# Animação e Ambientes Virtuais
# 2018/2019

Pós-graduação

DI- FCUL

Guião das aulas teóricas
GU-AAV-19- Facial Deformation Models

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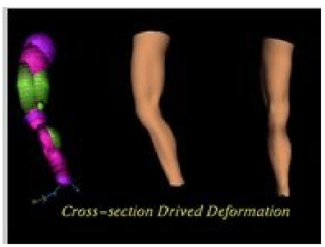
# Summary

Facial Deformation Models





# Motivation - Deformation Models






# **Facial** Deformation Models

**Facial deformation** is a main issue to generate **realistic facial expressions.**

It involves the study of

- facial anatomy

- and motion and behavior of faces involving the generation of facial expressions

# Anatomy of a face

**Skin**, muscles and bone

The **skin** is important both
- to the **appearance**
- and to the **movement** of the face

Its purpose is to attach the skin to underlying bone and muscle

**Structure in layers**: epidermis (outermost), dermis, hypodermis

This structure allows skin to move freely over the muscles and bones underneath

**Motion** of skin is due to
- mechanical properties of skin
- interaction of layers
- muscle activation



# Anatomy of a face

Skin, **muscles** and bone

**Muscles** determine facial movements

Structure – muscles lie between the bone and the skin
(usually, one end connected to the bone and the other to the skin)
(not conneted to a bone: muscle obicularis oris)

– facial muscles occur in pairs (one for each side of the face)

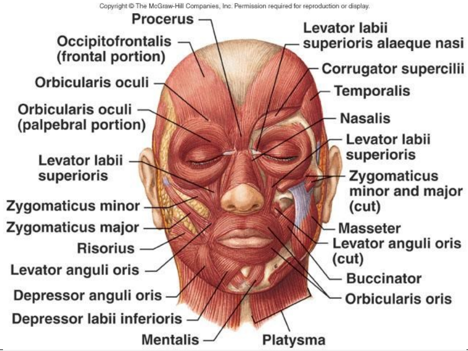
Movement – all facial actions occur as a consequence of muscular contraction



# Anatomy of a face

Skin, **muscles** and bone








# Anatomy of a face

Skin, muscles and **bone**

The bones of the head (skull) consist of
- cranium
- and mandible (moving)

The skull determines the
- proportion
- and shape of the face

The shape of the skull vary with
- race
- age
- gender

The **appearance of a face** depends on the **size**, **shape** and **distance** of the bones.
Other facial features are the **eyes**, **tongue** and **teeth.**

# Control Parametrization

**Facial animation**
is mainly based on the **manipulation** of **facial parameters**

There are three main schemes of parametrization:

- interpolation
- FACS (Facial Action Coding System)
- FAP (Facial Animation Parameters) from MPEG4



# Control Parametrization

## Interpolation

Interpolation is used to find an intermediate value between two or more values, usually, positions.

The intermediate value can be obtained through the parameters that combine the extreme values

The result depends on the type of interpolation (linear or non-linear)



# Interpolação

**Interpolar** corresponde a estimar valores de uma função entre valores conhecidos.

A forma mais simples de interpolação é a **interpolação linear**.

Na **interpolação linear** usa-se a equação da recta, que passa por dois pontos conhecidos, para obter a aproximação dos pontos intermédios

Ou seja, dados os pontos $(x_0, f(x_0))$ e $(x_1, f(x_1))$

$$f(x) = f(x_0) + (x-x_0)\,(f(x_1)-f(x_0)) / (x_1-x_0)$$



# Control Parametrization

## FACS (Facial Action Coding System)

- This system was developed by **psychologists** (**<u>Ekman</u>** and **Frisen** 1978) in order to **<u>describe all</u>** <u>possible visually distinguishable</u> **<u>facial movements</u>**

- It defined **46** basic actions, known as **Action Units** (AU)
- It was extended and revised in 2002

A **Action Unit** describes the contraction of one facial muscle or a group of related muscles.

- Action Units can be used to compose facial expressions

# Control Parametrization

**FACS (Facial Action Coding System)**

| AU | Description | Facial muscle | Example image |
|---|---|---|---|
| 1 | Inner Brow Raiser | *Frontalis, pars medialis* |  |
| 2 | Outer Brow Raiser | *Frontalis, pars lateralis* |  |
| → 4 | Brow Lowerer | *Corrugator supercilii, Depressor supercilii* |  |

http://www-2.cs.cmu.edu/afs/cs/project/face/www/facs.htm



# Control Parametrization

**FACS (Facial Action Coding System)**

| | | | |
|---|---|---|---|
| 22 | Lip Funneler | *Orbicularis oris* |  |
| 23 | Lip Tightener | *Orbicularis oris* |  |
| 24 | Lip Pressor | *Orbicularis oris* |  |

The same muscle is used for different expressions



# Control Parametrization

**FACS (Facial Action Coding System)**

Limitations:

- The initial set did not include all the visible actions for the lower part of the face particularly related to oral speech.

