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sense and simplicity

Prerequisits for Affective Signal Processing (ASP)

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Outline

1. Introduction

2. State-of-the-art review of ASP

3. Caveats and limitations

4. Prerequisits for succesfull ASP:
    1. Validation
    2. Triangulation
    3. Physiology-driven approach
    4. Contributions of Signal Processing community

5. Conclusions

Introduction

- Why ASP?:
  - Affect has major impact on health and cognition
  - Enhance man-machine communication
  - The path to true artificial intelligence (?)

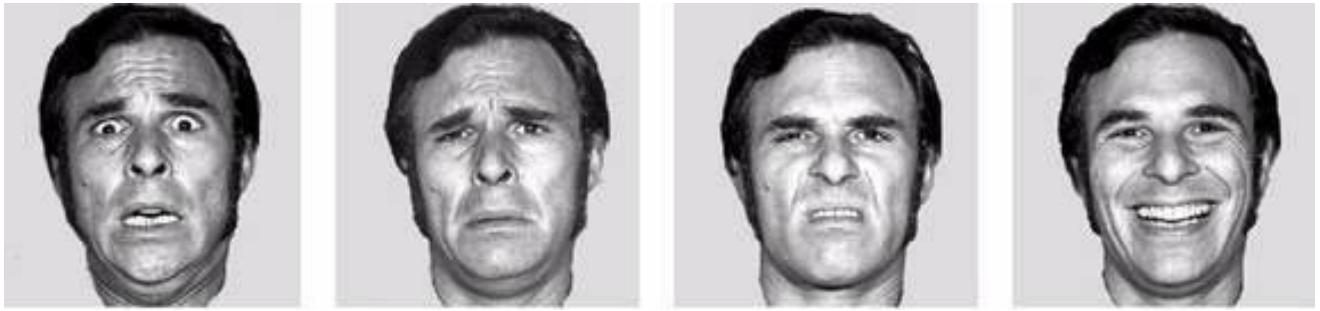
- Three approaches:
  - Facial expressions
  - Speech processing
  - Physiological signals

- Why physiological signals?
  - Unobtrusive measurement
  - No social masking

Martin Ouwerkerk et al. (Philips Research)

State-of-the-art: method

1. Affective state induced: films, pictures, music, autobiographical recollection, commercials, games, virtual reality, real-world experiences



2. Extraction of broad range of signals and features:
   1. Electrodermal activity (EDA): Mean, SD, SCRs
   2. Respiration: Rate, Amplitude
   3. HR, HRV: Rate, RMSSD, Power Bands, RSA
   4. Skin Temperature
   5. EMG: Facial, Back

   (review in paper)

3. Fed to statistical classification methods: e.g., ANN, LDA, SVM

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State-of-the-art: results

Table 2: A summary of 18 studies that have tried to infer affect from physiological signals.

Information source	Signals	Part	Fea	Sel / Red	Classifiers	Target	Result
(Sinha and Parsons, 1996)	$\mathcal{M}$	27	18		LDA	2 emotions	86%
(Picard et al., 2001)	$\mathcal{C},\mathcal{E},\mathcal{R},\mathcal{M}$	1	40	SFS, Fisher	LDA	8 emotions	81%
(Scheirer et al., 2002)	$\mathcal{C},\mathcal{E}$	24	5	Viterbi	HMM	2 frustrations	64%
(Nasoz et al., 2003)	$\mathcal{C},\mathcal{E},\mathcal{S}$	31	3		kNN, LDA	6 emotions	69%
(Takahashi, 2003)	$\mathcal{C},\mathcal{E},\mathcal{B}$	12	18		SVM	6 emotions	42%
(Haag et al., 2004)	$\mathcal{C},\mathcal{E},\mathcal{S},\mathcal{M},\mathcal{R}$	1	13		MLP	val / aro	90% 97%
(Kim et al., 2004)	$\mathcal{C},\mathcal{E},\mathcal{S}$	175			SVM	3 emotions	78%
(Lisetti and Nasoz, 2004)	$\mathcal{C},\mathcal{E},\mathcal{S}$	29			kNN, LDA, MLP	6 emotions	84%
(Wagner et al., 2005)	$\mathcal{C},\mathcal{E},\mathcal{R},\mathcal{M}$	1	32	SFS, Fisher	kNN, LDA, MLP	4 emotions	92%
(Yoo et al., 2005)	$\mathcal{C},\mathcal{E}$	6	5		MLP	4 emotions	80%
(Choi and Woo, 2005)	$\mathcal{G}$		3	PCA	MLP	4 emotions	90%
(Healey and Picard, 2005)	$\mathcal{C},\mathcal{G},\mathcal{R},\mathcal{M}$	9	22	Fisher	LDA	3 stress levels	97%
(Rani et al., 2006)	$\mathcal{C},\mathcal{G},\mathcal{S},\mathcal{M},\mathcal{P}$	15	46		kNN, SVM, RT, BN	3 emotions	85%
(Zhai and Barreto, 2006)	$\mathcal{C},\mathcal{G},\mathcal{S},\mathcal{P}$	32	11		SVM	2 stress levels	90%
(Leon et al., 2007)	$\mathcal{C},\mathcal{E}$	8	5	DBI	AANN	3 emotions	71%
(Liu et al., 2008)	$\mathcal{C},\mathcal{E},\mathcal{S},\mathcal{M}$	6	35		SVM	3 affect states	83%
(Katsis et al., 2008)	$\mathcal{C},\mathcal{E},\mathcal{M},\mathcal{R}$	10	15		SVM, ANFIS	4 affect states	79%
(Yannakakis and Hallam, 2008)	$\mathcal{C},\mathcal{E}$	72	20	ANOVA	SVM, MLP	2 fun levels	70%
(Kim and André, in press)	$\mathcal{C},\mathcal{E},\mathcal{M},\mathcal{R}$	3	110	SBS	LDA	2 fun levels	70%

