UNI KASSEL
VERSITÄT

Chair for
Communication Technology

Prof. Dr.-Ing. Klaus David

ComTec

Alignment for Context Prediction

Immanuel König

Overview

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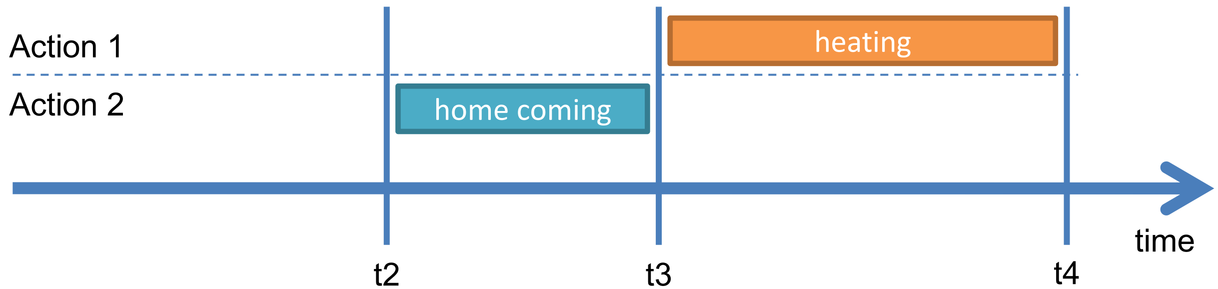
- What is Context Prediction
  - Why prediction
  - From data to Context
  - Nominal / Ordinal
  - Problems with time series
- Alignment
  - Local / Global
  - Algorithm
- Alignment with multiple context sources
  - Benefits
  - How to select beneficial context sources
  - Stability

Why prediction

Example 1: Heating my home

Without context prediction:



Example 1: Heating my home

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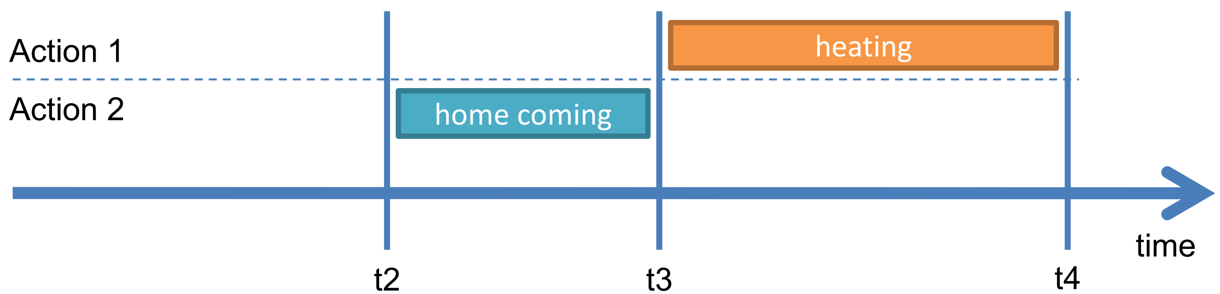
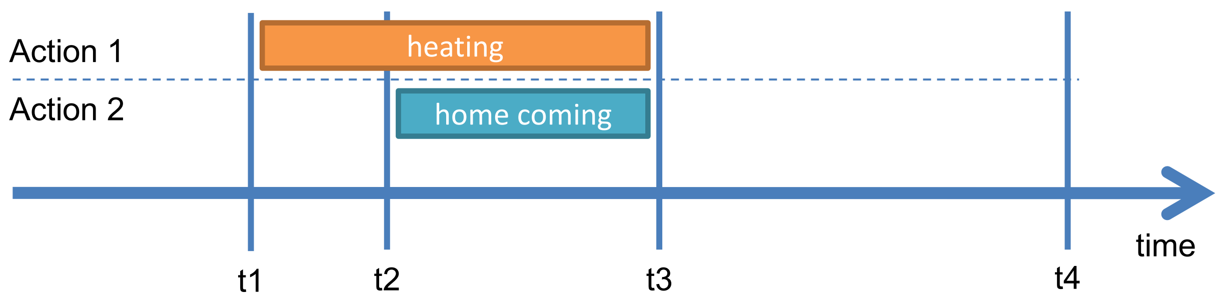
Without context prediction:



With context prediction:



Example 2: Location

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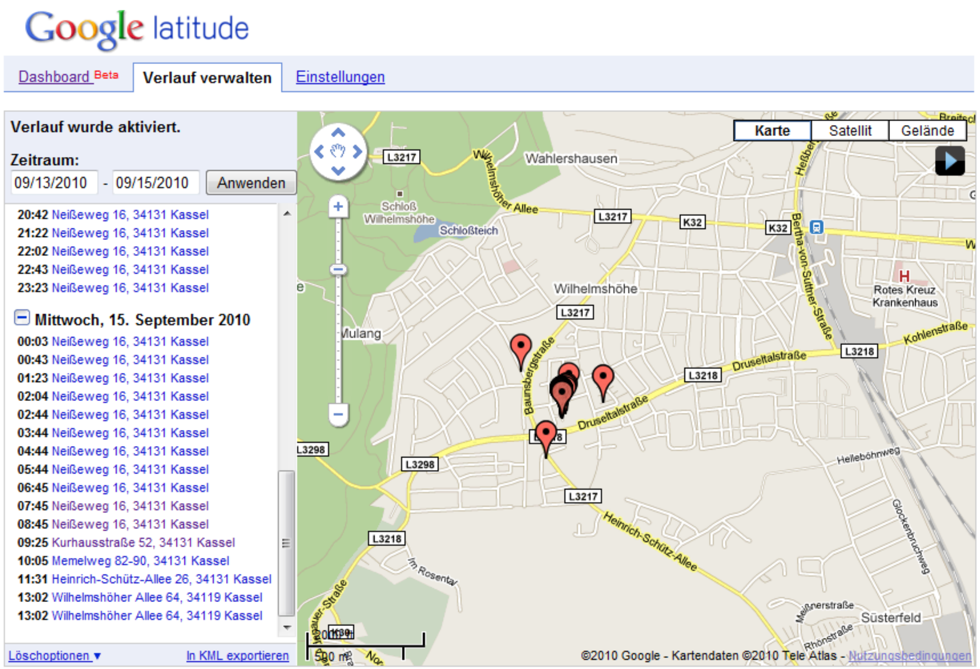


- Predict next location
- Inform friends "we could meet"

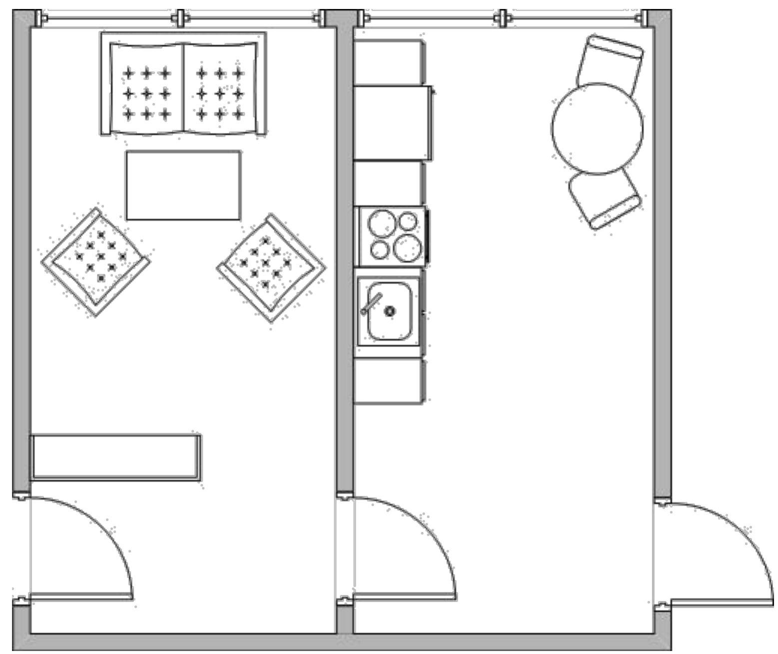
Example 3: Car navigation system

1

2

3

Example 4: Social / Medical environment



Example 4: Social / Medical environment

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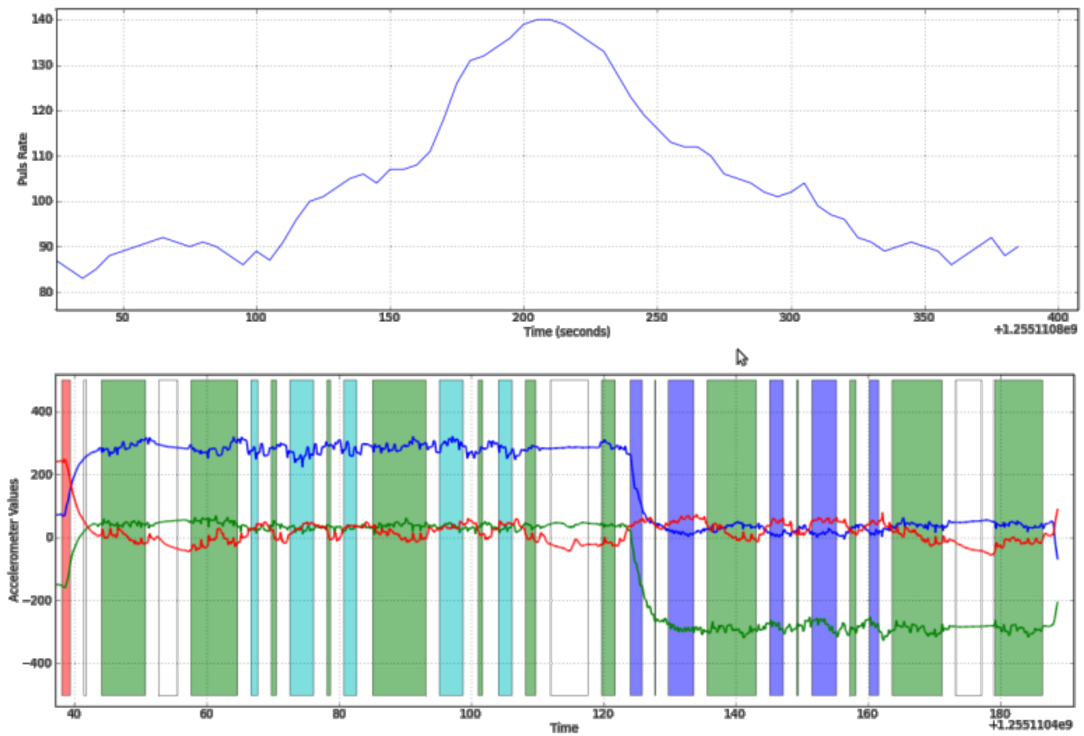

Example 4: Social / Medical environment

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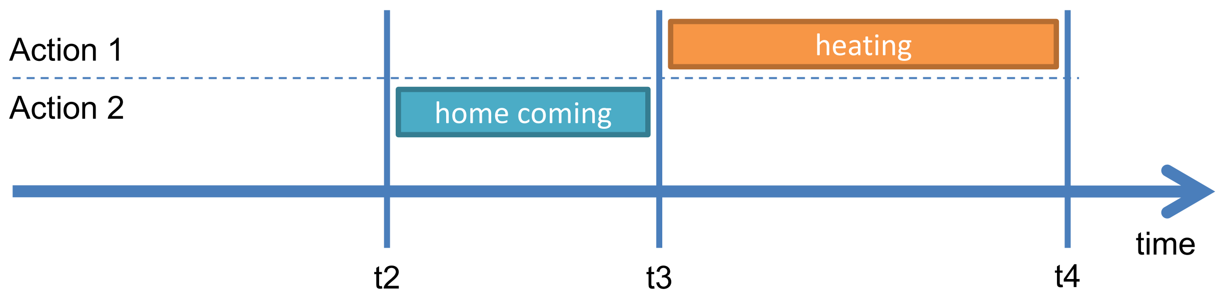
Example 4: Social / Medical environment

- Context prediction:
  - Prevent grandma from stupid ideas
  - Predict disease before the happen and it might be to late to act
  - Find unusual behavior with a difference between a prediction and the real situation

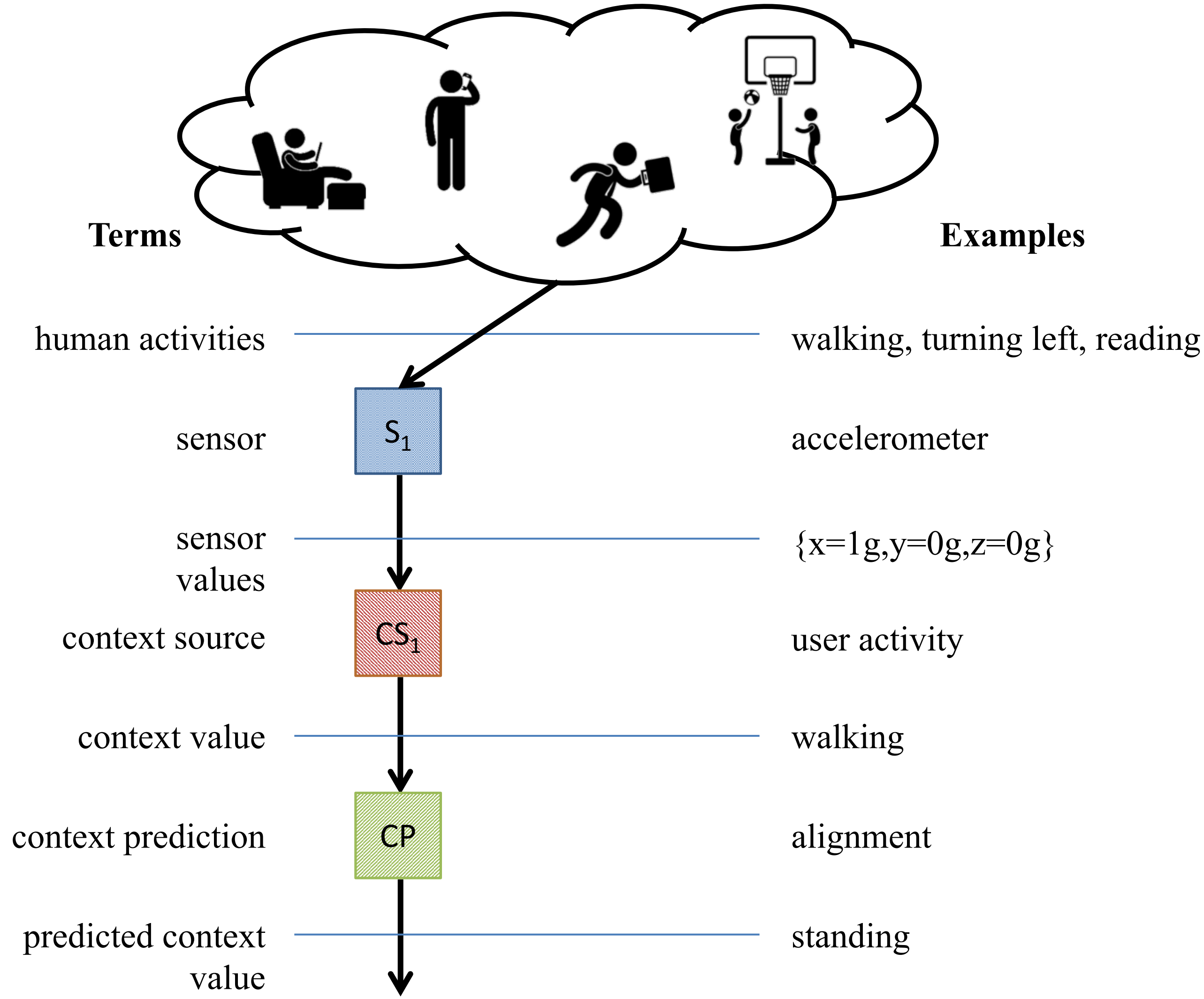
General rule: when do we need a prediction?