- FACS is limited to those muscles that can be controlled voluntarily



# Control Parametrization

**FACS (Facial Action Coding System)**

spontaneous smile
(Duchenne smile)

vs

social smile


("O Erro de Descartes", A. Damásio 1995)

## Control Parametrization
## FACS (Facial Action Coding System)

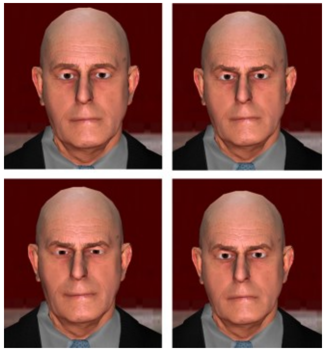
“A **Duchenne smile** involves contraction of both the zygomatic major muscle (which raises the corners of the mouth) and the orbicularis oculi muscle (which raises the cheeks and forms crow's feet around the eyes).”

“A non-Duchenne smile involves only the zygomatic major muscle.”



**Virtual Characters “can move all muscles”**
**FACS (Facial Action Coding System)**

**Neutral expression**



**AU4**
Brows brought together (sobrancelhas franzidas)

**AU4 and AU6+12**
(“Duchenne smile”)

AU12- Lips up

AU6- Cheek Raiser

**AU4 and AU15**

**AU15** - Lip Corners Down

(Renato Teixeira 2013/2014)



## Control Parametrization
### FAP (Facial Animation Parameters)

**MPEG-4**
- is an object-based multimedia compression standard
- allows for independent encoding of different audio-visual objects
- uses the FBA (Face and Body Animation) object
  to describe real persons or synthetic characters

FBA object includes 2 set of parameters
definition parameters ⟶ define the geometry of the face (FDP) and body (BDP)
animation parameters ⟶ define the animation of the face (FAP) and body (BAP)



## Control Parametrization
### FAP (Facial Animation Parameters)

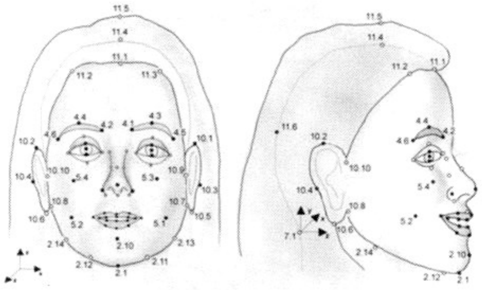
MPEG-4 specifies
- A face model in its neutral state
- A number of **feature points** on this neutral face as reference points
- A set of **Facial Animation Parameters** (**FAP**) each corresponding to a particular facial action deforming a face model in its neutral state

FAPs represent a complete set of basic facial animations including head motion, tongue, eyes and mouth control

They are based on the study of minimal facial actions and are closely **related to muscle actions**

# Control Parametrization

FAP - **FDP**



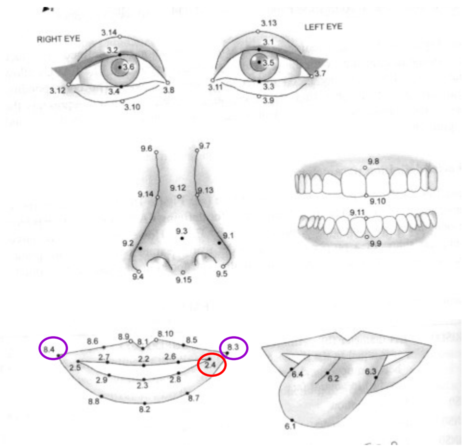
84 **feature definition points** (FDP)

Only the black filled circles are used for animation



# Control Parametrization

FAP - **FDP**






# Control Parametrization

**FAP (Facial Animation Parameters)**

There are 68 FAP splitted in 10 different groups

A **viseme** is a visual counterpart of a phoneme

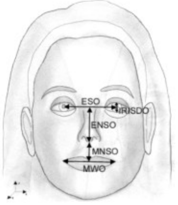
| Group | Number of FAPs |
|---|---|
| 1 viseme and expression | 2 |
| 2 jaw, chin, inner lowerlip, cornerlips, midlip | 16 |
| 3 eyeballs, pupils, eyelids | 12 |
| 4 eyebrow | 8 |
| 5 cheeks | 4 |
| 6 tongue | 5 |
| 7 head rotation | 3 |
| 8 outer lip position | 10 |
| 9 nose | 4 |
| 10 ears | 4 |



