Digital human models

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Abstract: This study describes digital human models. This study also describes trends in digital human models, shows that the most important trend in digital human models is integrated digital human models, shows that integrated digital human models are frameworks and models and describes frameworks and models that can be used to create digital human models. The results can be used to describe, select, or create digital human models.

Keywords: digital human models; integrated digital human models; frameworks; models.


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1 Introduction

Digital human models are becoming widely used in science, engineering and education. Digital human models can be used to study the relationships between environmental conditions and human responses, improve the usability, comfort and safety of products
and increase the realism and accuracy of training systems. As a result, scientists, engineers and educators need information on digital human models.

This study describes digital human models. This study also describes trends in digital human models, shows that the most important trend in digital human models is integrated digital human models, shows that integrated digital human models are frameworks and models and describes frameworks and models which can be used to create digital human models.

Section 2 describes digital human models. Section 3 describes trends in digital human models. Section 4 presents conclusions. The results show that digital human models are models, programmes, or devices, theoretical, analytical, or physical models and behavioural, functional, or structural models. The results show that digital human models are integrated or individual models. The results can be used to describe, select, or create digital human models.

# 2 Digital human models

Digital human models are models of humans. Digital human models are models, programmes, or devices, theoretical, analytical, or physical models and behavioural, functional, or structural models. Digital human models are integrated or individual models.

## 2.1 Three models

Figures 1–3 show three models which are theoretical models.

**Figure 1** A model which can be used to study human behaviours

![Diagram of a model with a framework, thinking, sensing, acting, object, and behaviour]

The model in Figure 1 is a behavioural model which can be used to study human behaviours. The model in Figure 1 is an integrated model which consists of a framework and sensing (seeing, hearing, touching, tasting, or smelling), thinking (communicating, remembering, deciding, solving, or learning) and acting (speaking, grasping, or moving) models (Carruth et al., 2007).
Figure 2  A model which can be used to study human functions

The model in Figure 2 is a functional model which can be used to study human functions. The model in Figure 2 is an integrated model which consists of a framework and sensing (detecting, identifying, or measuring), relating (selecting, matching, or transforming) and responding (generating, or modifying) models (Miller et al., 2010; Noble et al., 2012).

Figure 3  A model which can be used to study human structures

The model in Figure 3 is a structural model which can be used to study human structures. The model in Figure 3 is an integrated model which consists of a framework and sensing (experiencing, contacting, or receiving), associating (selecting, matching, or transforming) and organising (creating, or modifying) models (Smith and Yen, 2010).

2.2 Three programmes

Figures 4–6 show three programmes which are analytical models.
Digital human models

**Figure 4** A programme which can be used to analyse human bicycling behaviours (see online version for colours)

The programme in Figure 4 is a behavioural model which can be used to analyse human behaviours. The programme in Figure 4 is an integrated model which consists of a framework and sensing (seeing, hearing, touching, tasting, or smelling), thinking (communicating, remembering, deciding, solving, or learning) and acting (speaking, grasping, or moving) models (Cangley et al., 2012).

**Figure 5** A programme which can be used to analyse human circulatory functions (see online version for colours)
The programme in Figure 5 is a functional model which can be used to analyse human functions. The programme is an integrated model, which consists of a framework and sensing (detecting, identifying, or measuring), relating (selecting, matching, or transforming) and responding (generating, or modifying) models (Jiang and Mangharam, 2013).

Figure 6  A programme which can be used to analyse human atomic structures (see online version for colours)

The programme in Figure 6 is a structural model which can be used to analyse human structures. The programme is an integrated model, which consists of a framework and sensing (experiencing, contacting, or receiving), associating (selecting, matching, or transforming) and organising (creating, or modifying) models (Tachiwana et al., 2011).

2.3 Five devices

Figures 7–11 show five devices which are physical models.

Figure 7  An automaton which can be used to duplicate human writing behaviours (see online version for colours)
The devices in Figures 7–11 are behavioural models which can be used to duplicate human behaviours. The devices are integrated models which consist of frameworks and sensing (seeing, hearing, touching, tasting, or smelling), thinking (communicating, remembering, deciding, solving, or learning) and acting (speaking, grasping, or moving) models (Kolesnikov-Jessop, 2012; Waurzyniak, 2013; Rodic, et al., 2009; Iwata and Sugano, 2009; Mellman and Xu, 2010).