General rule: when do we need a prediction?

- An action needs to be started before a certain state occurs
  1. When the action takes some time
  2. We want to prevent a certain state



From sensor data to Context


Terms
Examples
human activities
walking, turning left, reading
sensor
S_1
accelerometer
sensor values
{x=1g,y=0g,z=0g}
context source
CS_1
user activity
context value
walking
context prediction
CP
alignment
predicted context value
standing

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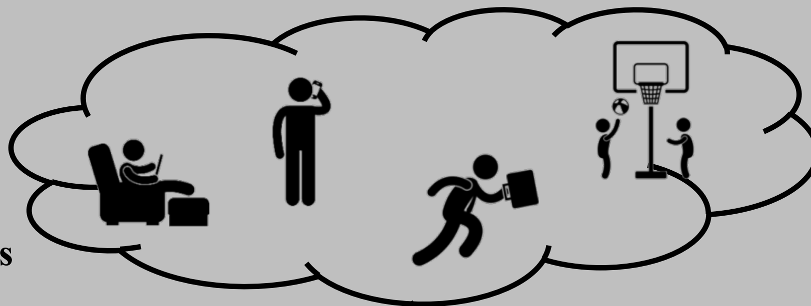
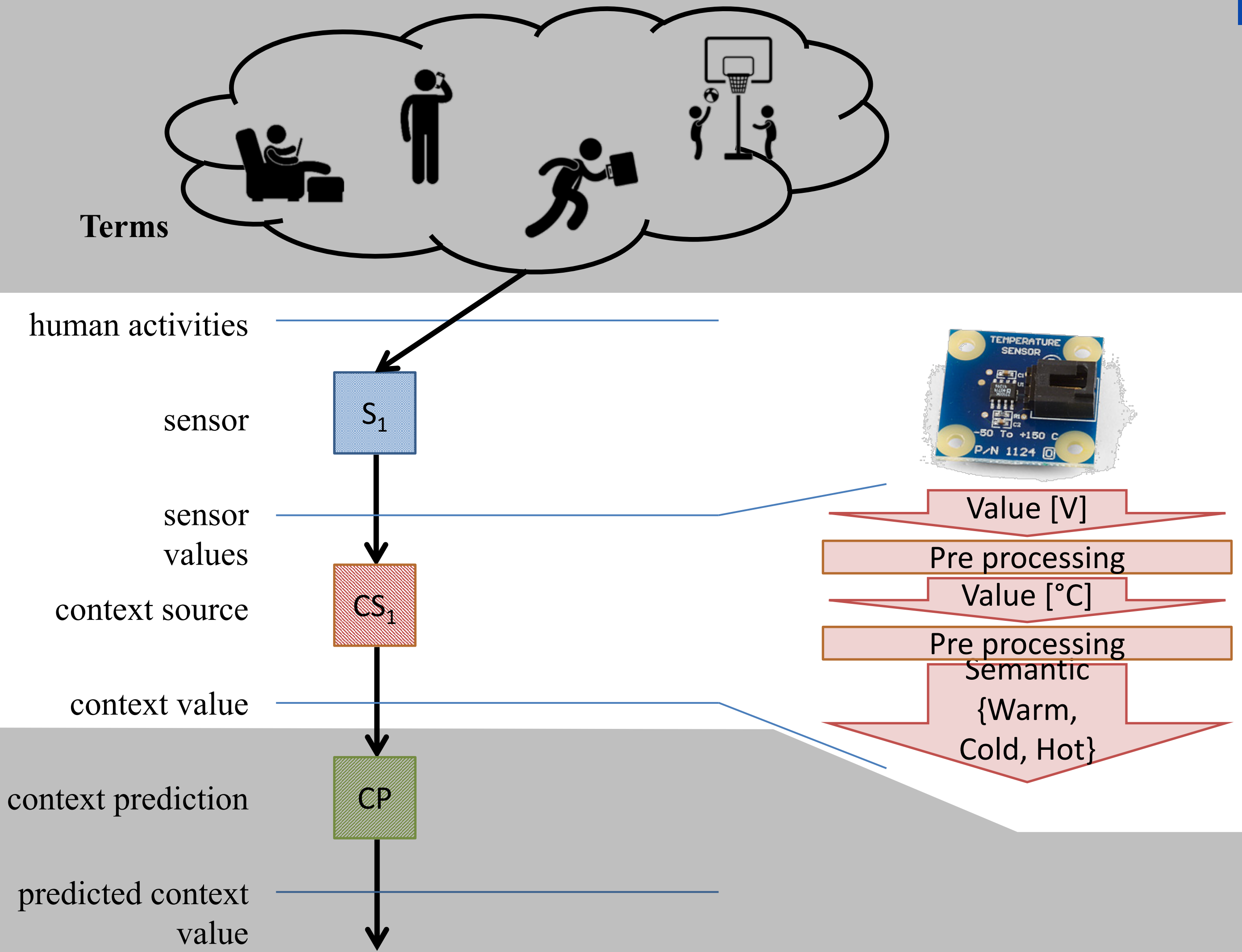


Terms		Examples
human activities		walking, turning left, reading
sensor	S_1	accelerometer
sensor values		{x=1g,y=0g,z=0g}
context source	CS_1	user activity
context value		walking
context prediction	CP	alignment
predicted context value		standing

Terms


human activities
sensor
S_1
sensor values
context source
CS_1
context value
context prediction
CP
predicted context value
TEMPERATURE SENSOR
-50 To +150 C
P/N 1124
Value [V]
Pre processing
Value [°C]
Pre processing
Semantic {Warm, Cold, Hot}

Low to High level

Level 1

t	1	2	3	4	5
f(t)	0.5V	0.3V	0.5V	0.3V	0.8V

Level 2

t	1	2	3	4	5
f(t)	20°C	15°C	20°C	15°C	25°C

Level 3

t	1	2	3	4	5
f(t)	warm	cold	warm	cold	hot

Low to High level: abstraction is needed

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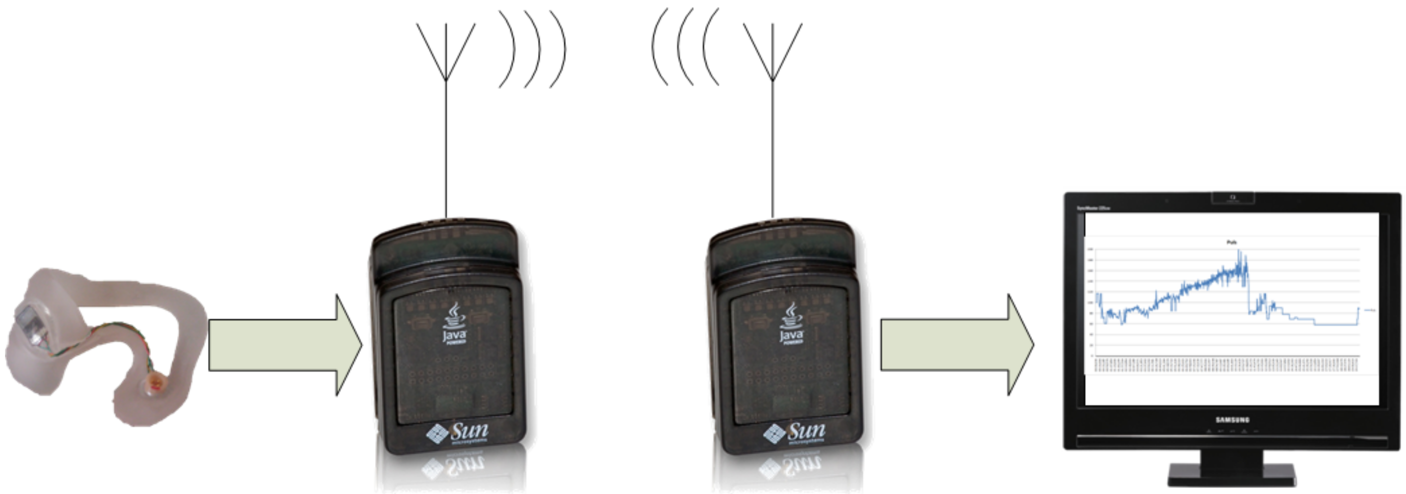
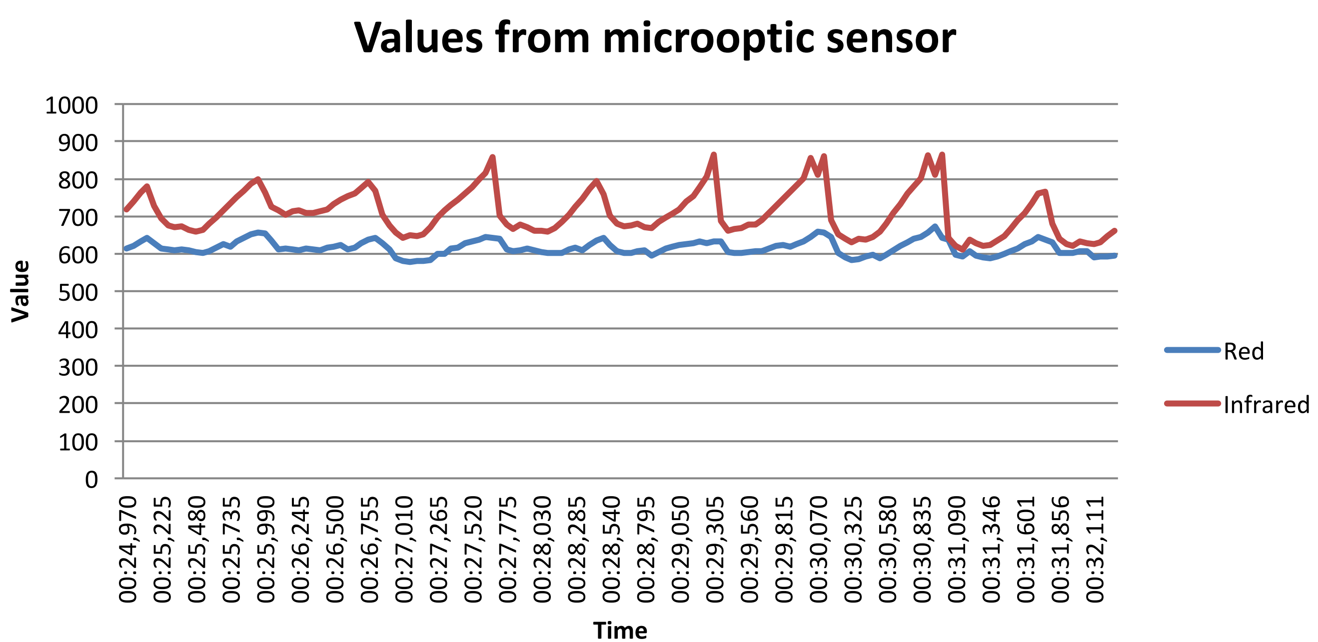


Low to High level: abstraction is needed

ComTec



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ordinal / nominal

ordinal / nominal: guess the next value

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t	1	2	3	4	5	6	7
f(t)	1	2	4	8	16	32	

➔ This is ordinal

ordinal / nominal

- Why is it possible to guess the next value?
  - You figured out the rules
  - The mathematical axioms are useable

ordinal / nominal: guess the next value

t	1	2	3	4	5	6	7
f(t)	hot	cold	warm	cold	hot	hot	

➔ This is nominal

ordinal / nominal

- Why is so hard to guess the next value?
  - You can not figure out a rule
  - The mathematical axioms are NOT useable
    - What is the follower of cold?
    - What is the distance between cold and warm?
  - You can NOT calculate a distance

ordinal / nominal

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- Is there really no knowledge in there? → There is still some knowledge in there.

t	1	2	3	4	5	6	7
f(t)	hot	cold	warm	cold	hot	hot	

f(t)	p(f(t))
hot	1/3
warm	1/6
cold	2/6

ordinal / nominal

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Sensor	Data
Movement	true / false + timestamp
Temperature	continuously values
Temperature	value + timestamp
Microphone	consciously moving voltage level
Camera picture	array of voltage levels + timestamp
Camera video	stream of array of voltage levels + timestamp
…	…

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Problems with time series

time series: disturbances

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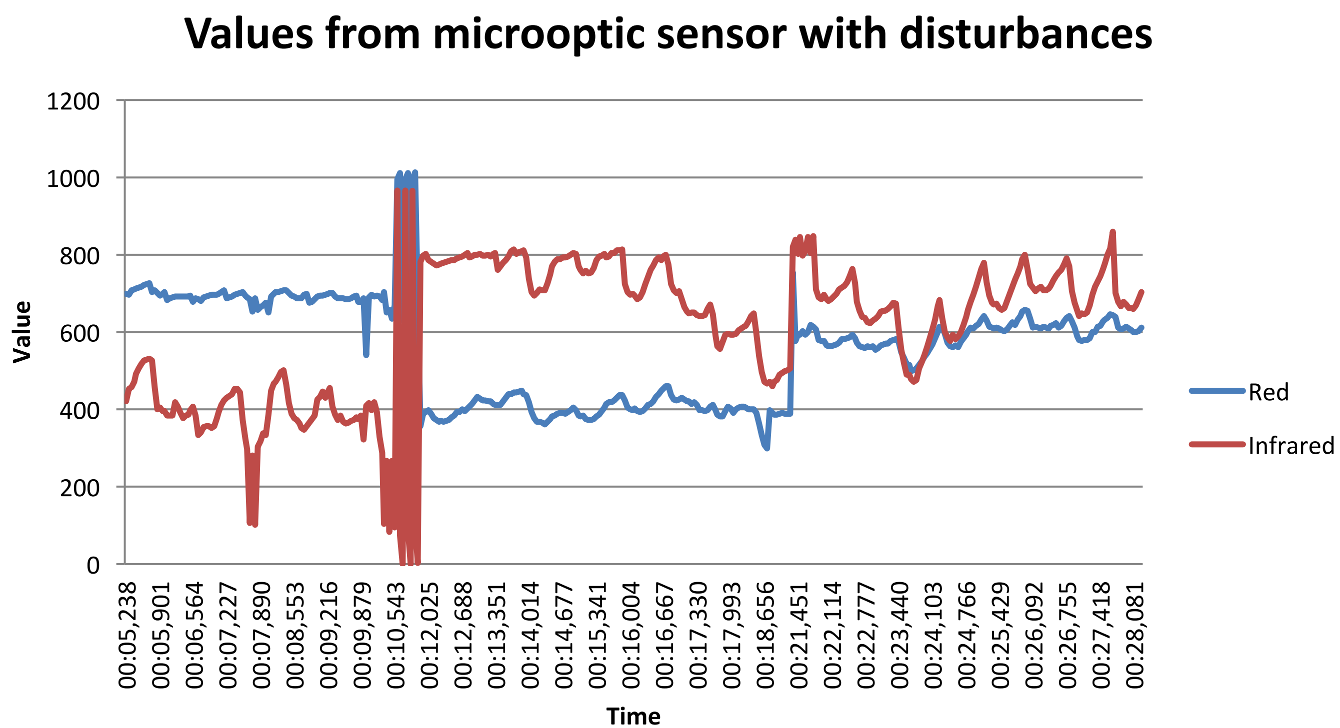