# Control Parametrization

FAP - **FAPU**

FAP are defined in **FAPU** (**Face Animation Parameters Units**), i.e., fractions of spatial distances between major facial features on the model and its neutral state




| | | | |
|---|---|---|---|
| IRISD0 | Iris diameter (by definition it is equal to the distance between upper and lower eyelid) in neutral face | IRISD = IRISD0/1024 | 3.1.y−3.3.y = 3.2.y−3.4.y |
| ES0 | Eye separation | ES = ES0/1024 | 3.5.x−3.6.x |
| ENS0 | Eye – nose separation | ENS = ENS0/1024 | 3.5.y−9.15.y |
| MNS0 | Mouth – nose separation | MNS = MNS0/1024 | 9.15.y−2.2.y |
| MW0 | Mouth width | MW = MW0/1024 | 8.3.x−8.4.x |
| AU | Angle Unit | $10^{-5}$ rad | |

8.3.x means x coordinate of the feature point 8.3

FDP

# Control Parametrization

## FAP (Facial Animation Parameter Set)

| FAP no | FAP name | FAP description | FAP units | Pos FAP motion | Group | FDP subgrp num |
|---|---|---|---|---|---|---|
| 1 | viseme | A value determining the viseme for this frame (e.g. pbm, fv, th . . . ) | na | na | 1 | na |
| 2 | expression | A value determining the facial expression | na | na | 1 | na |
| 3 | open_jaw | Vertical jaw displacement | MNS | down | 2 | 1 |
| 4 | lower_t_midlip | Vertical top middle inner lip displacement | MNS | down | 2 | 2 |
| 5 | raise_b_midlip | Vertical bottom middle inner lip displacement | MNS | up | 2 | 3 |
| 6 | stretch_l_cornerlip | Horizontal displacement of left inner lip corner | MW | left | 2 | 4 |
| 7 | stretch_r_cornerlip | Horizontal displacement of right inner lip corner | MW | right | 2 | 5 |

FAPU

FDP

(Pos FAP motion = Definition of the direction of movement for positive values)

http://onlinelibrary.wiley.com/doi/10.1002/0470023198.app3/pdf



# Control Parametrization

## **FAP** - FAT

**FATs** – **Facial Animation Tables** – define how a model is spatially deformed as a function of the amplitude of the FAPs

As a facial model is represented by a **set of vertices** and associated triangles joining them,

<u>for each FAP,</u>

the <u>FAT determines which vertices are affected and how they are affected</u>

Note:
MPEG-4 defines a parameter set for facial animation, however, **<u>the precise method of deformation is not standardized</u>**



# Control Parametrization

## **FAP** – high level parameters

There are 2 high level parameters in the FAP set

- **viseme** - is a visual counterpart of a phoneme
- **expression** – allows the definition of high-level facial expressions

The facial expression parameter has a textual description

FAP

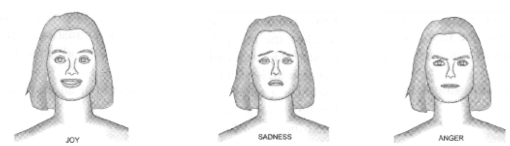


# Control Parametrization

## **FAP** – basic facial expressions

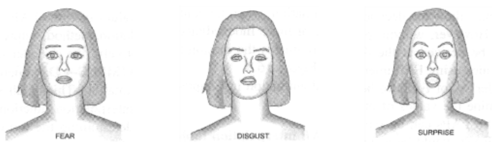
Textual description and facial expressions

| | No. | Name | Textual description |
|---|---|---|---|
| *Alegria* | 1 | Joy | The eyebrows are relaxed. The mouth is open and the mouth corners pulled back toward the ears. |
| *Tristeza* | 2 | Sadness | The inner eyebrows are bent upward. The eyes are slightly closed. The mouth is relaxed. |
| *Cólera* | 3 | Anger | The inner eyebrows are pulled downward and together. The eyes are wide open. The lips are pressed against each other or opened to expose the teeth. |



# Control Parametrization
**FAP** – basic facial expressions

| | | | |
|---|---|---|---|
| *Medo* | 4 | Fear | The eyebrows are raised and pulled together. The inner eyebrows are bent upward. The eyes are tense and alert. |
| *Aversão* | 5 | Disgust | The eyebrows and eyelids are relaxed. The upper lip is raised and curled, often asymmetrically. |
| *Surpresa* | 6 | Surprise | The eyebrows are raised. The upper eyelids are wide open, the lower relaxed. The jaw is opened. |






# Primary facial expressions Ekman's model

This 6 primary facial expressions where established by psychologists, namely Paul Ekman

P. Ekman conducted a study to prove that facial expressions of emotion are universal. [Ekman99], [Ekman03]

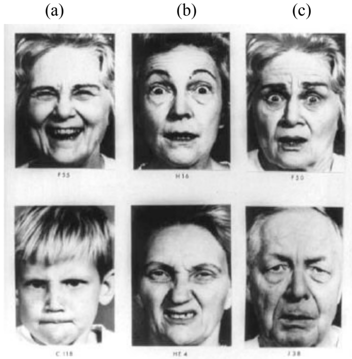
This idea was already stated by Darwin.