**Figure 8** An industrial robot which can be used to duplicate human lifting behaviours (see online version for colours)

**Figure 9** An agent-based robot which can be used to duplicate human monitoring behaviours (see online version for colours)
3 Trends in digital human models

Integrated models are the most important trend in digital human models. Integrated models consist of frameworks and models. Therefore, integrated models can be used to create simple, complex, or custom models. As a result, integrated models can be used to complete simple, complex, or custom tasks, with different levels of accuracy or computing time.
3.1 Three frameworks

Figures 12–14 show three frameworks which can be used to create digital human models.

**Figure 12** A framework which can be used to create behavioural models

The framework in Figure 12 can be used to create behavioural models. The framework uses sensing (seeing, hearing, touching, tasting, or smelling), thinking (communicating, remembering, deciding, solving, or learning) and acting (speaking, grasping, or moving) models to create behavioural models. The thinking (communicating, remembering, deciding, solving, or learning) models use condition-action rules to model human thinking (Carruth et al., 2007).

**Figure 13** A framework which can be used to create functional models

The framework in Figure 13 can be used to create functional models. The framework uses sensing (detecting, identifying, or measuring), relating (selecting, matching, or transforming) and responding (generating, or modifying) models to create functional models. The relating (selecting, matching, or transforming) models use XML APIs to model human relating (Miller et al., 2010; Noble et al., 2012).
The framework in Figure 14 can be used to create structural models. The framework uses sensing (experiencing, contacting, or receiving), associating (selecting, matching, or transforming) and organising (creating, or modifying) models to create structural models. The associating models use mathematical equations to create structural models (Smith and Yen, 2010).

3.2 Thirty models

3.2.1 Seventeen sensing models

Figures 15–30 show 17 sensing (seeing, hearing, touching, tasting, or smelling) models which can be used to create digital human models.

Figure 15 A camera (see online version for colours)

The seeing model in Figure 15 uses a camera to capture visible images. The camera uses a lens, an aperture and sensors to capture light, change focus, change focal length and capture visible images (Smith and Smith, 2011).
The seeing model in Figure 16 uses a biomimetic eye to capture visible images. The biomimetic eye uses a gel polydimethy-siloxane silicone (PDMS) lens, shape memory alloy (SMA) wires, grippers, load arms and an outer ring to capture light, change focus, change focal length and capture visible images (Choi et al., 2008).

The seeing model in Figure 17 uses an infrared camera to capture infrared images. The infrared camera uses a fixed-focus lens and infrared sensors to capture infrared light and capture infrared images (Kao and Smith, 2011).
The seeing model in Figures 18–20 uses an object-recognition algorithm to detect the shapes, sizes, locations and orientations of two-dimensional objects in images. The object-recognition algorithm uses histograms, regression analysis and shape rules to detect lines, detect shapes and detect the shapes, sizes, locations and orientations of two-dimensional objects in images (Smith and Smith, 2011).
The seeing model in Figures 21–22 uses a pattern-recognition algorithm to detect patterns (words) in images. The pattern-recognition algorithm uses colour spaces and support vector machines (SVMs) to detect colours, detect shapes and detect patterns (words) in images (Maldonado-Bascon, 2007).

Figure 23  An object-reconstruction algorithm

The seeing model in Figures 23–24 uses an object-reconstruction algorithm to detect three-dimensional objects in images. The object-reconstruction algorithm uses camera parameter estimation, key-point selection and hierarchical matching algorithms to determine viewpoints, select key-points, match key-points and detect three-dimensional objects in images (Zimmer and Miteran, 2001; Lu and Smith, 2006).

Figure 25  An object-tracking algorithm
The seeing model in Figures 25–26 uses an object-tracking algorithm to track three-dimensional objects in images. The object-tracking algorithm uses a camera parameter estimation algorithm and Kalman filters to determine viewpoints, detect three-dimensional objects and track three-dimensional objects in images (Kao and Smith, 2011).