time series: disturbances

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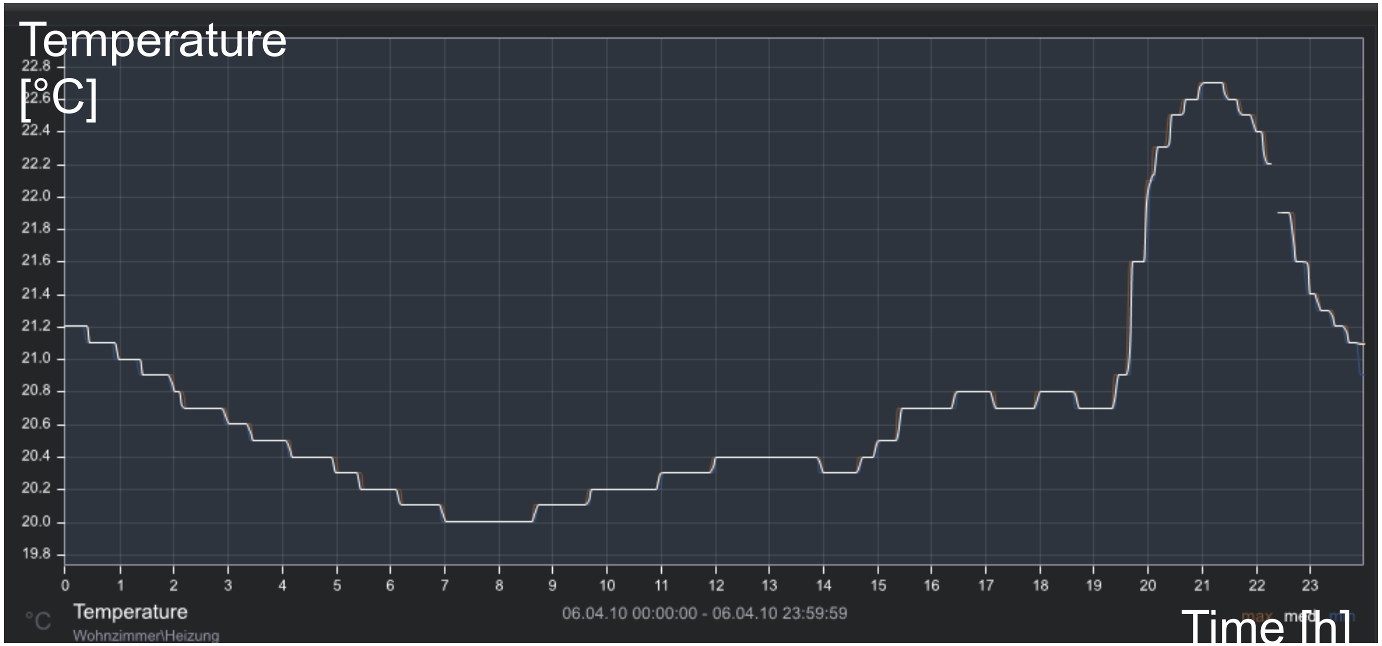
T	19	20	21	22	23	24	1
f(T)	cold	warm	hot	warm	hot	warm	warm

time series: gaps



time series: gaps

T	19	20	21	✗	23	24	1
f(T)	cold	warm	hot	✗	hot	warm	warm

Why are gaps or disturbances important?

Why are gaps or disturbances important?

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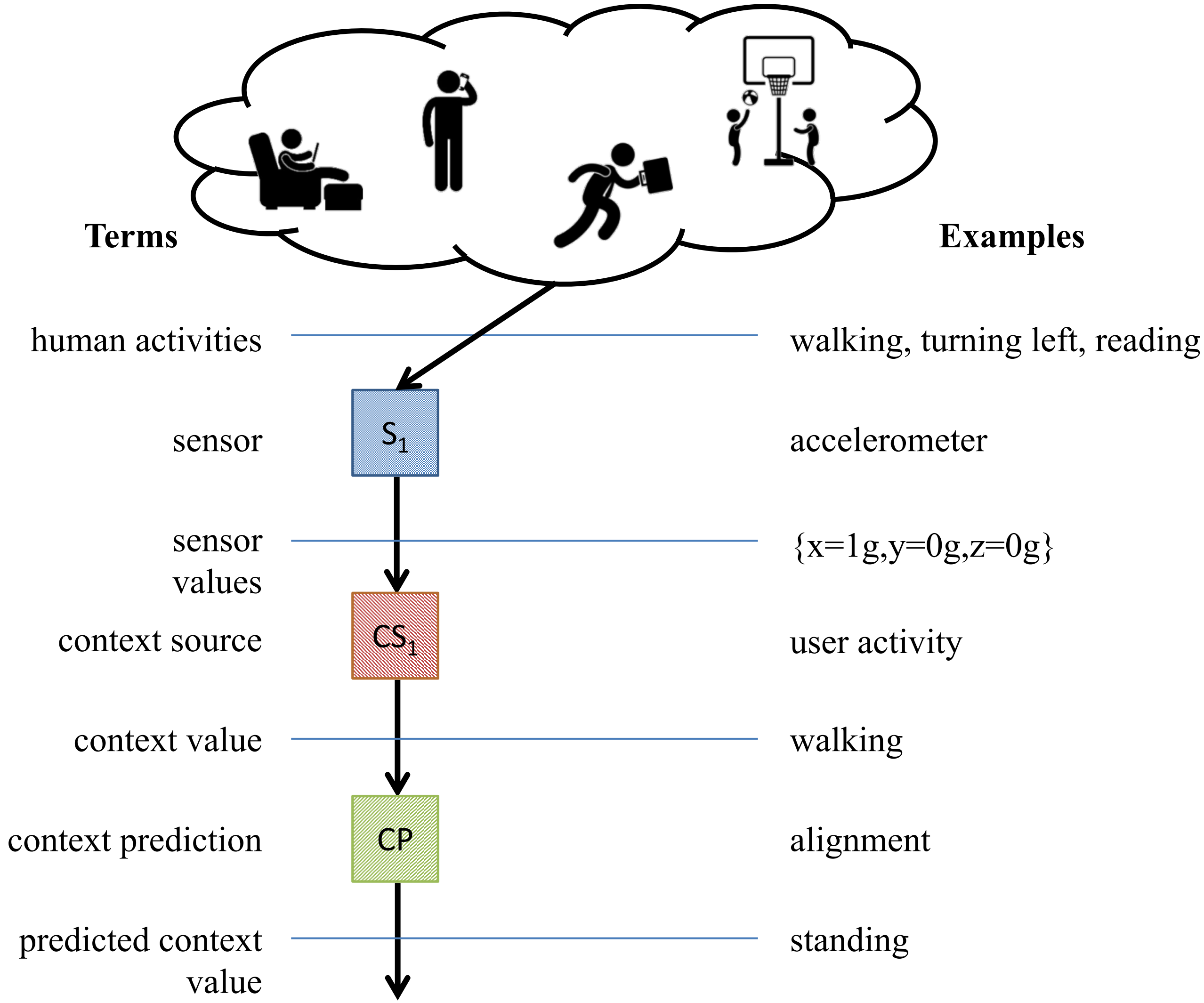
- They will always occur with sensor
- Human behaviour is *similar* to itself but usually not *identical*
- We need an algorithm capable of handling these

Alignment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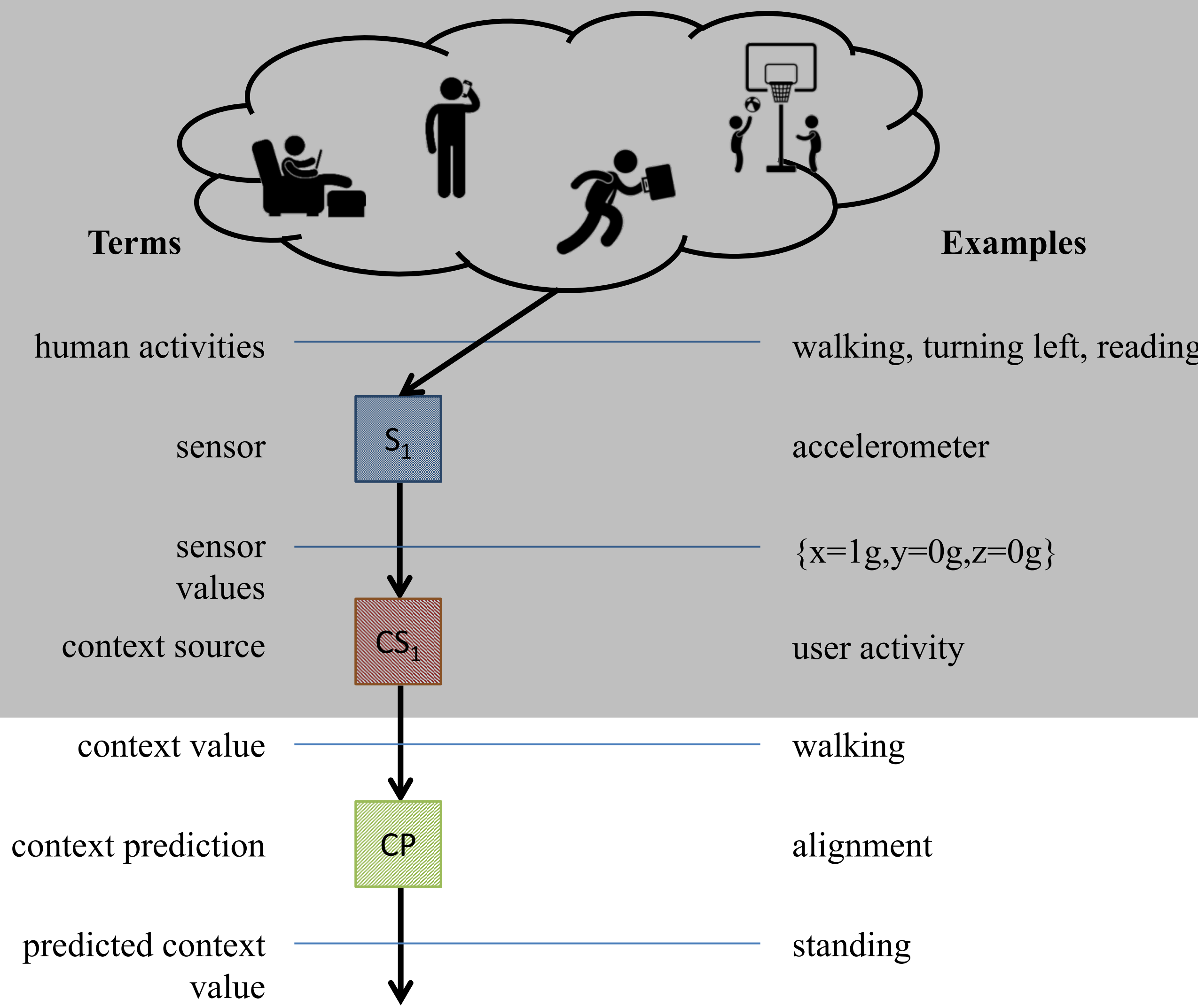
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Why Alignment

- Alignment was proposed for context prediction in our chair

- Alignment sas two main advantages:
  - Can be used with non ordinal values (typically context values are non ordinal)
  - Can work with gaps or mismatches (typically users do nor repeat their activities very accurate)

Where does Alignment originate

- Bioinformatics
  - Global Alignment: Finding DNS sequences
    - You know how a short sequence looks like and want to find *similar* sequences
  - Local Alignment: DNS matchings
    - You want to identify a relative – he is *similar* but *not equal*

Mindmap: Needleman-Wunsch-Algorithm vs. Smith-Waterman-Algorithm

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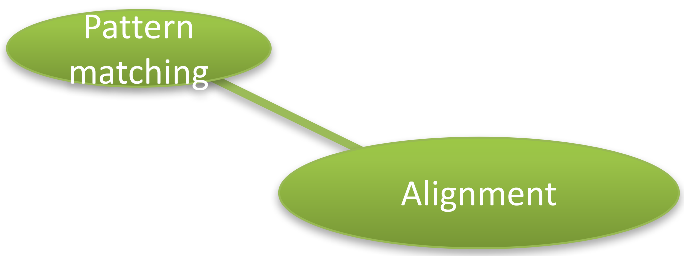
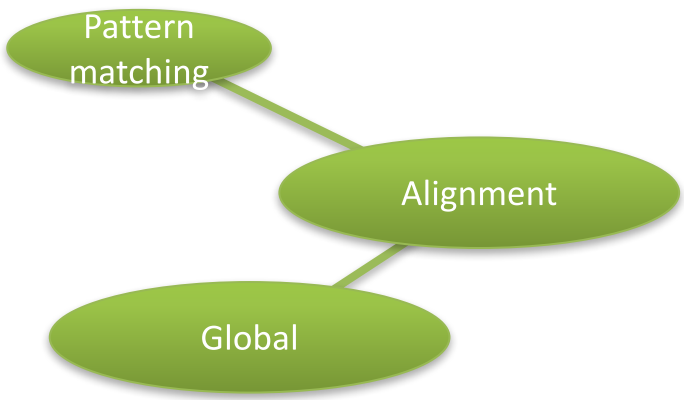
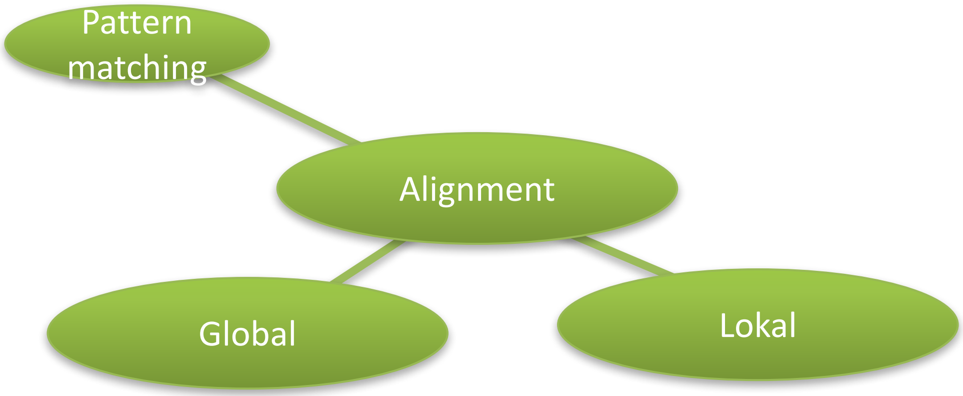


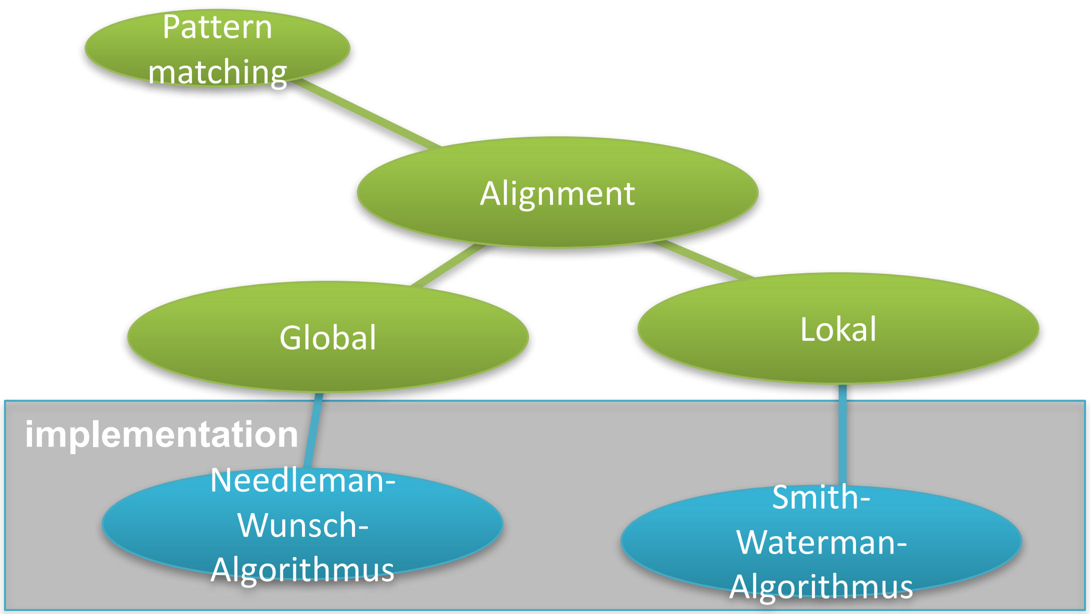
Mindmap: Needleman-Wunsch-Algorithm vs. Smith-Waterman-Algorithm