# Primary facial expressions

Photos showed to New Guinea people by Paul Ekman in 1966

(a) (b) (c)



(d) (e) (f)



| | | |
|---|---|---|
| (a) | joy | alegria |
| (b) | surprise | surpresa |
| (c) | fear | medo |
| (d) | anger | cólera (raiva) |
| (e) | disgust | aversão (repugnância) |
| (f) | sadness | tristeza |

# Primary facial expressions

P. Ekman showed also to americans photos of New Guinea people expressing the same emotions.

In both cases **fear** and **surprise** where the most difficult expressions to identify. They were often mix up.



# OCC model of emotions (Ortony, Clore and Collins, 1988)

- **Another model of emotion** used for virtual characters is the **OCC model**
- **Based on the cognitive structure of individual emotions**: the particular emotion a person experiences on some occasion is determined by the way s/he construes the world or changes it
- The intensity of a given emotion primarily depends on the **events**, **agents**, or **objects** in the environment of the agent exhibiting the emotion.



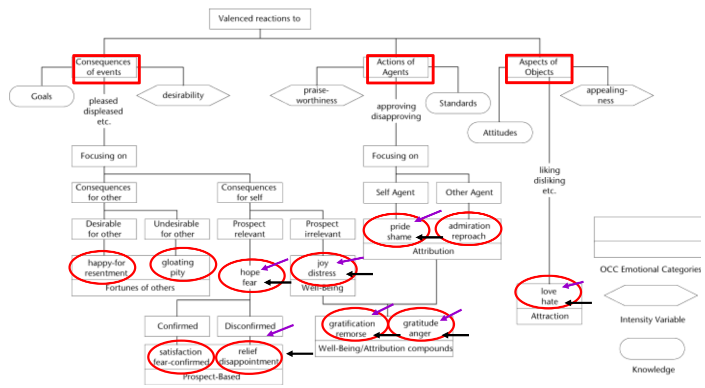
# OCC model of emotions

- The OCC model contains a sufficient level of **complexity** and **detail** to cover most situations an emotional interface character might have to deal with.

Positive or negative value

- It specifies **22 emotion** categories based on **valenced reactions** to situations constructed either
  - as being goal relevant events, — Consequences of events
  - as acts of an accountable agent (including itself), — Actions of agents
  - or as attractive or unattractive objects — Aspects of objects
- It also offers a **structure for the variables**, such as likelihood of an event or the familiarity of an object, which determines the **intensity** of the emotion types.






The original OCC model in [Bartneck 2002]

## Facial deformation models

The models can be classified according to the mechanism in which the geometry of the face model is manipulated:

– Some models are based on merely creating believable visual effects

– Others are derived using a physical basis comprising forces, muscular contraction and skin bio-mechanics.



## Facial deformation models

- Shape interpolation
  - Morph target
- Parametric models
  - Ad-hoc parameters, Skeletal Animation (rigging, skinning)
  - MPEG-4 Based Facial Animation
  - Parametric Generation of Facial Expressions Based on FACS
- Muscle-Based models ▶
  - Physics-based muscle modeling
  - Pseudo-muscle modeling
- Finite Element Method ▶



## Facial deformation models
**Shape interpolation**

An interpolation function (linear or non-linear) is applied to the vertex positions of the extreme expressions of faces

the method is simple

but

- the range of expressions obtained is restricted
- it needs explicit geometrical data for each expression

Ex: shapes keys or blend shapes



Shape interpolation
## Morph Target Animation

Given na original mesh, several **morph targets** are created by deformation of the original mesh.

**Shape keys** in Blender
**Blend shapes** in Maya or Unity 3D

Each morph target corresponds to an **expression** (emotion or viseme)

All morph targets must have the **same number of vertices**

Shape interpolation
Morph Target Animation

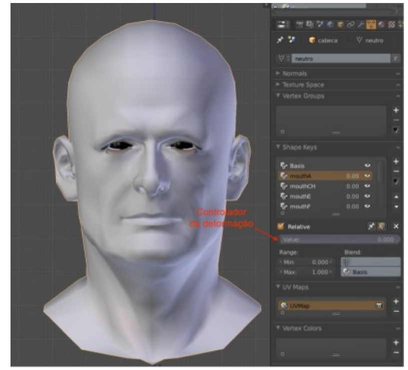
2 expressions and neutral face (Vítor Pinto 14/15)

In Blender,
- Replicate the original mesh
- Some vertices of each replicated mesh are displaced to create a new expression

Blender has a tool (grab) that allows **proportional editing**, ie, displacing a set of vertices proportionally



Shape interpolation
Morph Target Animation



In Blender,
- All the deformed meshes are combined with the original mesh as “Shape keys”

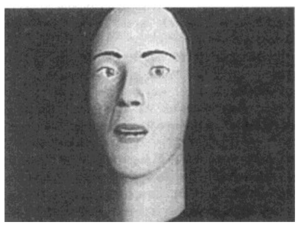
- Using a slider, we can change the intensity of the expression: between the neutral mesh and the defined shape key



## Facial deformation models

**Parametric model**

The vertices that describe the facial mesh are manipulated by a **set of parameters** (e.g., Parke’s model, 1974) [Thalmann04]



- a wide range of faces can be obtained with a small set of appropriate parameters

but
- it is difficult to obtain a complete set of parameters
- it can generate unrealistic movements



## Skeletal Animation

In **Skeletal animation** a character is represented in two parts:
- a surface representation used to draw the character (called **skin** or **mesh**) and
- a hierarchical set of interconnected bones (called the **skeleton** or **rig**) used to animate the mesh

**Skinning** is the technique that defines the deformation of the character skin for every animation frame, according to the current state of skeletal joints

## Processo de criação de *rigging animation* no Blender

Passo 1. **Modelação**
• Construção da malha poligonal exterior.

