A note on modelling a somatic motor space for affective facial expressions

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Mindreading

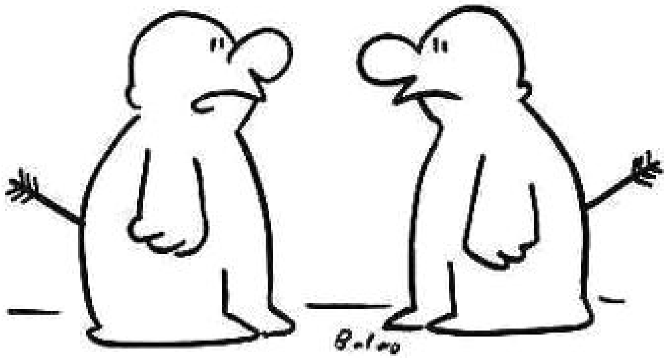
the capacity to identify the mental states of others, including **emotional states**

Goldman, A. I., & Sripada, C. S. (2005). Simulationist models of face-based emotion recognition. Cognition, 94(3), 193-213.

TT vs ST

Theory-Theory (TT)
mental-state attributor (**observer**) deploys a naive psychological theory (innate or acquired) to **infer mental states** in others from their behaviour.

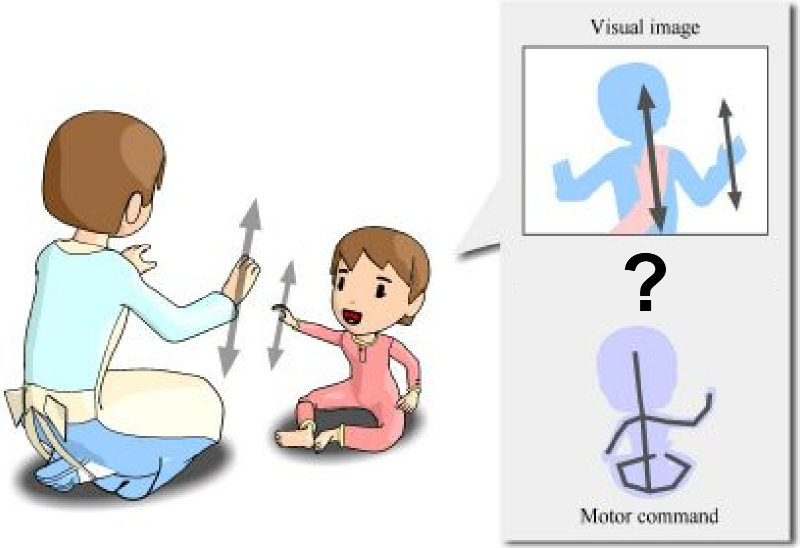
Simulation-Theory (ST)
mental-state attributor (**observer**) arrives at a mental attribution by **simulating**, replicating, or reproducing in his own mind the same state as the target's, or by attempting to do so.



"I know exactly how you feel."

Visuomotor mapping (VMM)

At the heart of the simulation-based framework is the modelling of a suitable visuomotor mapping of **perceived facial cues** to an **internal somatic motor space**.



Nagai, Y., Kawai, Y., & Asada, M. (2011, August). Emergence of mirror neuron system: Immature vision leads to self-other correspondence. In Development and Learning (ICDL), 2011 IEEE International Conference on (Vol. 2, pp. 1-6). IEEE.

Biological VMM

The **Asymmetric Tonic Neck Reflex** forces newborns to look at their hands.

This multi-muscle synergy coupling arm and head movements provides an effective means for **linking** visual and proprioceptive maps.