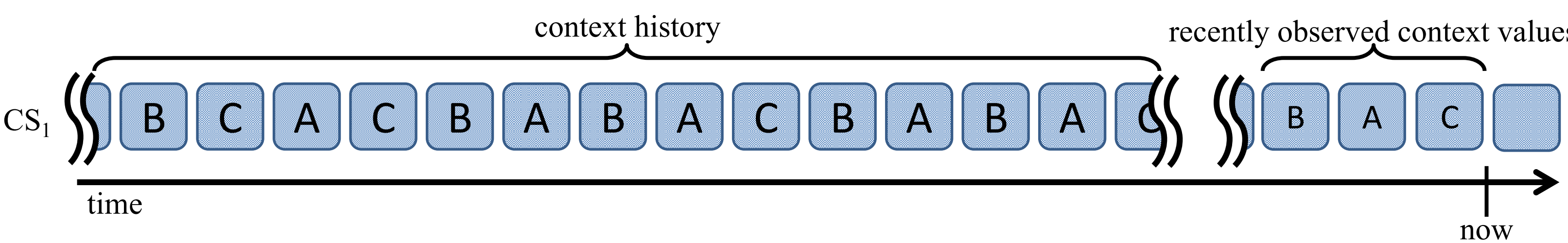
Mindmap: Needleman-Wunsch-Algorithm vs. Smith-Waterman-Algorithm



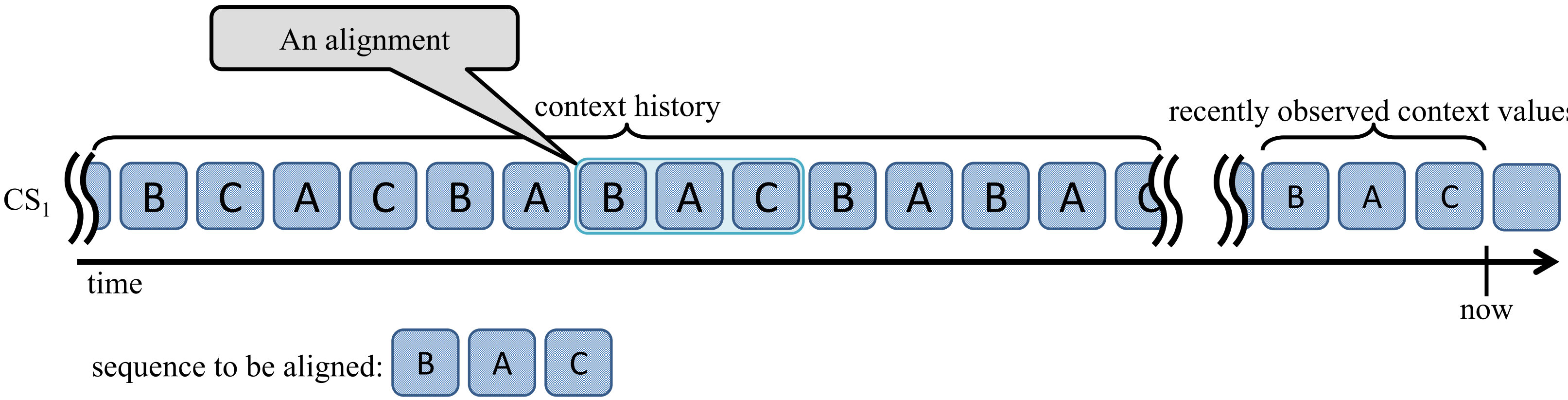
Mindmap: Needleman-Wunsch-Algorithm vs. Smith-Waterman-Algorithm



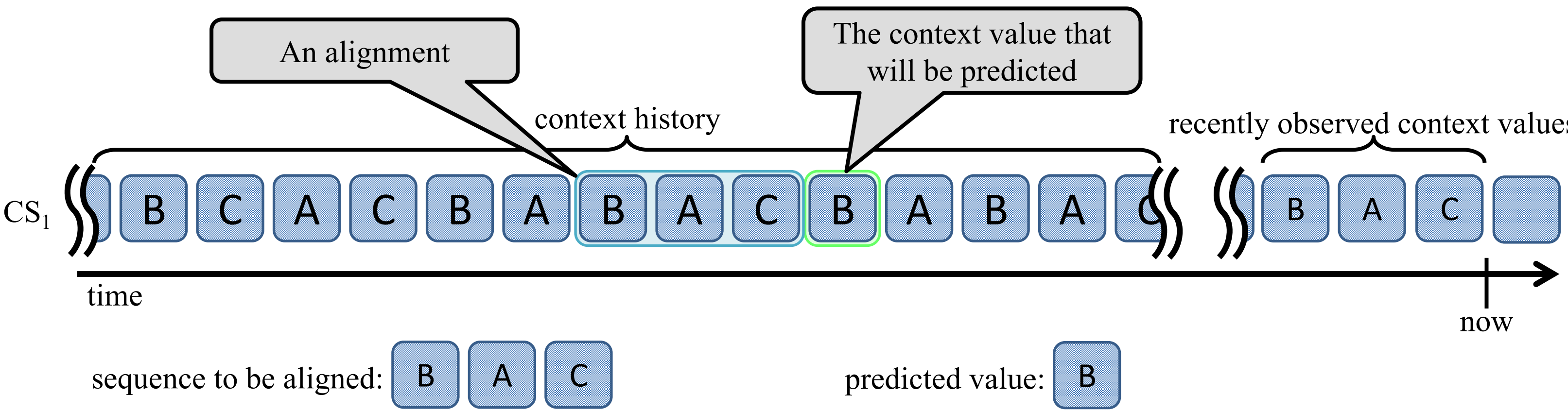
Alignment: History



Alignment: step 1



Alignment: step 2



Alignment: (Alignment with a gap)

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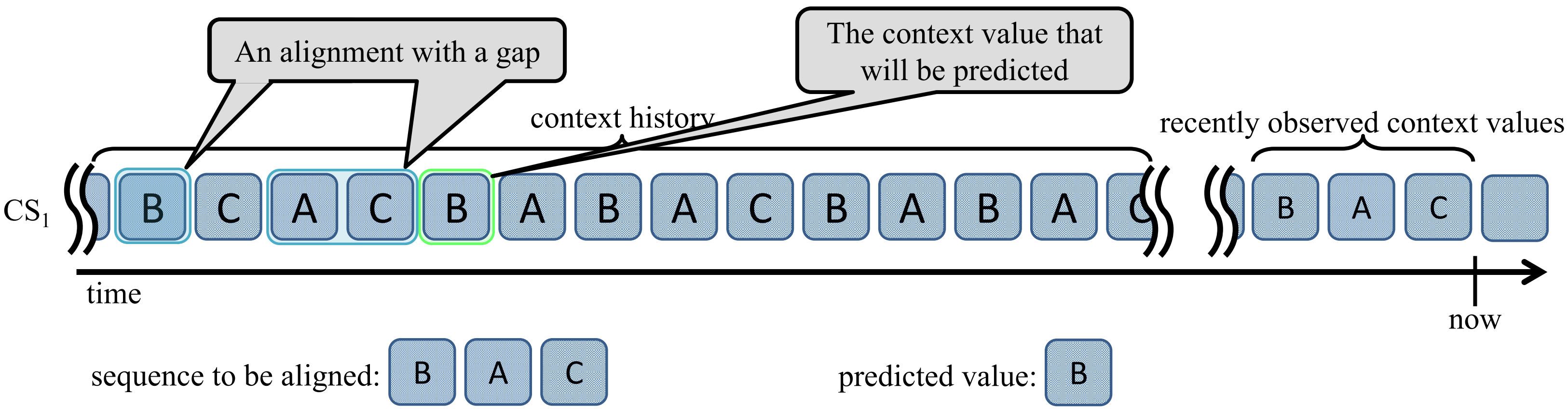
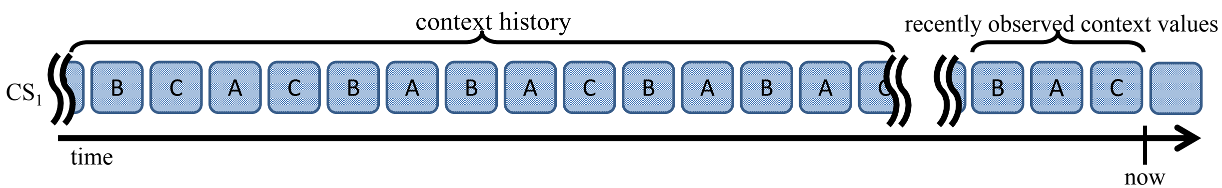


How does the alignment algorithm work

Alignment algorithm: History



Alignment algorithm: construct the table

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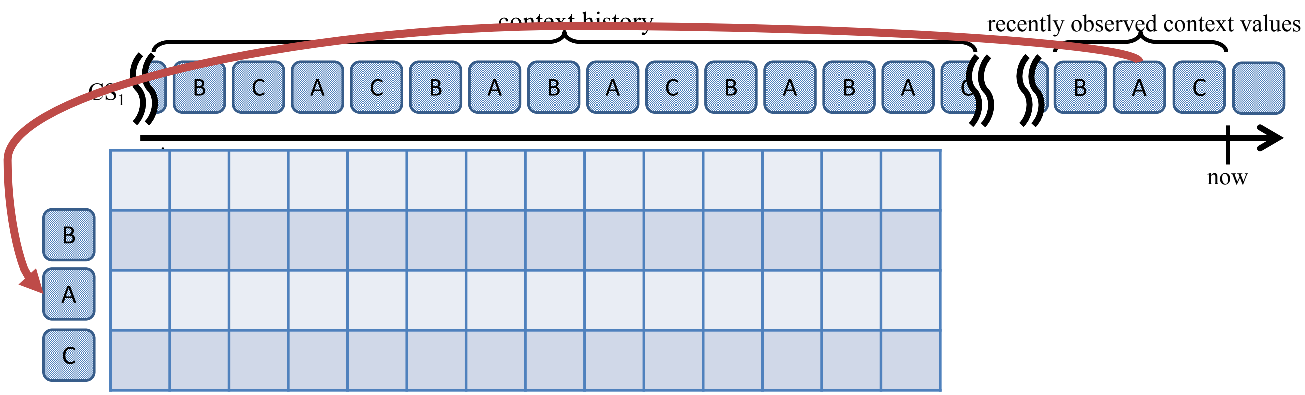

Alignment algorithm: Initialize table

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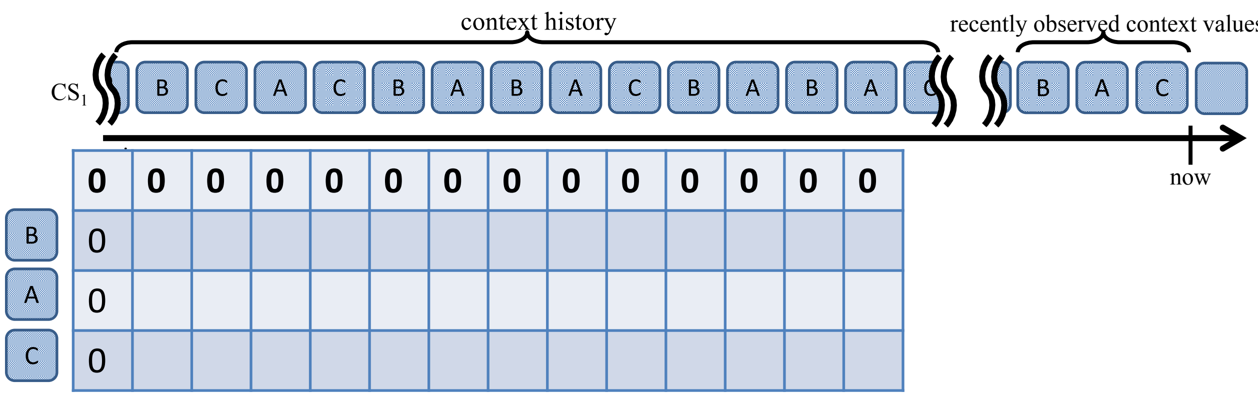
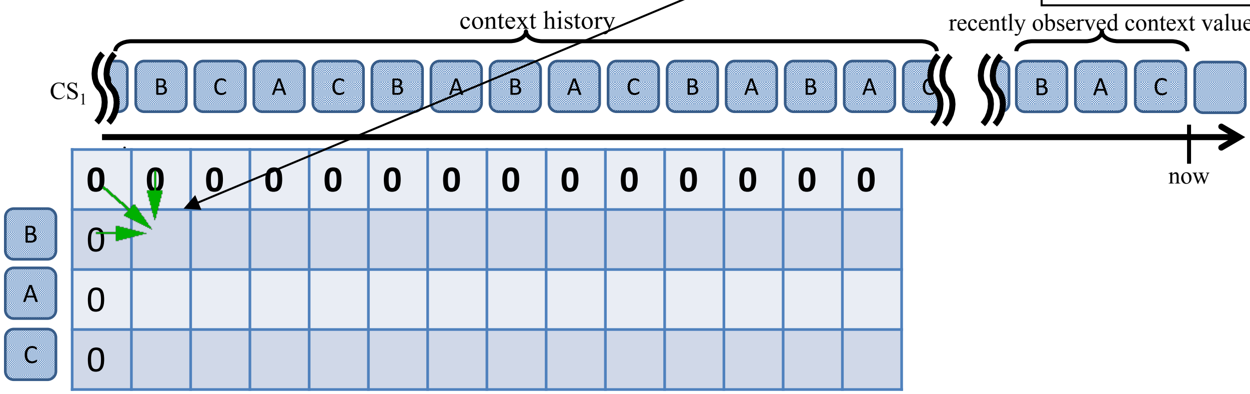