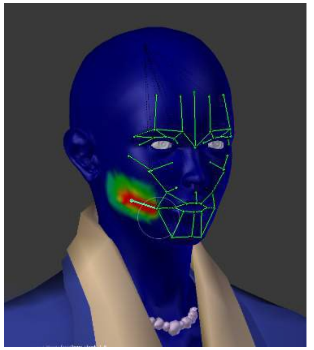
Passo 2. **Rigging**
• Criação de um esqueleto/armação que permite controlar o movimento das personagens.
• O número de ossos influencia o desempenho da aplicação pelo que o seu número deve ser o menor possível.

Passo 3. **Skinning**
• Associação de determinado conjunto de polígonos da malha criada no passo 1 a um osso da armação criado no passo 2.
• O mesmo conjunto de polígonos pode estar associado a ossos diferentes. Nesse caso prevalece o osso que tem maior influência no conjunto.



## Skinning, no Blender

O skinning, no Blender, é feito à custa da operação *weight painting*.



A influência de um osso num determinado conjunto de polígonos é representado por cores

- a cor vermelha representa o valor máximo (1) e
- azul o valor mínimo (0)

[RenatoTeixeira 13/14]



## Morph Target vs Skeletal animation

Advantage of morph target animation:

- There are more **control** over the movements because the user defines the **individual positions of the vertices** of the mesh,

(not possible with a skeleton where it is more difficult to reproduce the movement of muscles)

Disadvantage of morph target animation:

- It is usually more labour-intensive than skeletal animation because every vertex position must be manually manipulated

(Therefore the number of target morphs is usually limited)



## Create Once, Use Many

http://www.faceinmotion.com/events/SIGGRAPH07/index.html

# Facial deformation models

MPEG-4 Based Facial Animation

As stated before
MPEG-4
- defines a parameter set for facial animation
- but does not define the method of deformation

Different deformation methods have been proposed based on

Feature Definition Points (FDP)

or

Facial Animation Tables (FAT)

See slides Facial Motion Capture



# Facial deformation models

Parametric Generation of Facial Expressions Based on FACS

Wojdel presents a parameterised model based on FACS:

• Each facial parameter corresponds to one of the AU from FACS

• **Constraints** and **co-occurrence rules** for parameters are defined to **avoid** one disadvantage of parameterization -- the **occurrence of unrealistic facial expressions**

(Wojdel05, Parametric Generation of Facial Expressions Based on FACS)



# Facial deformation models

Parametric Generation of Facial Expressions Based on FACS

For each parameter AU the following functios are defined:

$\varphi : \Re^3 \to \Re^+$—density function,

$\Psi : \Re^3 \to \Re^3$—direction function,

$\tau \in [0, 1]$—the value of the activation intensity of a given AU.



# Facial deformation models

Parametric Generation of Facial Expressions Based on FACS

Density function:
- defines de range of the visible changes induced by an AU when activated with 100% intensity
- when a given AU is activated, only vertices which are inside the defined area will change their positions

Direction function:
- describes the direction of the movement at a given point on the face when specific AU is activated

Activation intensity:
- a value between 0 (no activation) and 1 (full activation)

# Facial deformation models

## Parametric Generation of Facial Expressions Based on FACS

For each point on the face, $v \in \Re^3$ $\triangle \mathbf{v} = \psi(\mathbf{v})\, \phi(\mathbf{v})\, \tau$

$\triangle \mathbf{v}$ is a vector displacement to be applied to vertex v for a given AU

The above formula does not hold for AU that incorporate <u>long movements on large areas</u>.

In this case the direction of movement depends on v coordinates and also on the value of the activation intensity

$$\triangle \mathbf{v} = \psi'(\mathbf{v}, \tau)\, \phi(\mathbf{v})\, \tau$$



# Facial deformation models

## Parametric Generation of Facial Expressions Based on FACS

Based on the <u>kind of movement</u> they inflict and on <u>which facial objects they act</u>

AU are divided in 3 categories:

- Single object AU – contains the majority of AU
- Multiple object AU – the AU activation results in deformation (or translation) of more than one object

Ex: When the head rotates, the facial surface rotates as well as the teeth and the eyes

In this case we have to define appropriate AU components for all of the objects from a facial model that a given AU can affect



# Facial deformation models

## Parametric Generation of Facial Expressions Based on FACS

- Sub-object AU – their activation results in movements of the upper and lower lip in opposite directions.