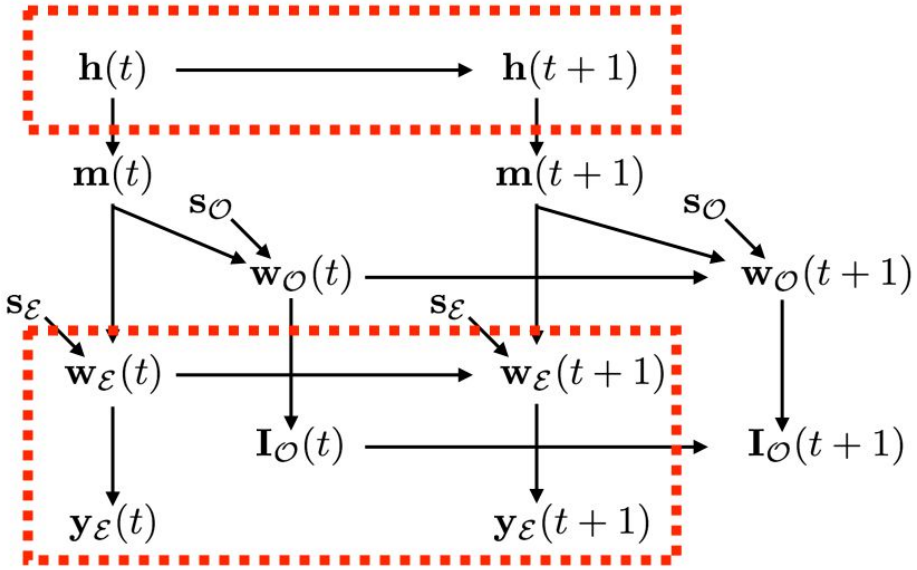
Metta, G., Sandini, G., & Konczak, J. (1999). A developmental approach to visually-guided reaching in artificial systems. Neural networks, 12(10), 1413-1427.

Requirements

- Internal motor space must be endowed with **generative capabilities,** to support actual simulation (e.g. facial mimicry).
- **Static parameters** that control the biometric characteristics of each individual.
- The **motor parameters** control the facial deformation due to muscle action.
- **Facial action state-space** is affect-driven and generates the motor parameters.

Proposed model

- Facial action state-space RV $\mathbf{h}(t)$
- Motor parameters $\mathbf{m}(t)$
- Shape parameters $\mathbf{s}_\mathbf{I}$
- Internal motor space $\mathbf{w}(t)$
- Perceived facial cues $\mathbf{y}_\mathbf{I}(t)$



Generative stage

- Facial action state-space RV $\mathbf{h}(t)$
- Motor parameters $\mathbf{m}(t)$
- Shape parameters $\mathbf{s}_\mathbf{I}$
- Internal motor space $\mathbf{w}(t)$
- Perceived facial cues $\mathbf{y}_\mathbf{I}(t)$

$$\tilde{\mathbf{h}}(t+1) \sim P(\mathbf{h}(t+1) \mid \mathbf{h}(t));$$

$$\tilde{\mathbf{m}}(t+1) \sim P(\mathbf{m}(t+1) \mid \tilde{\mathbf{h}}(t+1)),$$

$$\mathbf{w}_\mathcal{E}(t+1) = \mathbf{w}(\tilde{\mathbf{m}}(t+1), \mathbf{s}_\mathcal{E})$$

$$\tilde{\mathbf{w}}_\mathcal{E}(t+1) \sim P(\mathbf{w}_\mathcal{E}(t+1) \mid \mathbf{w}(t), \tilde{\mathbf{m}}(t+1))$$

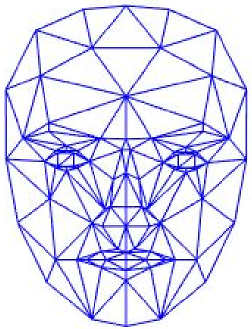
$$\tilde{\mathbf{y}}_\mathcal{E}(t+1) \sim P(\mathbf{y}_\mathcal{E}(t+1) \mid \tilde{\mathbf{w}}_\mathcal{E}(t+1))$$

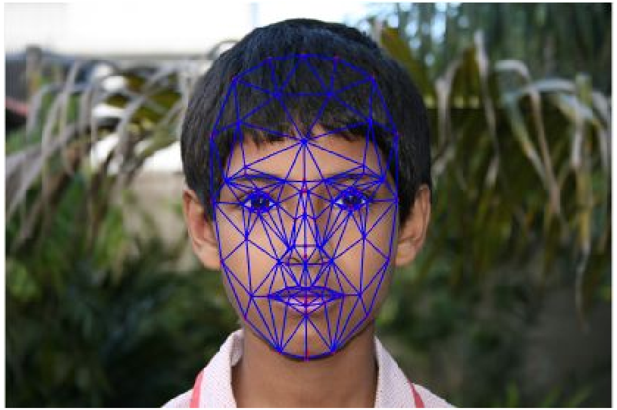
Motor space

Formalised as a 3D *deformable shape model*.

$$\mathbf{w}_i(t+1) = \mathbf{w}_i(t) + \mathbf{R}(t)\mathbf{w}_i(t) + \mathbf{dW}_i^S\mathbf{s} + \mathbf{dW}_i^M\mathbf{m}(t) + \mathbf{t}(t)$$

Implemented adopting Candide-3 model, of **113 vertices** w_i and **184 triangles**.