Alignment algorithm: calculate values for table

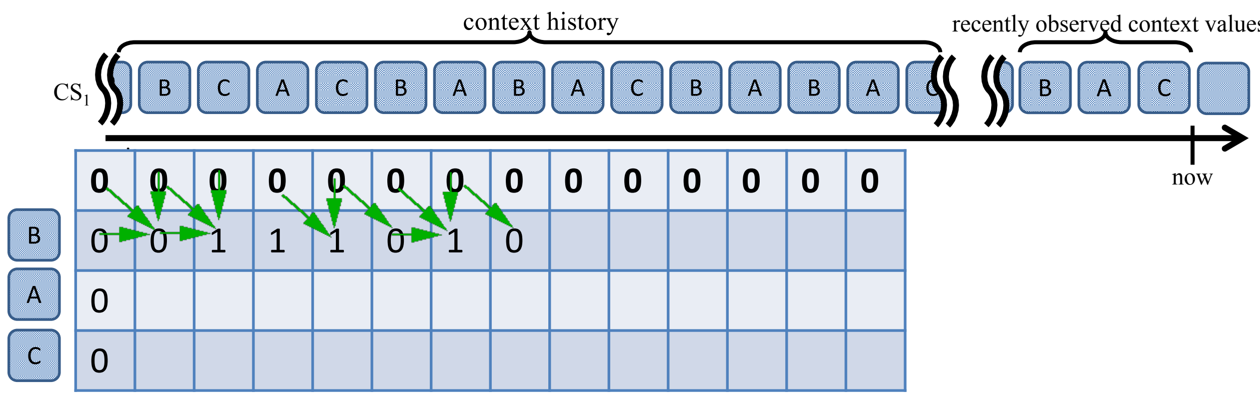
The value of v(i,j) is constructed as the minimum of all adjacent entries plus the penalty cost:

v(i,j)=min{ v(i-1,j-1)+d(i,j),
v(i-1,j)+penalty,
v(i,j-1+penalty)}



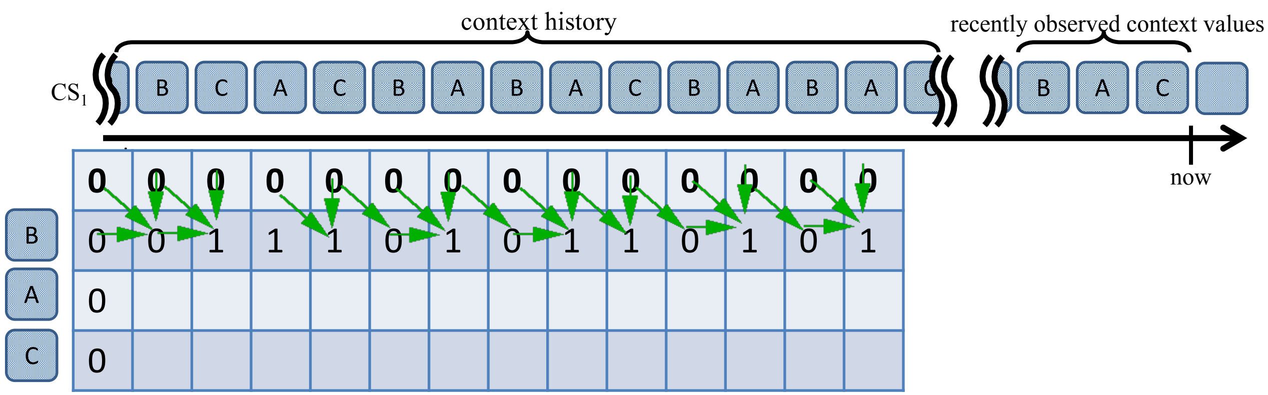
	Symbol	Penalty cost
exact matching	↘	**0**
erroneous matching	↘	**1**
gab symbol inserted in first sequence	↓	**1**
gab symbol inserted in second sequence	→	**1**

Alignment algorithm: calculate values for table

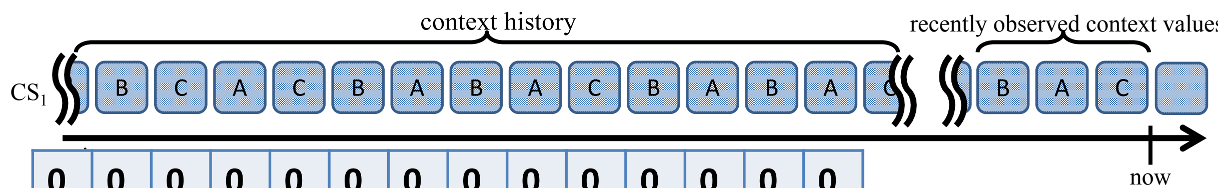


Alignment algorithm: calculate values for table

ComTec

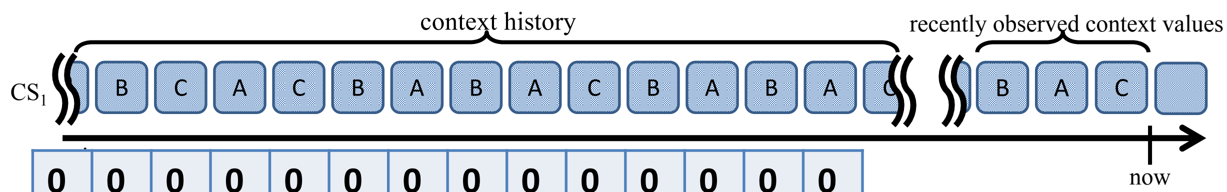


Alignment algorithm: calculate values for table



	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
B	0	0	1	1	1	0	1	0	1	1	0	1	0	1
A	0	1	1	1	2	1	0	1	0	1	1	0	1	0
C	0	1	0	1	1	2	1	1	1	0	1	1	1	1

Alignment algorithm: select the lowest costs



	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
B	0	0	1	1	1	0	1	0	1	1	0	1	0	1
A	0	1	1	1	2	1	0	1	0	1	1	0	1	0
C	0	1	0	1	1	2	1	1	1	0	1	1	1	1

Alignment algorithm: back track

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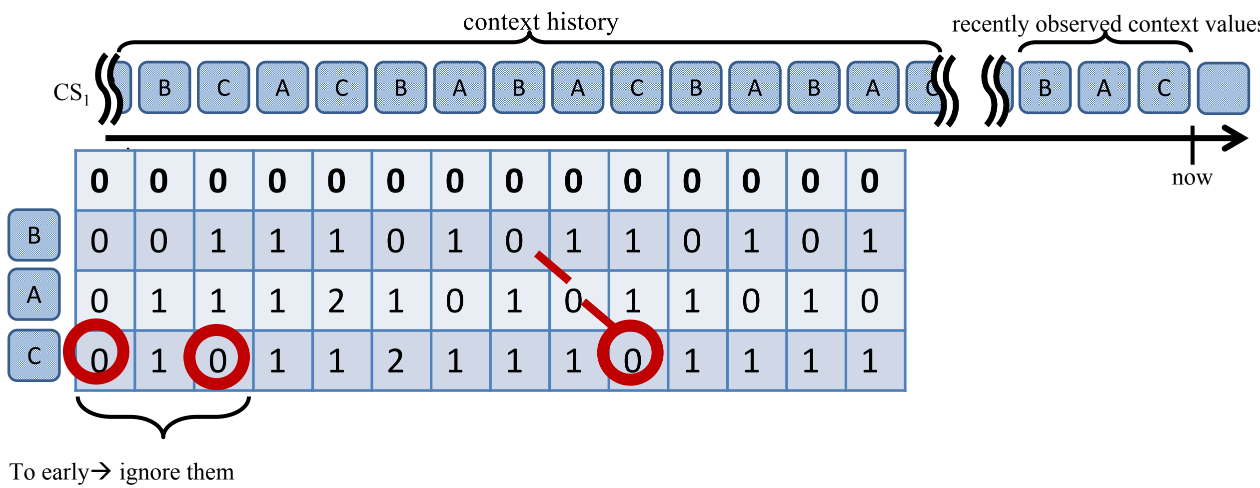

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Enhancing Alignment by multiple context sources

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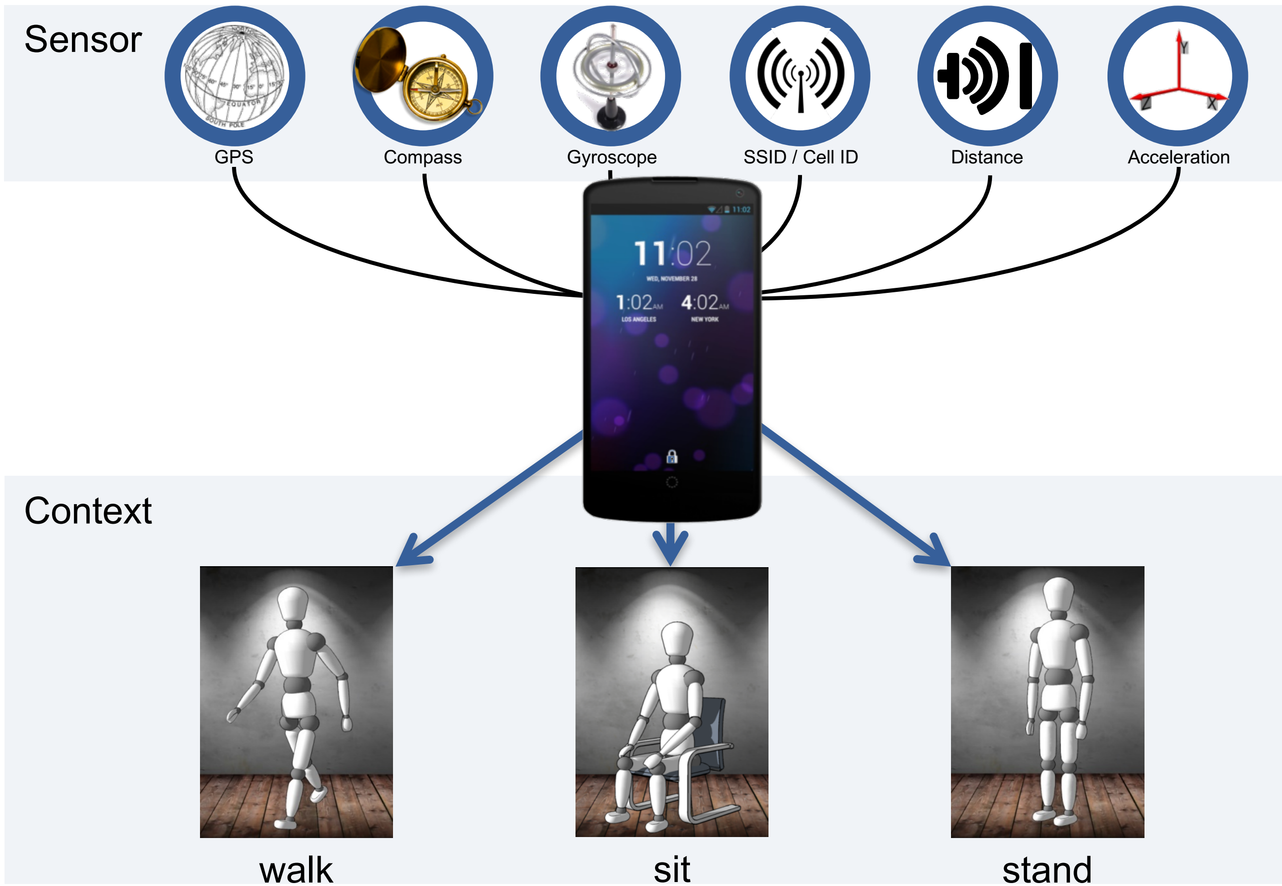
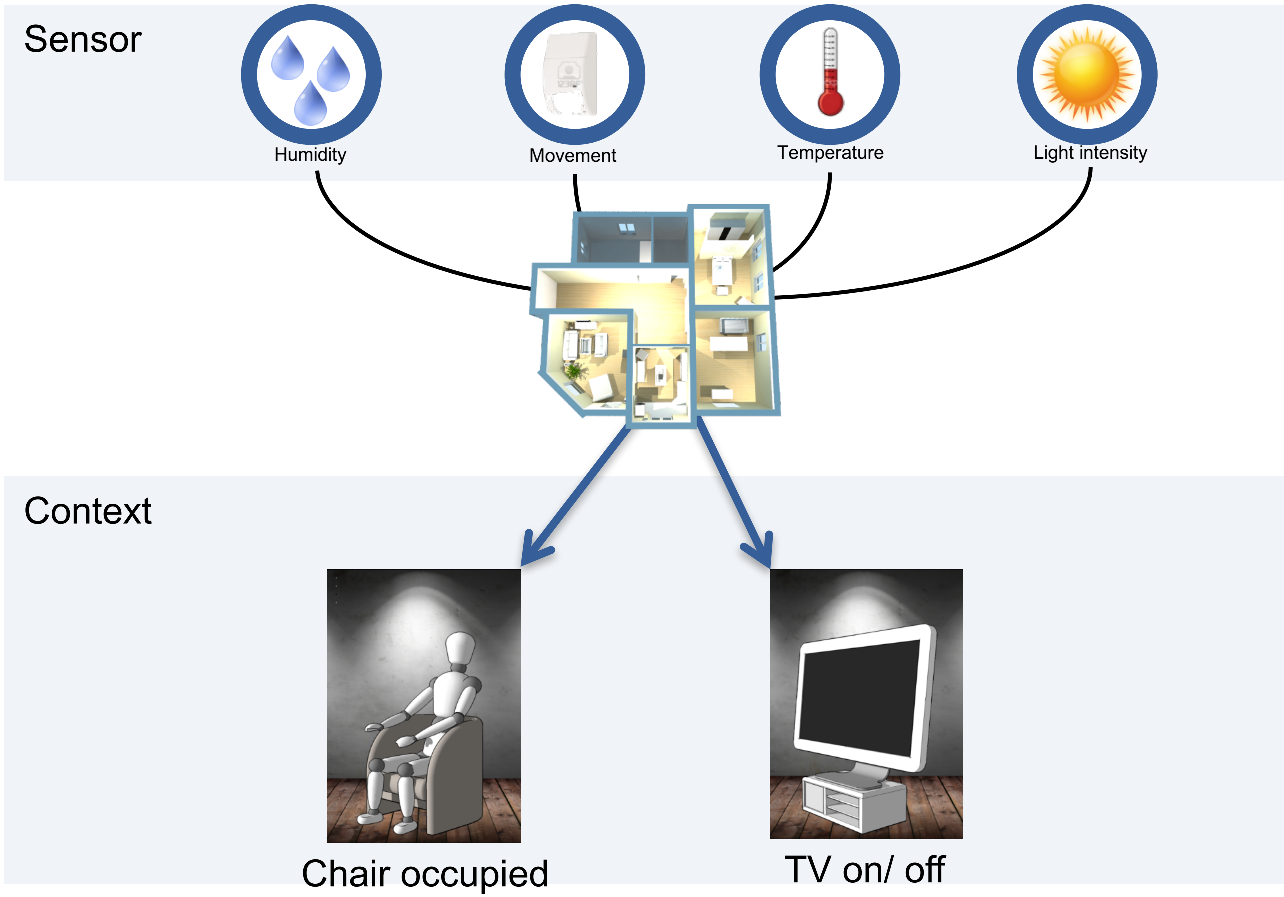
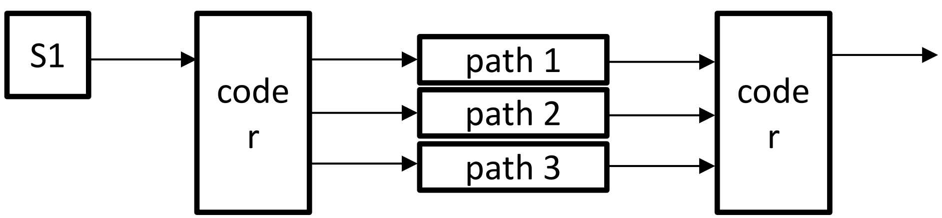

Sensor
GPS
Compass
Gyroscope
SSID / Cell ID
Distance
Acceleration
Context
walk
sit
stand


Sensor
Humidity
Movement
Temperature
Light intensity
Context
Chair occupied
TV on/ off

Alignment by multiple context sources

- Why use multiple context sources for context prediction?