In this case there are

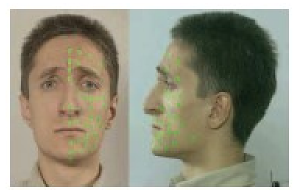
- 2 independent density funtions and
- 2 independent direction funtions



# Facial deformation models

## Parametric Generation of Facial Expressions Based on FACS

Implementation



**1st step**:

- 38 control markers on one side of the face
- simultaneous pictures of the frontal and lateral view of the face
- in each case
  - only one AU is activated and
  - this AU has maximal intensity
- measurements were taken that describe facial movement when a given AU is activated

# Facial deformation models

## Parametric Generation of Facial Expressions Based on FACS

**2nd step**

Select function density and function direction

based on the visual inspection;

these functions depend on the AU, but their generic form is independent of the modeled person

**3rd step**

Adjust the parameters of function density and function direction of a given AU

in such a way that the resulting displacement optimally fits the measured data



# Facial deformation models

## Parametric Generation of Facial Expressions Based on FACS

**Facial expressions rarely contain only one single AU activation**

Mixing AU

Additive

the resulting vector of movement is a summation of the composite vectors

Successive

the original wireframe is adapted through the successive AU modifiers in a specific order

In this case the result depends on the order in which AU are mixed



# Facial deformation models

## Parametric Generation of Facial Expressions Based on FACS

- Changes on the face resulting from several active AU are different from the changes inflicted by each of them separately
- To combine 2 or more AU, we have to known how they influence each other

Co-occurrence rules

- Domination
- Exclusion
- Opposition



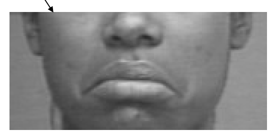
# Facial deformation models

## Parametric Generation of Facial Expressions Based on FACS

**Co-occurrence rules - AU examples**

**Domination** a dominant AU can cancel the appearance changes of another AU

AU15 lip corner depression **dominates** AU12 lip corner puller



http://www-2.cs.cmu.edu/afs/cs/project/face/www/facs.htm

# Facial deformation models

Parametric Generation of Facial Expressions Based on FACS

**Co-occurrence rules - AU examples**

**Exclusion-** it not possible to combine both AU

AU18 lip puckerer cannot occur together with AU28 lip suck

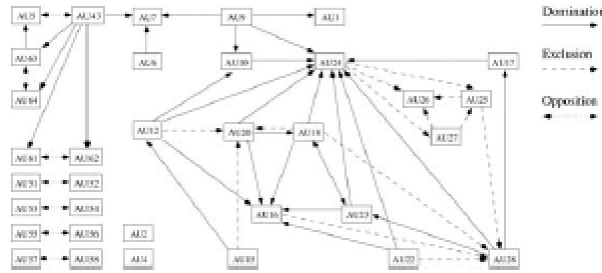
**Opposition,** particular case of exclusion, it corresponds to opposite movements

AU51 head turn left is opposite to AU52 head turn right



# Facial deformation models

Parametric Generation of Facial Expressions Based on FACS




Dependencies between AU [Wojdel05]



# Facial deformation models

Parametric Generation of Facial Expressions Based on FACS

Given a list of AU with their respective activation values

↓

a new list of activation values is produced with activations modified according to co-occurrence rules

indice



# Facial deformation models

**Muscle-Based models**

- The complete anatomical description of a face is complex
- Simplified models have been developed:
  - manipulation of facial geometry is based on **simulating the characteristics of the facial muscles**
  - this approach offers **generality** as the same set of muscles is valid for all faces
- The muscle-based models are usually based on the **FACS** parametrization scheme

# Facial deformation models

**Muscle-Based models**

There are **two types** of muscle-based models

- **physics-based muscle modeling**

  based on the physics or mechanics of the underlying phenomena that model the muscle behavior.

  Spring (*mola*) models

- **pseudo-muscle modeling**

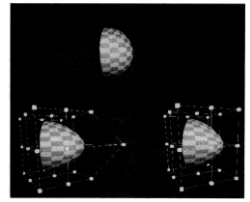
  the facial mesh can be deformed in muscle-like fashion but ignoring the complicated underlying anatomy and physics

  Free-form deformation
  based on control points that produce deformations on the surface



# Facial deformation models

**Pseudo-muscle modeling**



Example of rational free form deformation
(incorporates weight factors for each control point)

indice



# Facial deformation models

**Muscle-Based models vs Finite Element models**

Almost physics-based muscle modeling use **linear models** that are inadequate because

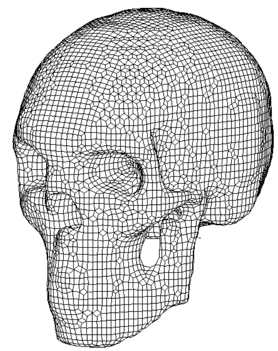
**facial soft tissues** often undergo large **local rotations** and **straining**

in which <u>nonlinear finite deformation elasticity theory</u> is more appropriate



# In **Finite Element Analysis** applications

the object or system is represented by a geometrically similar model consisting of multiple, linked, simplified representations of discrete regions—i.e., finite elements on an **unstructured grid**.