Ahlberg, J. (2001). Candide-3-an updated parameterised face.

Facial action state-space

The latent action space can be specified by resorting to a Dynamical Variational Gaussian Process Latent Variable Model (**DVGP- LVM**).

$$m_k(t) = f_k(\mathbf{h}(t)) + \nu_{\mathbf{h}}(t), \quad \nu_{\mathbf{h}} \sim \mathcal{N}(0, \sigma_{\mathbf{h}}^2),$$

where f_k is a latent mapping from the low dimensional action space to the k-th dimension of the parameter space of m.

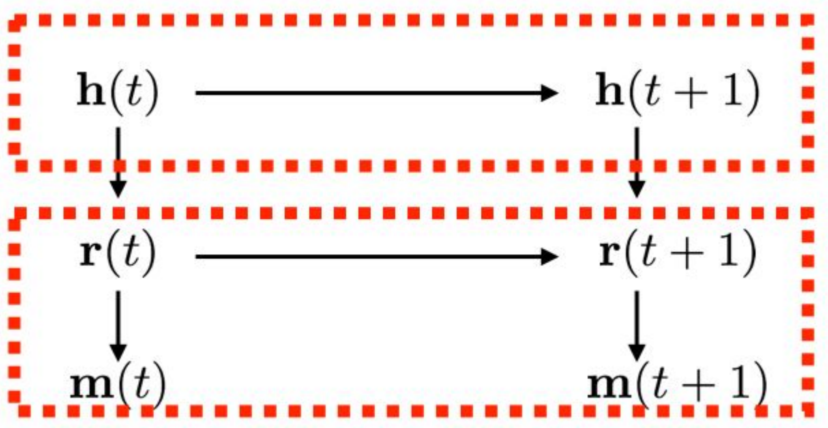
Damianou, A. C., Titsias, M. K., & Lawrence, N. D. (2016). Variational inference for latent variables and uncertain inputs in Gaussian processes. The Journal of Machine Learning Research, 17(1), 1425-1486.

Facial action state-space - EXTENSION

Introduce a further control level, in the form of a **Kalman filter**.

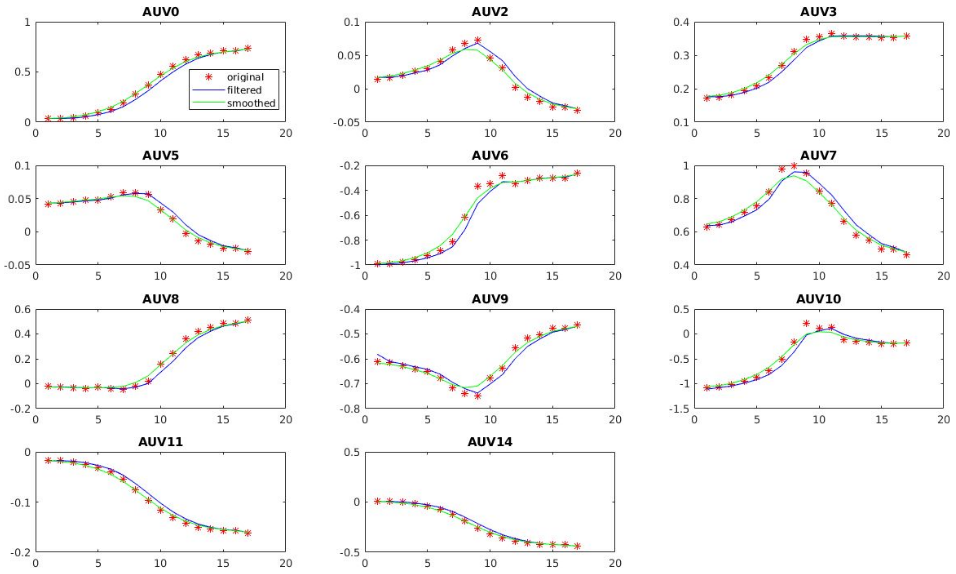
$$\overline{\mathbf{r}}(t+1) = \mathbf{A}\widehat{\mathbf{r}}(t) + \boldsymbol{\eta}(t)$$
$$\boldsymbol{\eta}(t) \sim \mathcal{N}(\boldsymbol{\mu}_{\mathbf{r}}(t), \Sigma_{\mathbf{r}}(t)).$$

$$\overline{\mathbf{m}}(t) = \mathbf{H}(t)\overline{\mathbf{r}}(t) + \boldsymbol{\zeta}(t),$$
$$\boldsymbol{\zeta}(t) \sim \mathcal{N}(0, \Sigma_{bu}),$$