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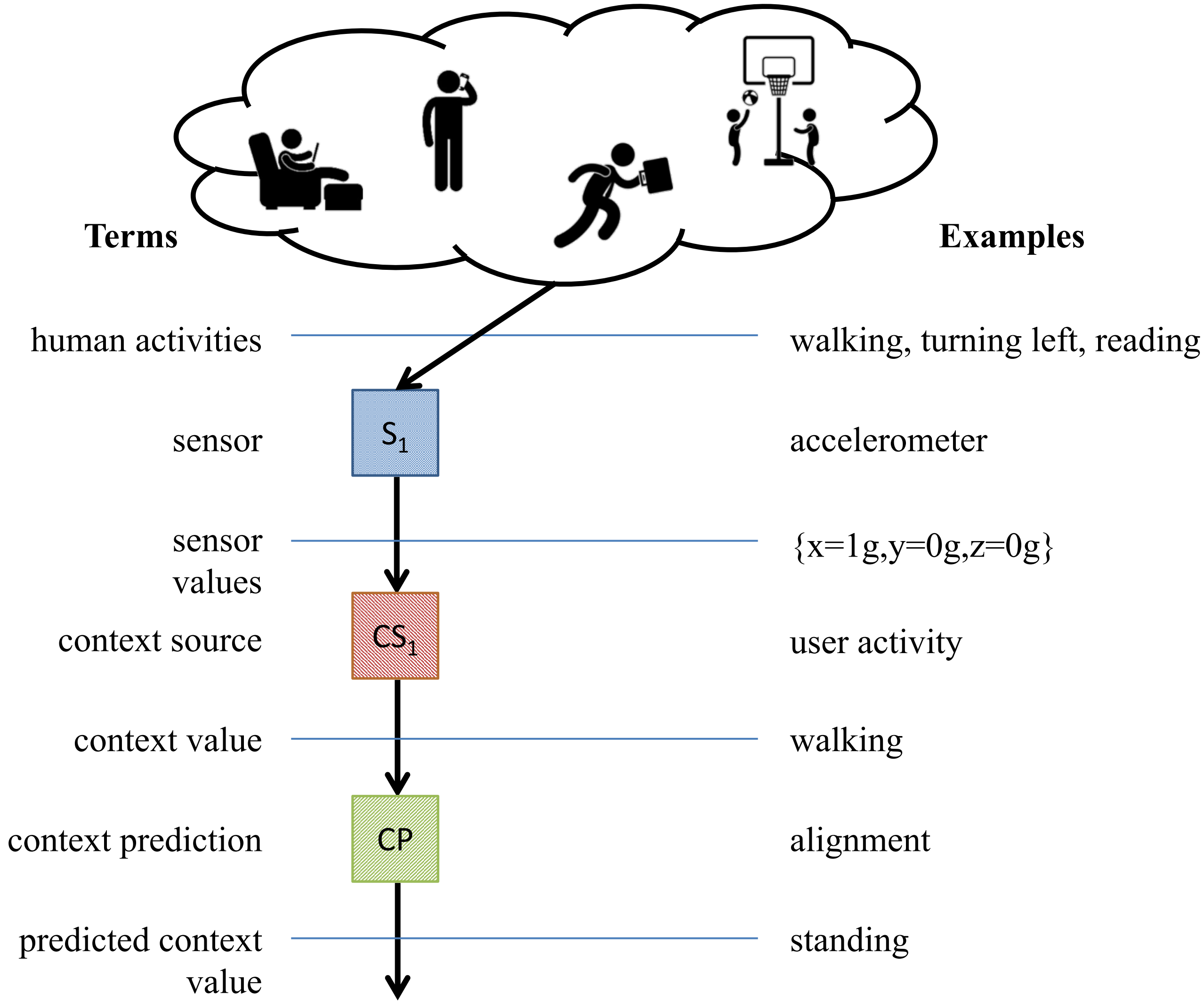
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S_1
accelerometer
sensor values
{x=1g,y=0g,z=0g}
context source
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user activity
context value
walking
context prediction
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predicted context value
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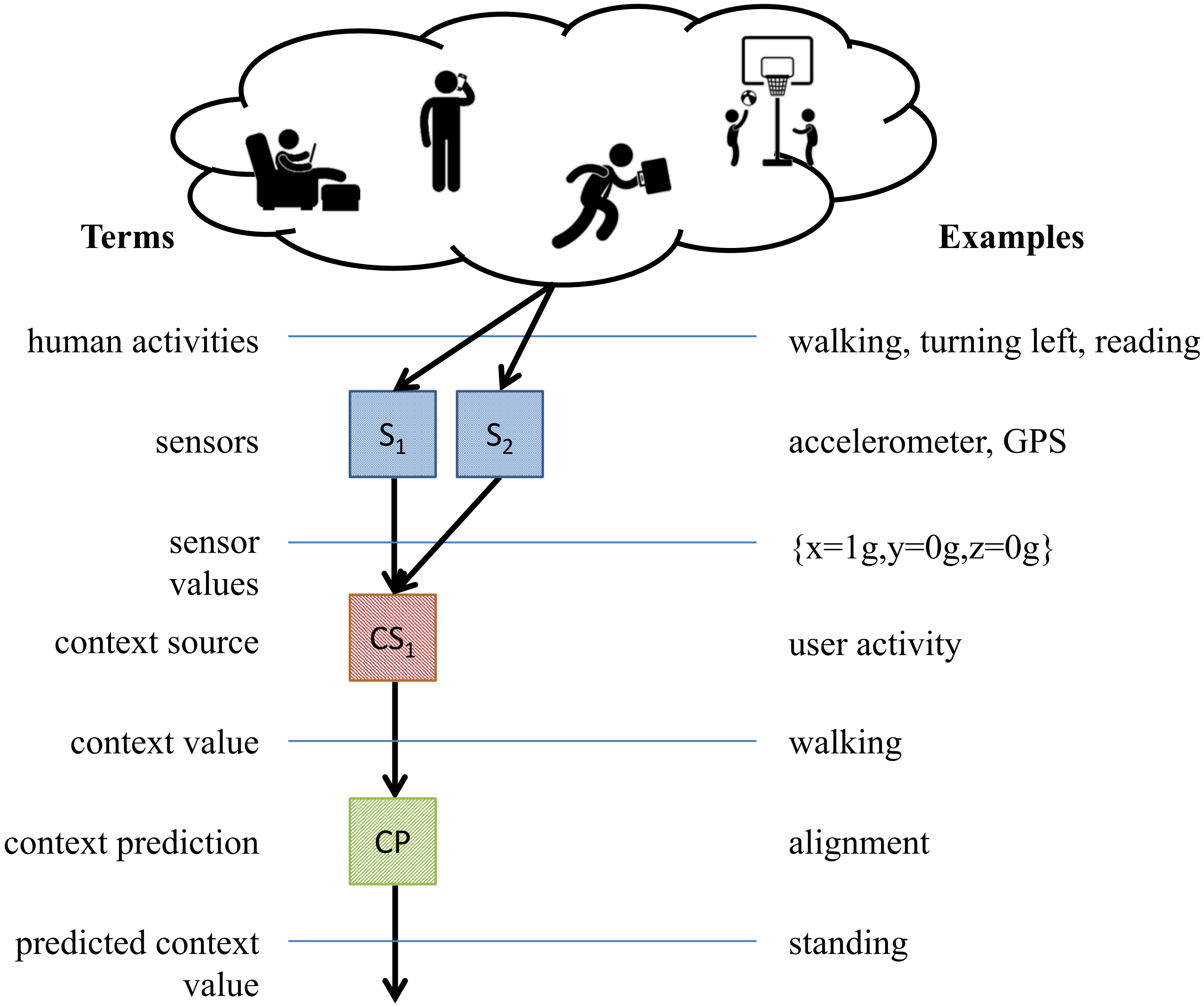
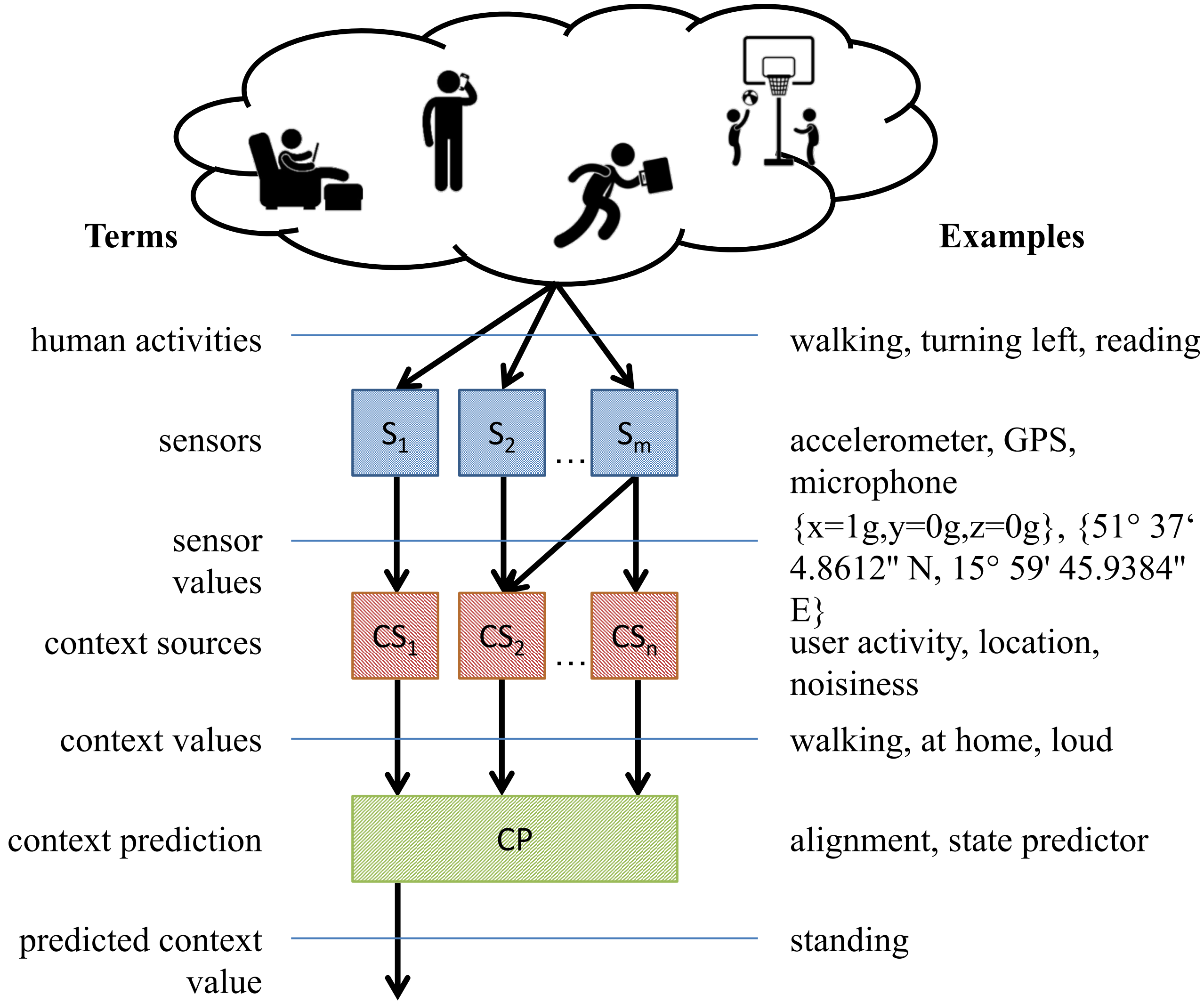


Terms
Examples
human activities
walking, turning left, reading
sensors
S1
S2
accelerometer, GPS
sensor values
{x=1g,y=0g,z=0g}
context source
CS1
user activity
context value
walking
context prediction
CP
alignment
predicted context value
standing

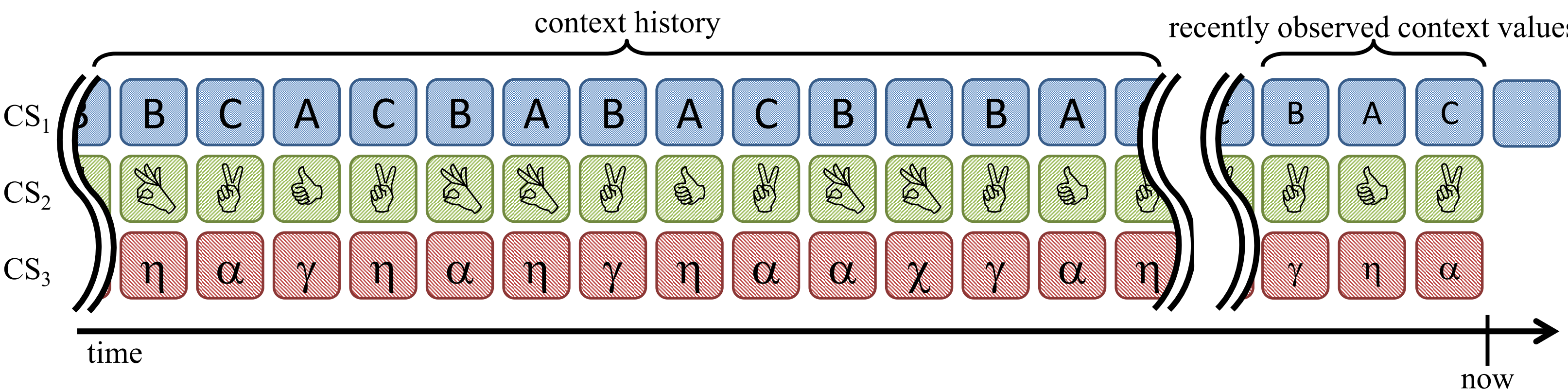


Terms
Examples
human activities
walking, turning left, reading
sensors
S1
S2
…
Sm
accelerometer, GPS, microphone
sensor values
{x=1g,y=0g,z=0g}, {51° 37‘ 4.8612" N, 15° 59' 45.9384" E}
context sources
CS1
CS2
…
CSn
user activity, location, noisiness
context values
walking, at home, loud
context prediction
CP
alignment, state predictor
predicted context value
standing

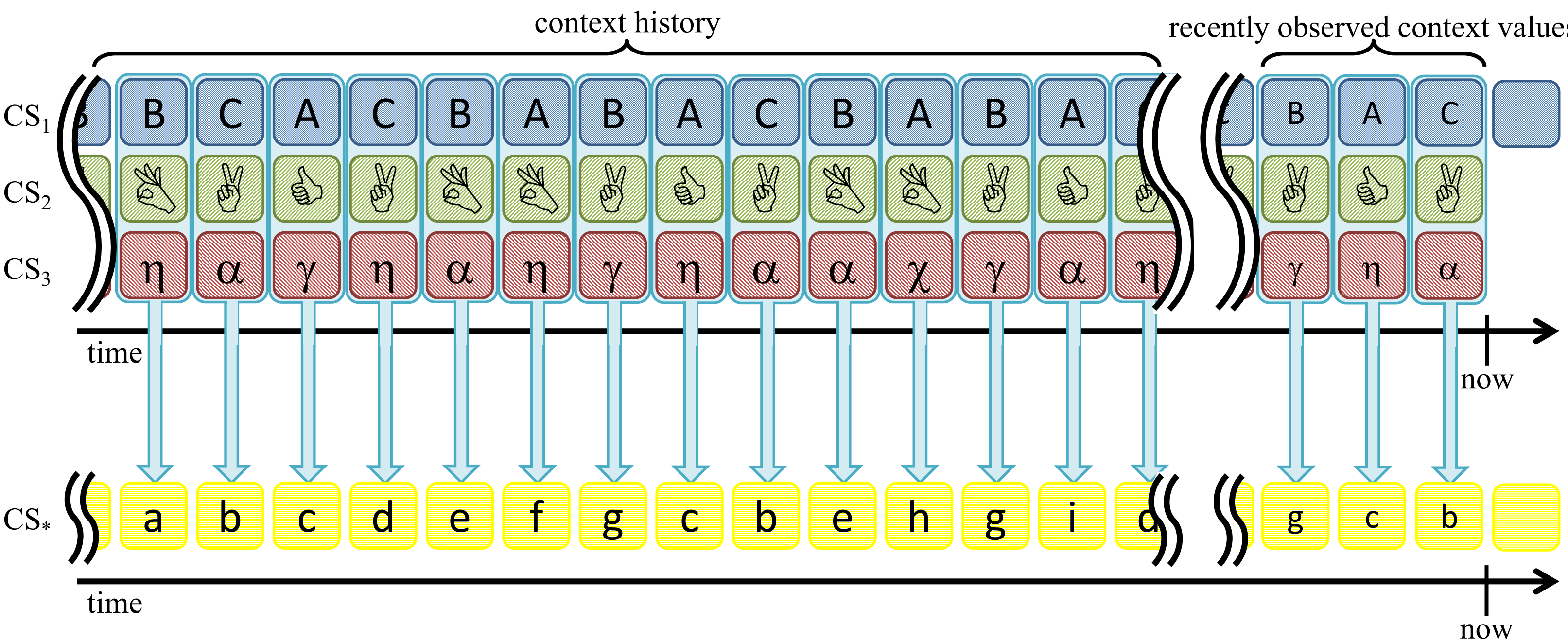
Alignment with multiple context sources

Idea → Include other context source to benefit from the information of other sources