In **Finite Element Analysis** applications,

To **simulate object transformations**, **equations of equilibrium**, in conjunction with applicable **physical** considerations, are applied to each element, and a system of simultaneous equations is constructed.

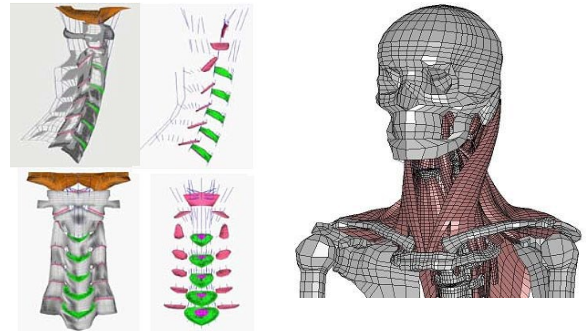
The **system of equations** is solved for unknown values using the techniques of linear algebra or nonlinear numerical schemes, as appropriate.

These models can be used, for instance, to predict injuries

http://www.ncbi.nlm.nih.gov/pubmed/19923034

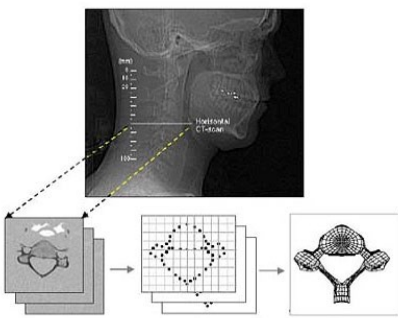


## FE model of the human neck and head.





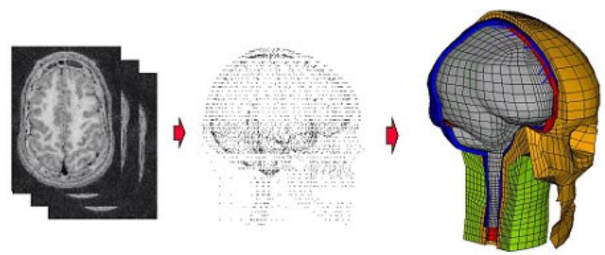
## Schematic image that describes the generation of the neck's model geometry





## The scheme of creating a 3D FE-mesh from 2D images:

- The <u>geometry</u> has been determined by CT, MR and sliced color photos.
- Points on the boundaries of the different tissues were determined and used to determine the lines and surfaces that define the geometry of the scalp, the skull, the dura, the brain tissue etc.



# Facial deformation models

**Finite Element Model for Facial Expressions** [Wu2013]

A detailed finite element model of the human head construted from anatomical data segmented from MR images:

- superficial soft-tissue mesh (skin, subcutaneous layer and superficial musculo-aponeurotic system)
- finite element meshes of 20 individual muscles of facial expressions
- glands and skeletal bones

(Wu2013, Simulating and Validating Facial Expressions using an Anatomically Accurate Biomechanical Model Derived from MRI DataTowards Fast and Realistic Generation of Animated Characters)



# Facial deformation models

**Finite Element Model for Facial Expressions** [Wu2013]

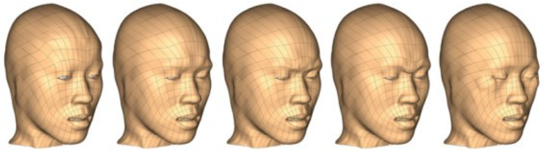
Left - fitted geometric meshes of the superficial soft tissue continuum
Centre - muscles of facial expression
Right - deep structures



# Facial deformation models

**Finite Element Model for Facial Expressions** [Wu2013]

Exploratory simulations activating one muscle at a time



Frontalis Corrugator Depressor supercilii Procerus Orbicularis oculi (orbital)



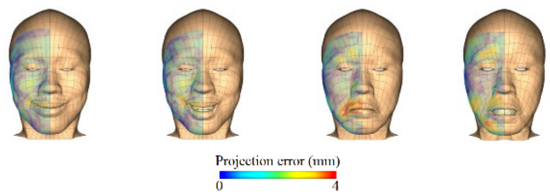
# Facial deformation models

**Finite Element Model for Facial Expressions** [Wu2013]

| **Expression** | **Activated muscles** |
|---|---|
| Smile (mouth closed) | Buccinator, levator anguli oris, orbicularis oculi (orbital part), risorius, zygomaticus major and zygomaticus minor |
| Smile (mouth opened) | Depressor labii inferioris, levator anguli oris, levator labii superioris alaeque nasi, orbicularis oculi (orbital part), zygomaticus major and zygomaticus minor. |
| Sad | Corrugator, depressor anguli oris, frontalis, mentalis, orbicularis oris, platysma and risorius. |
| Terror | Depressor anguli oris, depressor labii inferioris, frontalis, mentalis, platysma and risorius. |

## Facial deformation models

**Finite Element Model for Facial Expressions** [Wu2013]




Numerical simulations of four primary facial expressions, showing the projection errors between the simulated deformed configuration and data obtained from structure-light 3D scanner



## Facial Motion Capture

**Motion capture** can be refered to as the process of recording objects´ motions in a computer relevant form.

The **goal** is to substitute designing the character animation by hand.