Notes. Part: the number of participants; Fea: the number of features; Sel / Red: Algorithms used for selection or reduction of features; $\mathcal{C}$: Cardiovascular activity; $\mathcal{E}$: Electrodermal activity; $\mathcal{R}$: Respiration; $\mathcal{M}$: Electromyogram; $\mathcal{B}$: Electroencephalogram; $\mathcal{S}$: Skin temperature; $\mathcal{P}$: Pupil Diameter; MLP: MultiLayer Perceptron; HMM: Hidden Markov Model; RT: Regression Tree; BN: Bayesian Network; AANN: Auto-Associative Neural Network; SVM: Support Vector Machine; LDA: Linear Discriminant Analysis; kNN: k Nearest Neighbors; ANFIS: Adaptive Neuro-Fuzzy Inference System; DBI: Davies-Bouldin Index; PCA: Principal Component Analysis; SFS: Sequential Forward Selection; SBS: Sequential Backward Selection.

State-of-the-art: results

- Review in paper: recog. rate 42% - 97%

- Results difficult to i
  - lack of validity
  - different target
  - different signals (1 to 5)
  - number of participants (1 to 175)
  - number of days (1 to 21)

- No general standards
- Low performance
- Inconsistent results

- More variability in data and targets >> lower classification performance

ASP's caveats and limitations

- Affective signals are temporally indirect
  - Lag between affective and physiological changes
- Sensors are unreliable:
  - movement artifacts, bodily position, air temperature & humidity
- Sensors are obtrusive
- Many-to-many relationships: noisy
- Physiological and affective time windows variable
- Humans are not linear time invariant
  - Habituation
- Individual differences

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2. Difficulties in ASP

3. Prerequisits for succesfull ASP:
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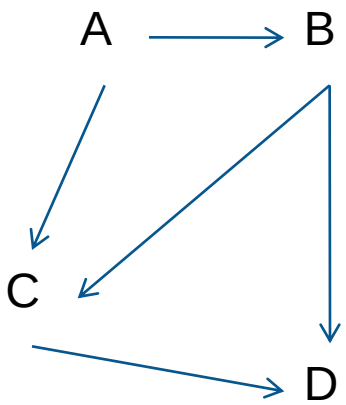
Prerequisits: Validation

- Content validity: degree to which a feature represents construct, or set of features represent all facets of domain
  - E.g.: SCL and emotion (weak) or arousal (strong)
- Criteria-related validity: reliability and resolution of measurement
  - E.g.: more affective states discriminated > higher validity
- Construct validity: theoretical grounding of construct of interest
  - E.g.: difference between emotions and moods
- Ecological validity: context of measurements
  - E.g.: natural affect events are sparse, affective signals easily contaminated by context variance

Prerequisits: Triangulation

- Social sciences: “Use multiple operationalizations of constructs” (Heath, 2001)
  - Use different signals/modalities/measurements



- Advantages:
  - Signals can validate each other
  - More solid ground truth
  - Extrapolations for more certainty