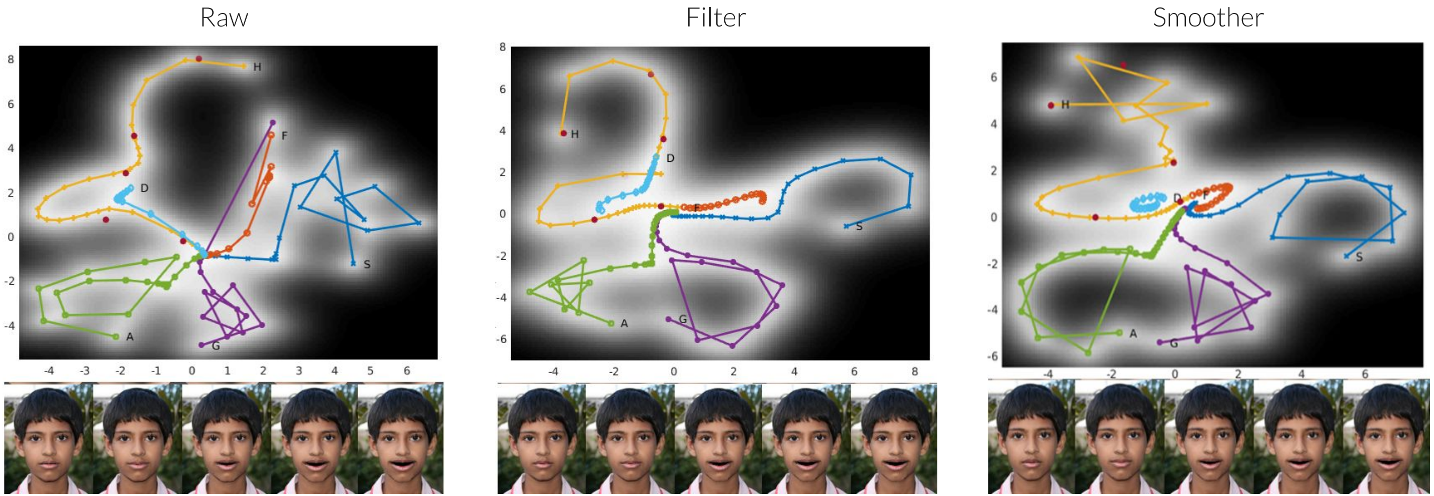
Preliminary results

Result of the **Kalman filter** and **smoother**, as well as the original **motor parameters** from the prototypical “disgust” emotion of a subject from the **Cohn-Kanade** dataset.