With **motion capture** the design of animation is
• easier,
• quicker
• and more realistic
Besides that the animator is free to edit the capture data to modify the animation



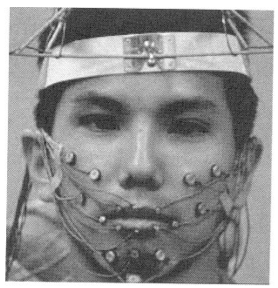
## Facial Motion Capture

Optotrack

Optotrack is a motion capture system that

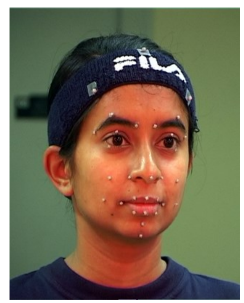
• uses small infra-red markers attached to the skin of a person

• 3D positions of the markers are extracted with opto-electronic techniques





## Facial Motion Capture




More recent motion capture systems

• with retro-reflective markers
• tracked with cameras sensitive to light in the red region

(Kshirsagar,2000)

## Facial Motion Capture

MPEG-4 based Face Capture (Thalmann)

**Optical system** using (Vicon http://www.vicon.com/)

- 8 cameras
- 27 markers corresponding to a subset of MPEG-4 feature point locations related to the Face Animation Parameters (FAP)
- <u>3 additional markers</u> are used to track the global orientation of the head



## Facial Motion Capture

**Tracking the global orientation of the head**

Let (**$s_i$**, **$s'_i$**) be the **positions of the points** on the surface of a rigid body observed at 2 different instants.

$$s'_i = R.s_i + T \quad i=1,2,...,N$$

**R**, rotation matrix, specifying the rotation angle of the rigid body about an arbitrary 3-D axis

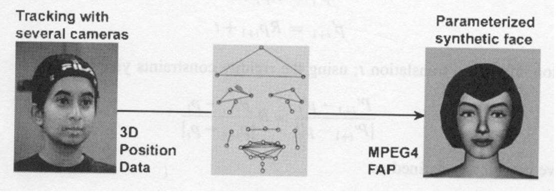
**T**, translation vector, specifying arbitrary shift after rotation

•It can be proved that a **3 non-collinear point** correspondence is necessary and sufficient to determine R and T uniquely.
•Three markers attached to the head are used to capture the rigid head movements.



## Facial Motion Capture

Feature points used for tracking




[Thalmann04]



## Facial Motion Capture

Displacements of feature points

Once extract the global head movements,

the motion trajectories of all **feature point** markers are compensated for the global movements

and the absolute local displacements are calculated

consequently the MPEG-4 FAPs are calculated

## Facial Motion Capture
static expressions

As it is not always possible to do motion capture to generate the animation, it is important to capture basic expressions to re-use in other animations:

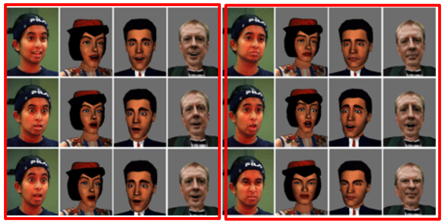
• Capture an actors´s facial movements using the motion capture system to design the static expressions (key-frames)

• These expressions are applied to the facial model using the parameters

• The animator can edit and modify the model.



## Facial Motion Capture
6 basic expressions



6 basic facial expressions have been captured from a performer´s action and re-targeted to various synthetic faces by extraction of MPEG-4 FAPs



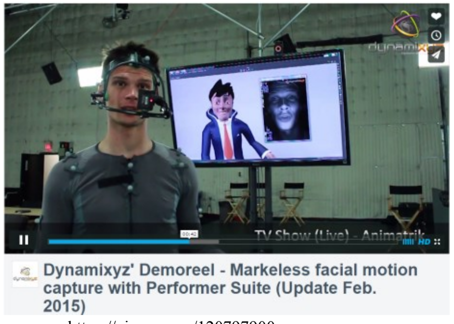
## Motion capture
Markerless

Dynamixyz' video-based facial capture

Natural features (eyebrows, eyes, mouth) are the markers

http://www.dynamixyz.com/

**http://vimeo.com/70540889**



https://vimeo.com/120797900