- Example: Bailenson et al., 2008
  - Uses subjective ratings, facial expressions, observers, and physiological signals:
    - Stronger ground truth and better classification results

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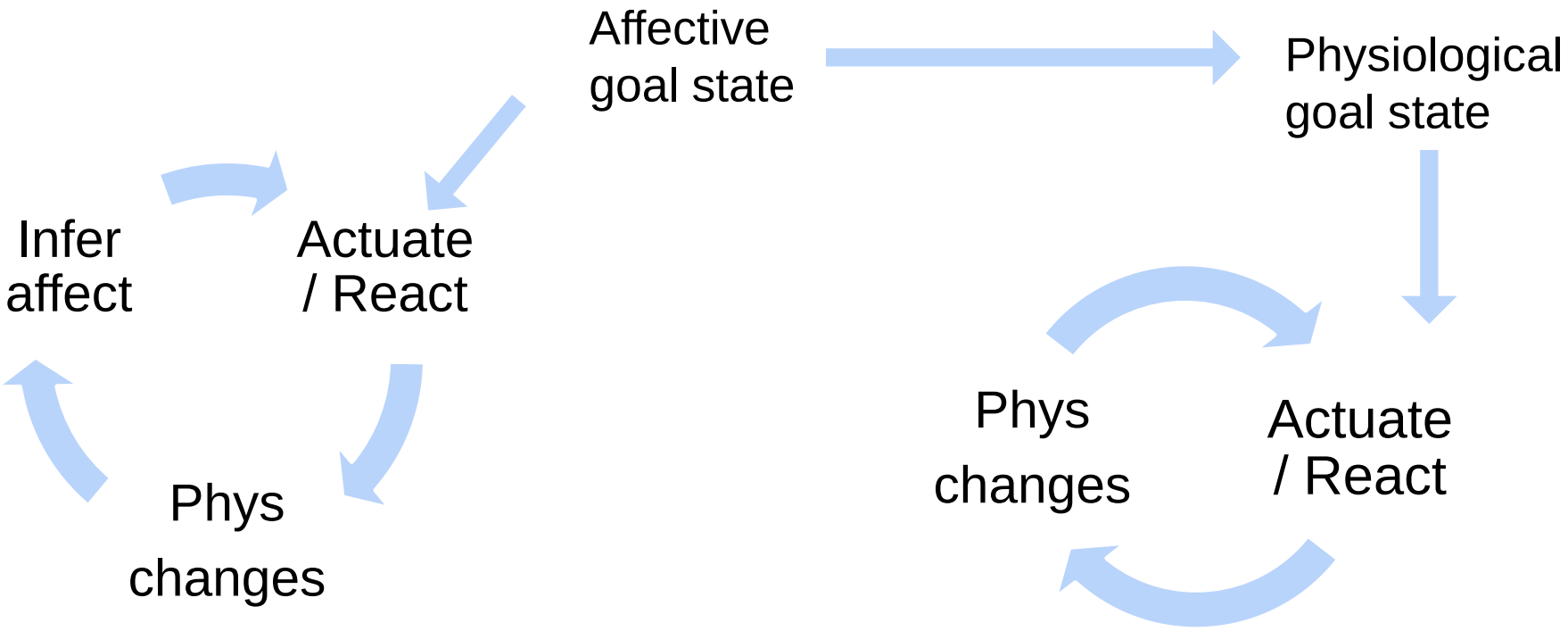
Prerequisits: Physiology-driven

- Affective signals often contaminated
- Instead of inferring; generalize!



Prerequisits: Contributions of signal processing

E.g.:

- Determine optimal sample frequencies and signal loss / distortion for all signals
- Benchmark needed!
  - Comparing different signals, approaches, techniques

Applying the prerequisits

- Prerequisits have been applied to:
  - Healey, J.A. & Picard, R.W. (2005). Detecting stress during real-world driving tasks using physiological sensors. *IEEE Transactions on Intelligent Transportation Systems, 6 (2),* pp. 156 – 166.
  - They agreed with us
  - It's all in the paper!

Conclusion

- We are confident that ASP will find its way into technology

- Many applications will benefit from succesfull ASP, e.g.:
  - Personalized psychotherapy (Eliza++)
  - Stress management
  - Affective music player
  - Advertisement impact (affective memory)
  - 24/7 biofeedback
  - Affective tutoring
  - Enabling commen sense AI (Minsky)