Alignment with multiple context sources



Alignment with multiple context sources: mapping approach



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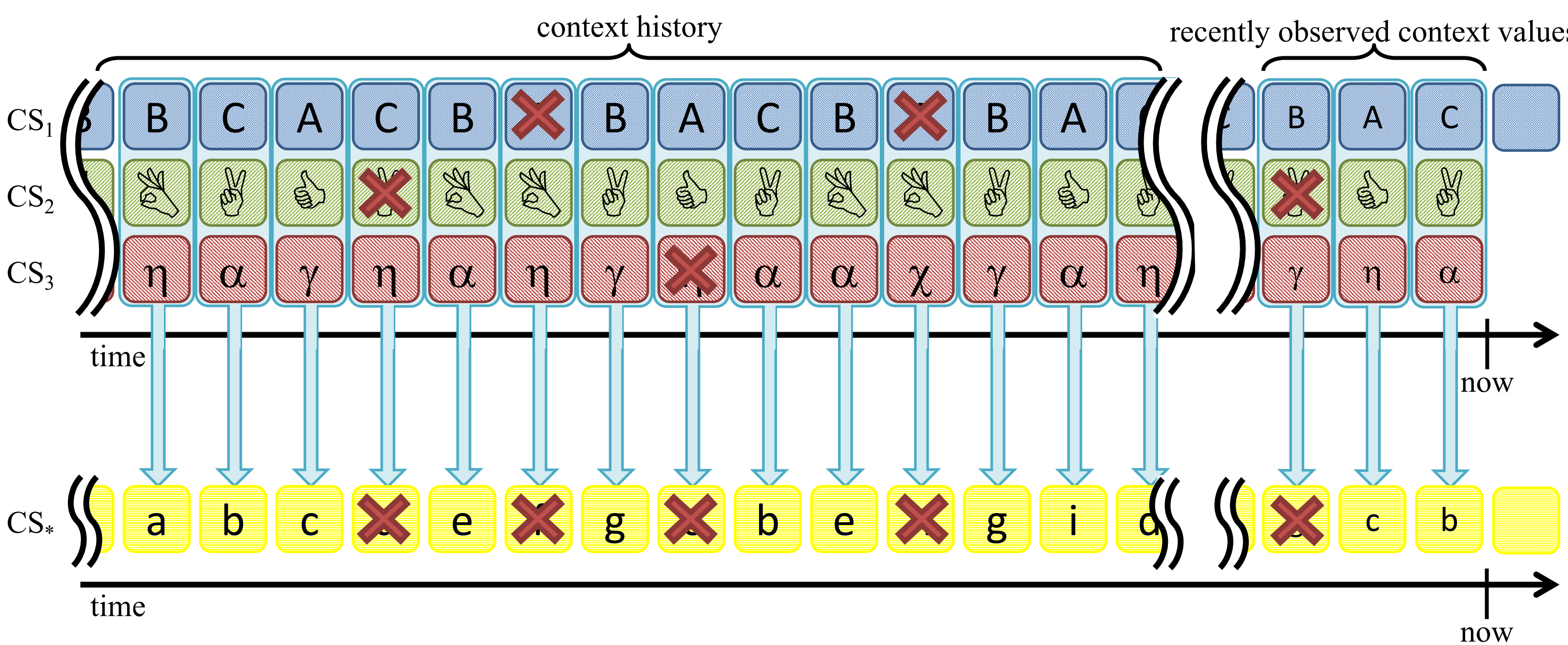

Alignment with multiple context sources: multi alignment approach

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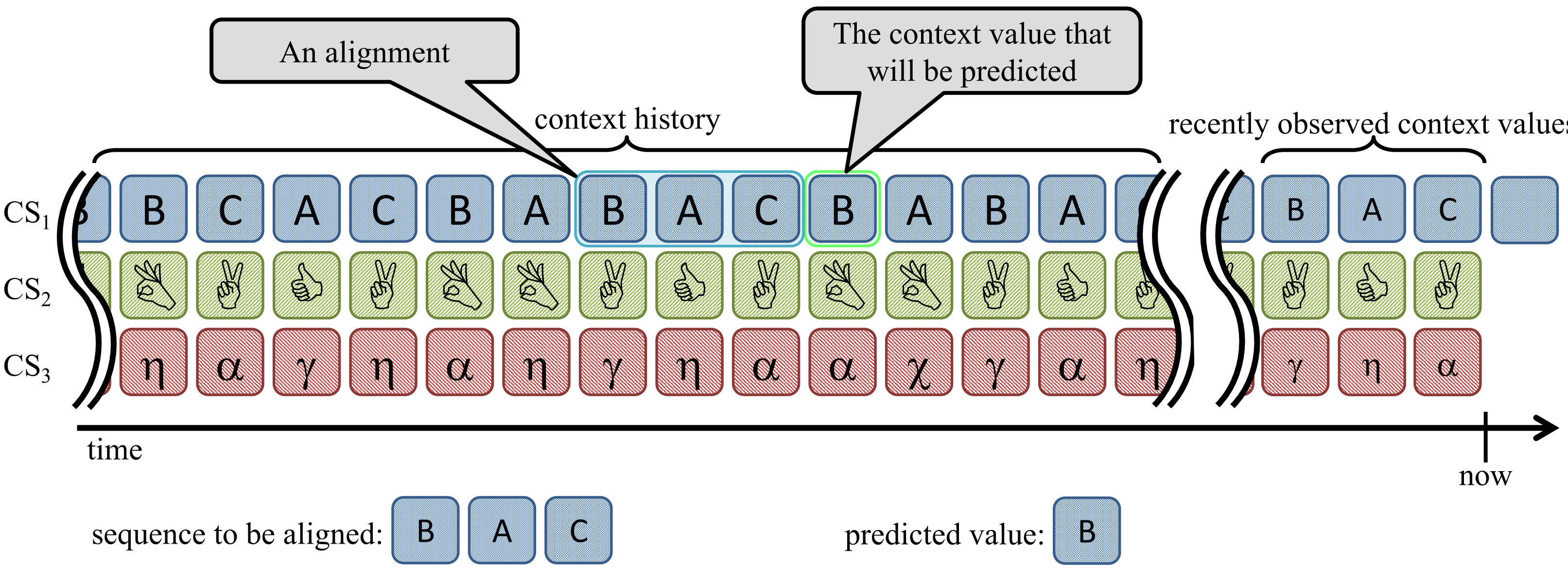
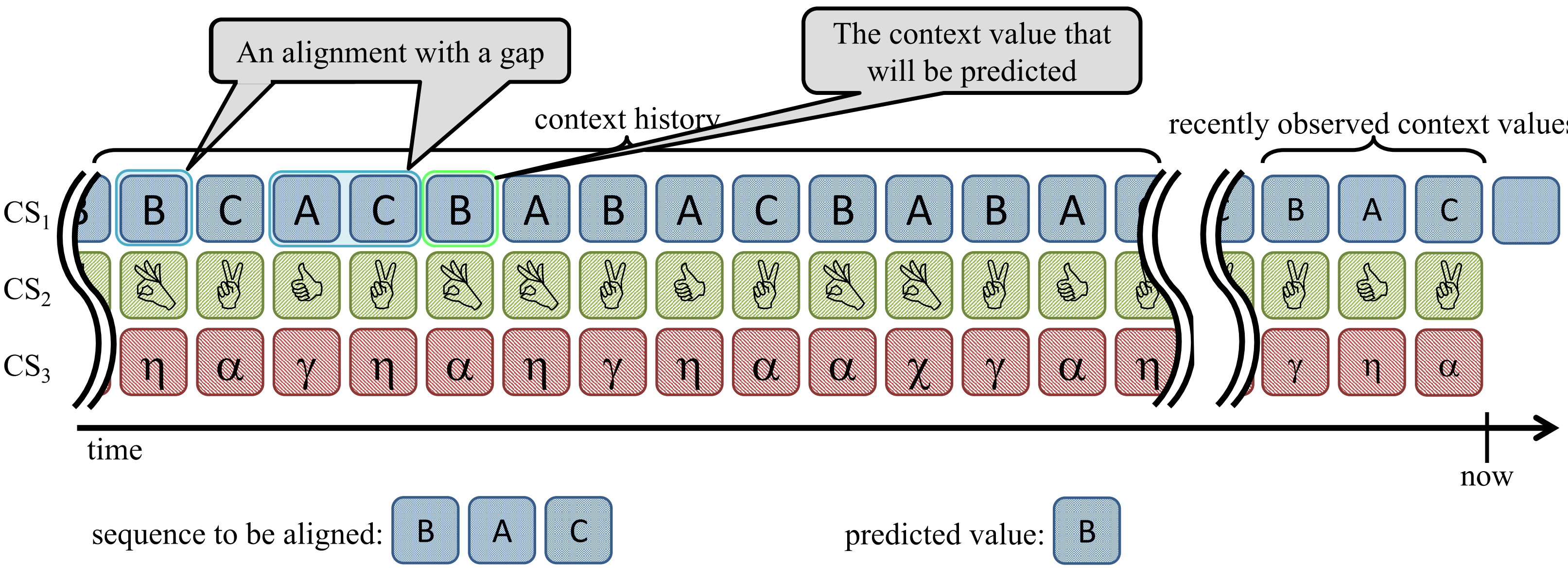
- mapping correlation has disadvantages of information losses
- Can't we use the information from each context source for each context source independently?

Alignment with multiple context sources: multi alignment approach



Alignment with multiple context sources: multi alignment approach



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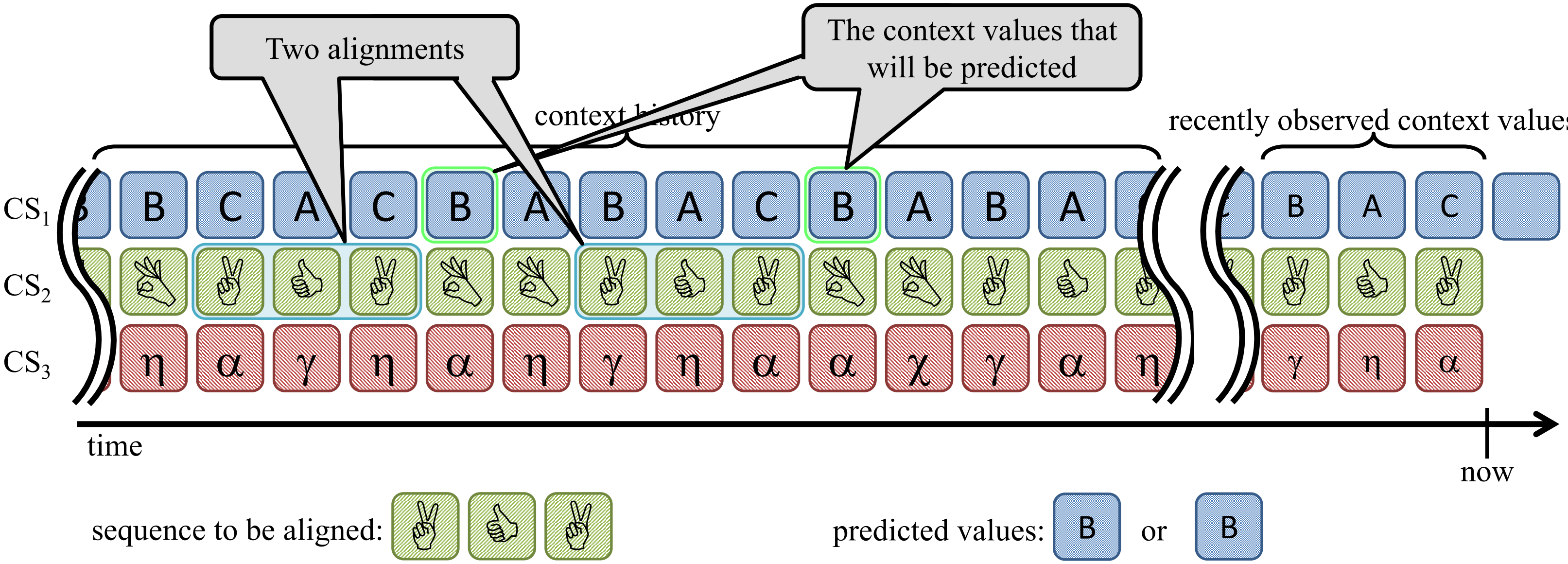

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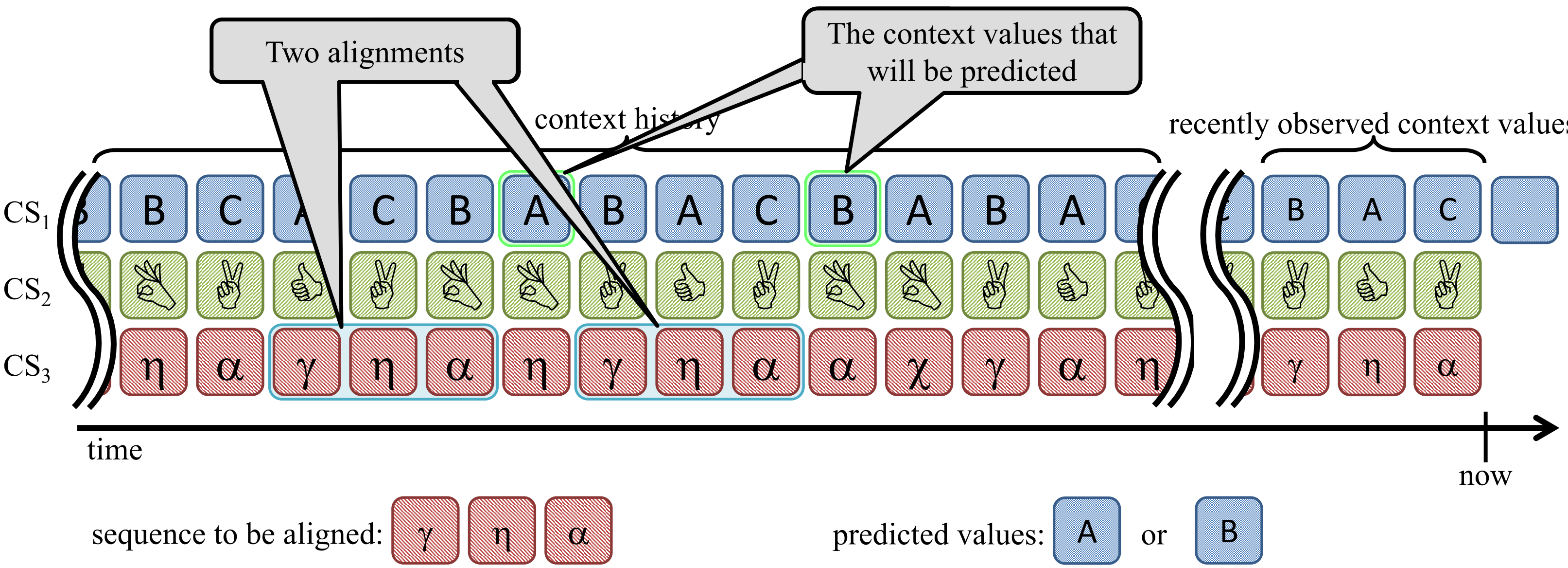

