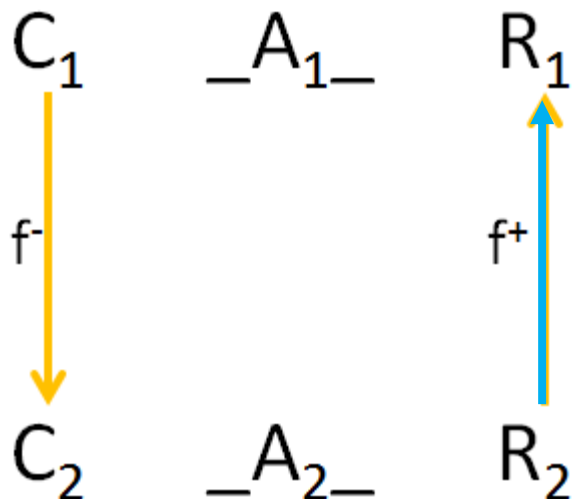


$$\begin{aligned}
 & (\forall c_1 \in C_1)(\forall r_2 \in R_2) \\
 & \quad A_2(f(c_1), r_2) \\
 & \quad \Downarrow \\
 & \quad A_1(c_1, f^+(r_2)) \\
 & f^+(nar_2) = nar_1
 \end{aligned}$$

Theoretical problems

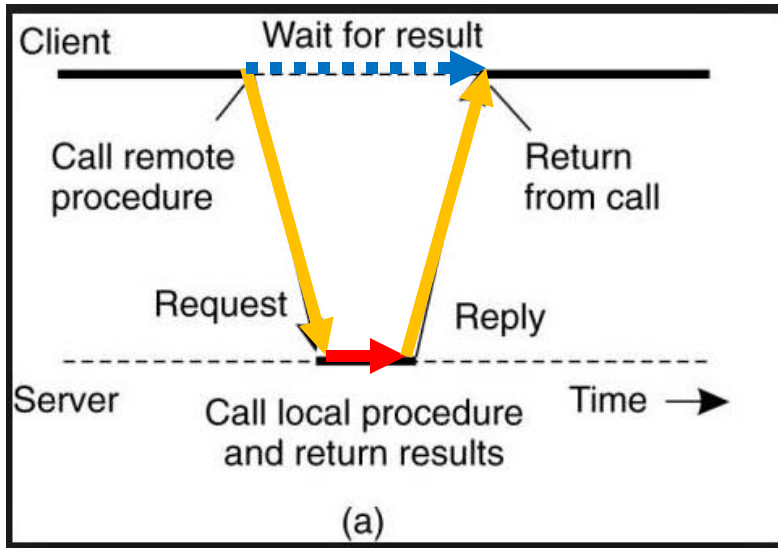


what does it mean there is a CRR reduction between two graphs $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$ and all possible graph theoretic questions



$\mathbb{C} = \{(S_1, S_2): \text{where } S_1 \text{ and } S_2 \text{ are finite CR situations, } S_i = (C_i, R_i, A_i)\}$,
 $\mathbb{R} = \{(f_-, f_+): \text{pairs of finite functions}\}$
 Δ checks whether (f_-, f_+) form a CR-reduction from S_1 to S_2

ChRR in decision support, client server



Problem situations

- **client - server**
- **Manager - decision support expert/tool**
- **Customer - recommender system of e-shop**

A					
B					
C					
D					
E					

Collaborative filtering model + history of users' behavior data

					A
					B
					C
					D
					E