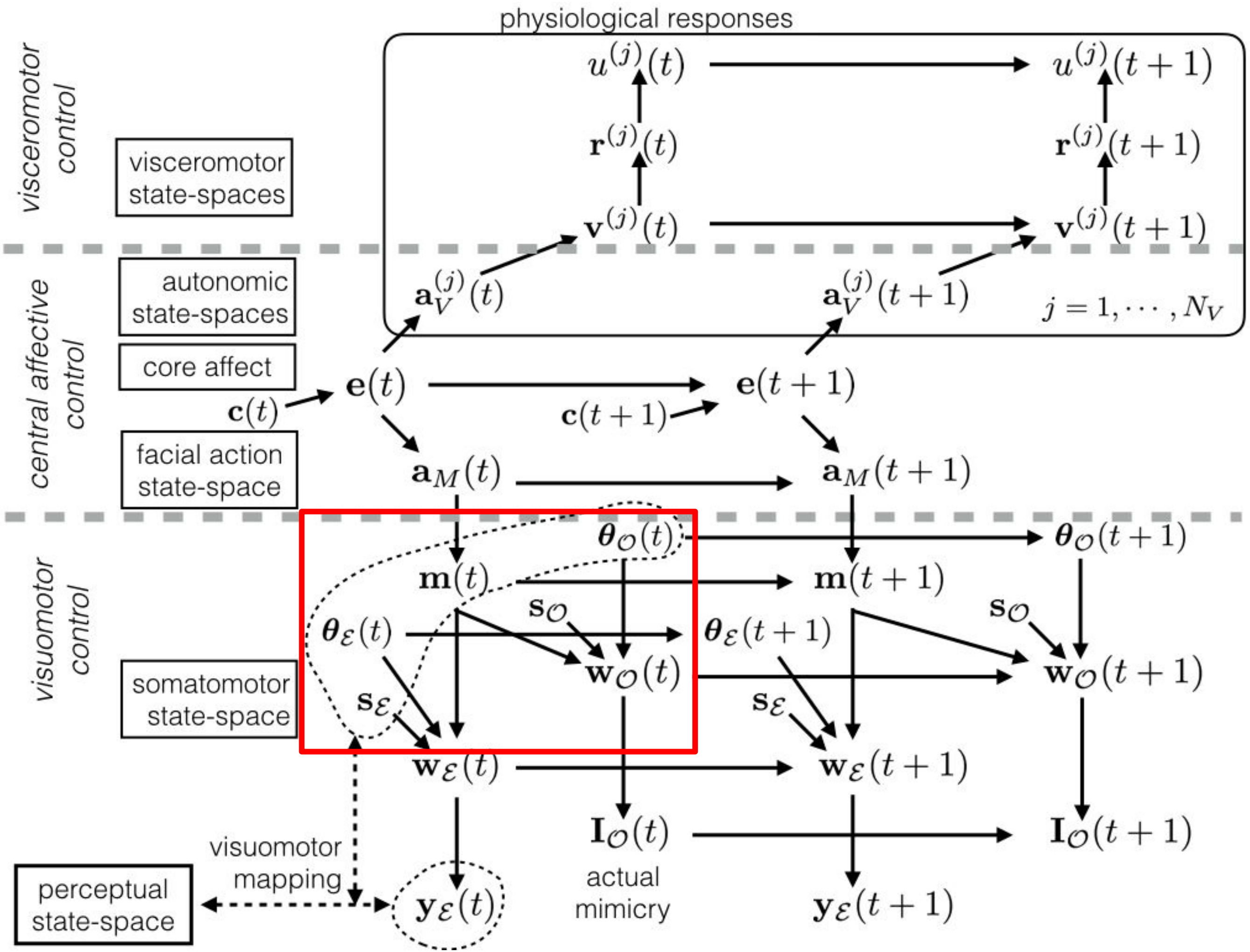


Preliminary results

Latent action manifold as learned by adopting the different control scheme.



This is just a tiny drop in the ocean...



physiological responses
visceromotor control
visceromotor state-spaces
central affective control
autonomic state-spaces
core affect
facial action state-space
visuomotor control
somatomotor state-space
perceptual state-space
visuomotor mapping
actual mimicry
$u^{(j)}(t)$
$u^{(j)}(t+1)$
$\mathbf{r}^{(j)}(t)$
$\mathbf{r}^{(j)}(t+1)$
$\mathbf{v}^{(j)}(t)$
$\mathbf{v}^{(j)}(t+1)$
$\mathbf{a}_V^{(j)}(t)$
$\mathbf{a}_V^{(j)}(t+1)$
$j = 1, \cdots, N_V$
$\mathbf{e}(t)$
$\mathbf{e}(t+1)$
$\mathbf{c}(t)$
$\mathbf{c}(t+1)$
$\mathbf{a}_M(t)$
$\mathbf{a}_M(t+1)$
$\boldsymbol{\theta}_{\mathcal{O}}(t)$
$\boldsymbol{\theta}_{\mathcal{O}}(t+1)$
$\mathbf{m}(t)$
$\mathbf{m}(t+1)$
$\mathbf{s}_{\mathcal{O}}$
$\mathbf{s}_{\mathcal{O}}$
$\boldsymbol{\theta}_{\mathcal{E}}(t)$
$\boldsymbol{\theta}_{\mathcal{E}}(t+1)$
$\mathbf{w}_{\mathcal{O}}(t)$
$\mathbf{w}_{\mathcal{O}}(t+1)$
$\mathbf{s}_{\mathcal{E}}$
$\mathbf{s}_{\mathcal{E}}$
$\mathbf{w}_{\mathcal{E}}(t)$
$\mathbf{w}_{\mathcal{E}}(t+1)$
$\mathbf{I}_{\mathcal{O}}(t)$
$\mathbf{I}_{\mathcal{O}}(t+1)$
$\mathbf{y}_{\mathcal{E}}(t)$
$\mathbf{y}_{\mathcal{E}}(t+1)$

Thanks

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