Alignment with multiple context sources: multi alignment approach: experiment

- We wanted to compare the two approaches
- collected two contexts:
  - location
    - 41 locations (home, work, …)
  - temperature
    - outside, inside, unknown
- made a series of predictions (split the dataset into test set and history)

2 Alignment with multiple context sources: multi alignment approach: results

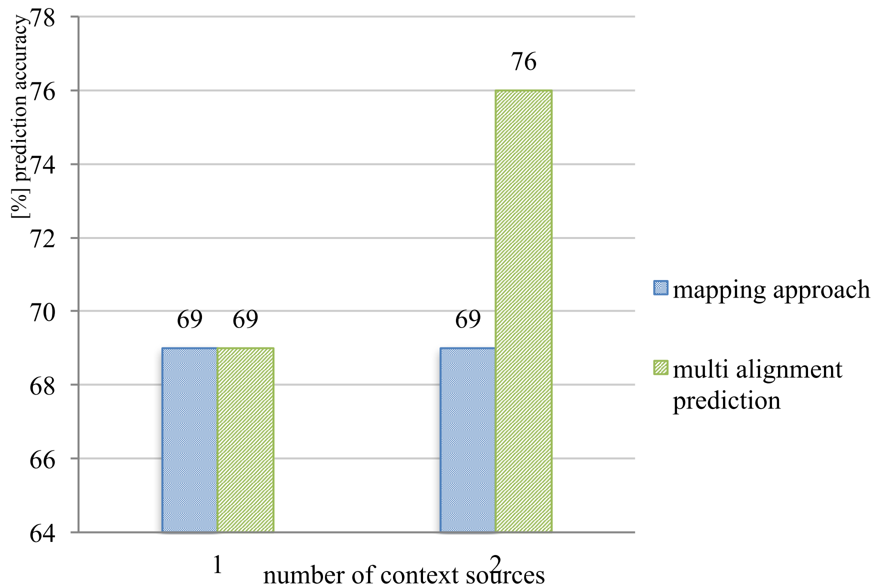

Figure 14: prediction accuracy over number of context sources for two different context prediction approaches

Selecting beneficial context sources

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- A vast amount of sensors is available
- A (vast) amount of context sources can be available

- One combination may be useful to gain prediction accuracy
- One combination may irritate the prediction

- How to choose which combination of context sources will be useful?

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Selecting beneficial context sources

Selecting beneficial context sources

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- The upper limit of prediction accuracy can be calculate: predictability

- Predictability:
  - Depends on the history we want to predict on
  - Is different for each history, each user, each behaviour

Selecting beneficial context sources

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- Using on Fano‘s inequality Song derived:

$$\mathcal{H}(\mathcal{X}) = -\Pi^{max} \log_2 \Pi^{max} - (1 - \Pi^{max}) \log_2 \frac{1 - \Pi^{max}}{N - 1}$$

- Π^{max} Predictability
- $\mathcal{H}(\mathcal{X})$ Entropy
- N Size of the alphabet (number of different context values)

Selecting beneficial context sources

- Using an estimator to calculate $\mathcal{H}(\mathcal{X})$:

$$H^{est} = \left(\frac{1}{n}\sum_{i=1}^{n}\Lambda_i\right)^{-1} \ln n$$

- n number of elements in the context history
- Λ_i length of the shortest time series starting at position i in the history which does not appear before i

Selecting beneficial context sources

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- Idea →
  1. calculate the predictability of each combination of context sources
  2. choose the combination with the highest predictability

Selecting beneficial context sources: Experiment

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1. collect sensor data from two users and multiple sensors to derive context values in different context sources from the sensor data
2. make a series of prediction accuracy tests with different combinations of the context sources
3. calculated the predictabilities of different combination of the context sources
4. compare the predictability values with the prediction accuracy values of the different context source combinations

Selecting beneficial context sources: Results

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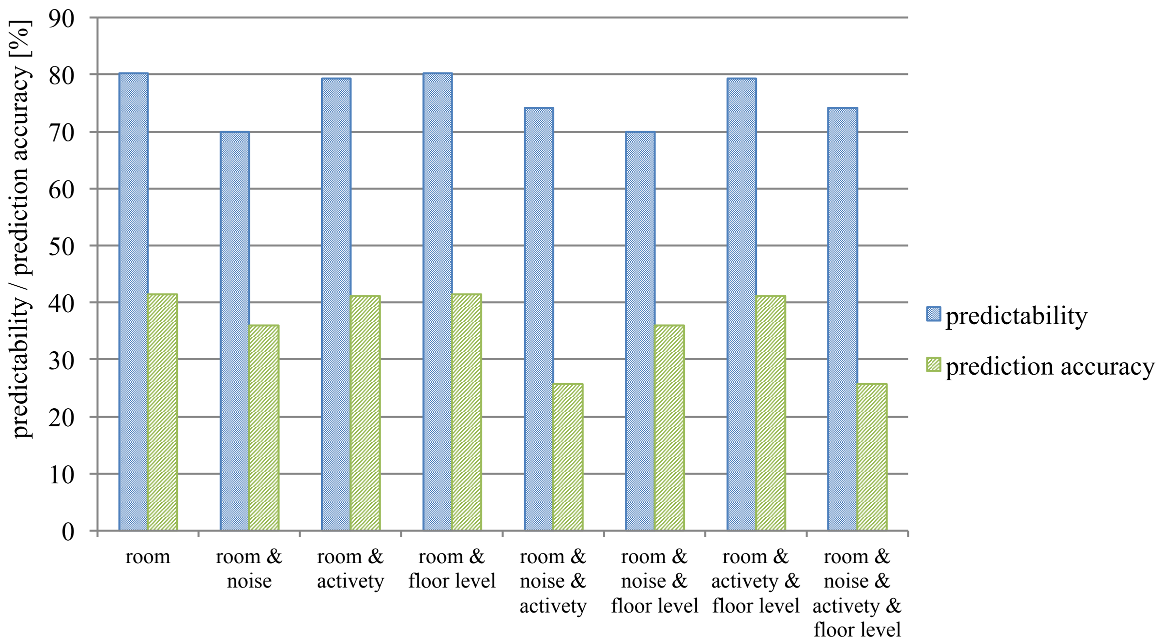

Figure: comparison of tendency between predictability and prediction accuracy

Selecting beneficial context sources: Conclusion

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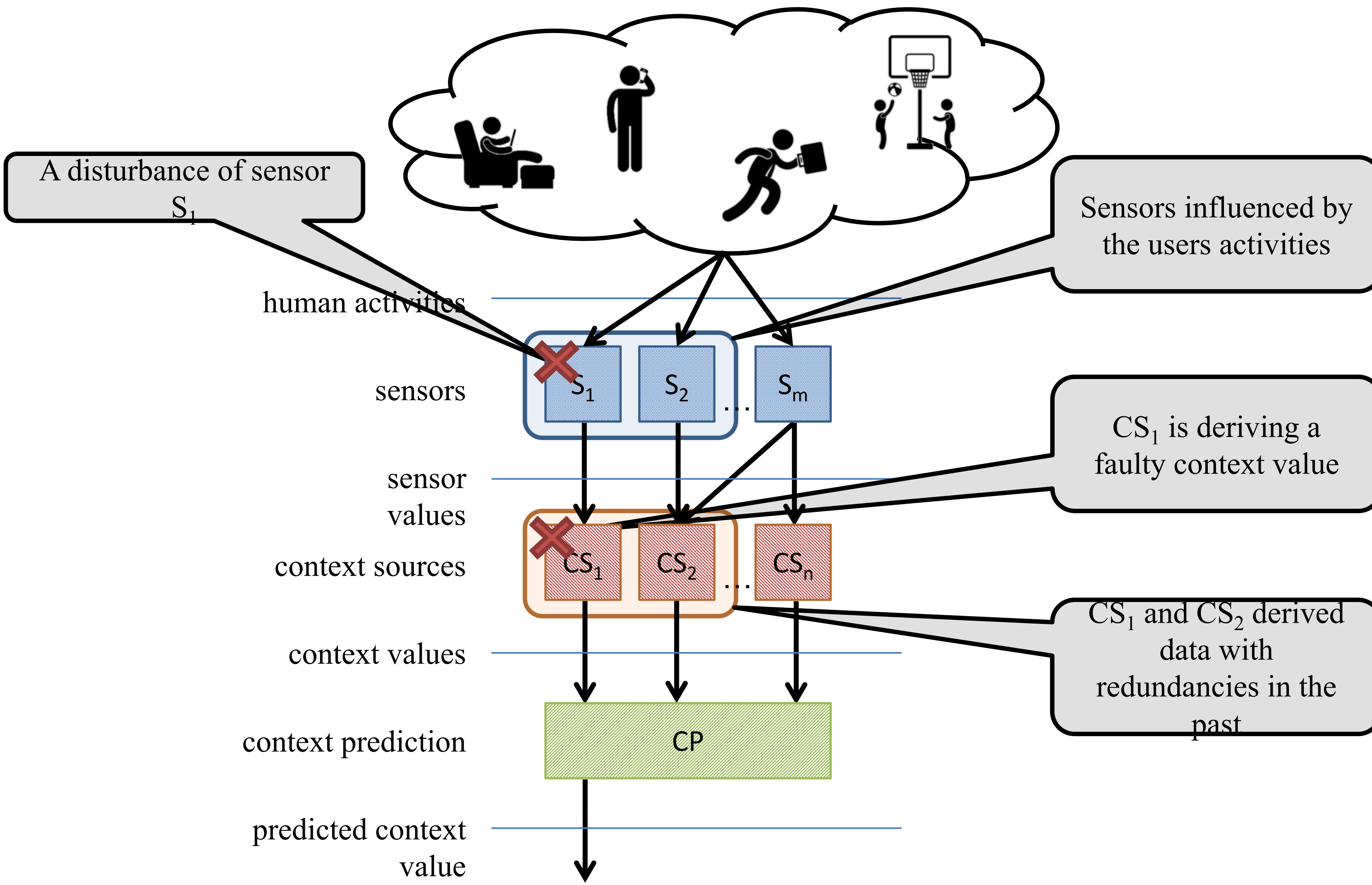
- most times when the predictability increased also the prediction accuracy increased
  - the approach can be used
- it is depending on the user
  - another user showed different results in terms of best combination

The effect of prediction stability against disturbances of sensors

The effect of prediction stability against disturbances of sensors

- In communication technics a multi channel approach is used to gain stability against disturbances
- We have multiple ‘senders’
- We can not control the amount of redundancy but there may be redundancy between different context sources
- Idea→ if one context source get disturbed, other context sources may still provide correct information about the user


A disturbance of sensor S_1
Sensors influenced by the users activities
human activities
sensors
S_1
S_2
...
S_m
sensor values
CS_1 is deriving a faulty context value
context sources
CS_1
CS_2
...
CS_n
CS_1 and CS_2 derived data with redundancies in the past
context values
context prediction
CP
predicted context value

The effect of prediction stability against disturbances of sensors: Experiment

- We collected sensor data from four context sources
  - smartphone
    - user activity
      - sitting, standing, walking
    - floor level
      - upper floor, lower floor
    - noise level
      - low, medlow, med, medhigh, high
  - smart home
    - Location
      - rooms 1..8
- 2 persons, >3800 datasets from each

The effect of prediction stability against disturbances of sensors: Experiment

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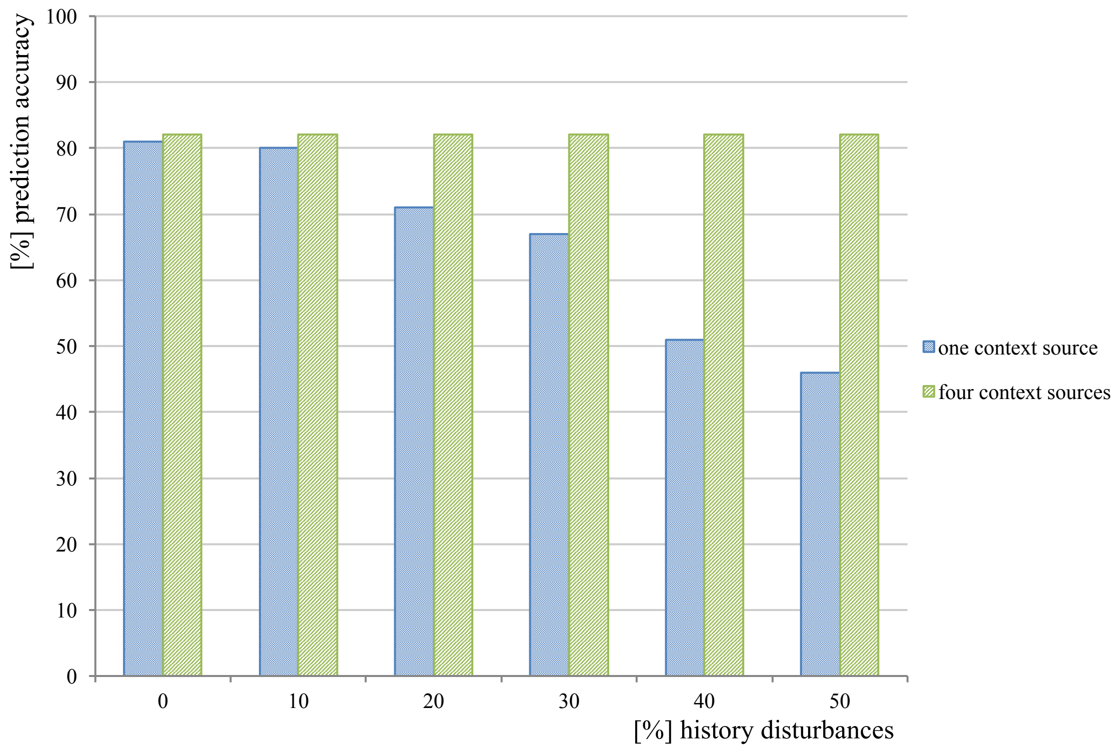
- We artificially added disturbances to the history
- We calculated the mount of disturbances afterwards
- We continued the disturbance process until we reached the desired amount (0%, 10%, 20%, 30%, 40%, 50%)

- We tested the prediction accuracy with each disturbed history

The effect of prediction stability against disturbances of sensors: Results



The effect of prediction stability against disturbances of sensors: Conclusion

- we can usually not decide how much redundancies are generated by the different context sources

- Nevertheless, we can use the given redundancies to make a context prediction system more stable against disturbances