The hearing model in Figure 27 uses microphones to capture sounds. The microphones use sound pressure level transducers and electrical wires to detect sound-wave induced vibrations, convert sound-wave induced vibrations into electrical signals, transmit electrical signals and capture sounds (Lee et al., 2014).

The hearing model in Figure 28 uses a biomimetic ear to capture sounds. The biomimetic ear uses an ear simulator, a receiver microphone, a microphone preamplifier, a power supply and electrical wires to amplify sound waves, detect sound-wave induced vibrations, convert sound-wave induced vibrations into electrical signals, amplify electrical signals, transmit electrical signals and capture sounds (Bravo et al., 2008).
The hearing model in Figure 29 uses a sound-localisation algorithm to detect the locations of objects from sounds. The sound localisation algorithm uses receivers, ILDs (interaural level differences), IPDs (interaural phase differences) and GMMs (Gaussian mixture models) to detect sound levels, detect sound phases, detect sound sources and detect the locations of objects from sounds (May et al., 2011).
The hearing model in Figure 30 uses a speech-recognition algorithm to detect words from sounds. The speech recognition algorithm uses HMMs (hidden Markov models) and LR parsers (language-recognition parsers) to detect phonemes from sounds and detect words from sounds (Minami et al., 1995).

The touching model in Figure 31 uses a biomimetic finger to detect vibrations. The biomimetic finger uses an artificial finger and a vibration sensor to contact physical objects and detect vibrations (Smith et al., 2012b).

The amplitudes of a vibration (see online version for colours)
The touching model in Figures 32–33 uses an object-recognition algorithm to detect objects from vibrations. The object-recognition algorithm uses Fourier transforms to detect the amplitudes of vibrations, to detect the frequencies of vibrations and to detect objects from vibrations (Smith et al., 2012b).

The tasting model in Figure 34 uses a chemical taste sensor to detect tastes from chemical concentrations. The chemical taste sensor uses an array of electrochemical sensors and two-stage RBFNs (radial basis function networks) to detect chemical concentrations and to detect tastes from chemical concentrations (Ishihara et al., 2005).

The touching model in Figures 32–33 uses an object-recognition algorithm to detect objects from vibrations. The object-recognition algorithm uses Fourier transforms to detect the amplitudes of vibrations, to detect the frequencies of vibrations and to detect objects from vibrations (Smith et al., 2012b).

The tasting model in Figure 34 uses a chemical taste sensor to detect tastes from chemical concentrations. The chemical taste sensor uses an array of electrochemical sensors and two-stage RBFNs (radial basis function networks) to detect chemical concentrations and to detect tastes from chemical concentrations (Ishihara et al., 2005).
The tasting model in Figure 35 uses two information processing models (model $\alpha$, model $\beta$) to detect objects from tastes. The two information processing models (model $\alpha$, model $\beta$) use three neural networks (NN-$\alpha_1$, NN-$\alpha_2$, NN-$\beta$) to detect sensory information from chemico-physical information, to detect tastes from chemico-physical information and to detect objects from tastes (Oguri et al., 2000).

**Figure 36** A biomimetic sensor (see online version for colours)

The smelling model in Figure 36 uses a biomimetic sensor to detect smells from odour-induced electrical signals in human olfactory tissue. The biomimetic sensor uses human olfactory tissue, LAPS (light-addressable potentiometric sensors), power supplies and principal component analysis to create odour-induced electrical signals in human olfactory tissue, to group odour-induced electrical signals in human olfactory tissue into smells and to detect smells from odour-induced electrical signals (Liu et al., 2010).

**Table 1** Two object recognition algorithms

<table>
<thead>
<tr>
<th>Representation space</th>
<th>Parameters</th>
<th>Classification accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>$\sigma$ 0.02, $C$ 200</td>
<td>78.76</td>
</tr>
<tr>
<td>$S_T$</td>
<td>$\sigma$ 0.04, $C$ 140</td>
<td>90.52</td>
</tr>
</tbody>
</table>

The smelling model in Table 1 uses two object-recognition algorithms to detect objects from smells. The two object recognition algorithms (the ‘Standard’ and ‘$S_T$’ object-recognition algorithms) use features and a Euclidean metric to detect objects (the ‘photo’ set) from smells (Bicego, 2005).

### 3.2.2 Eight thinking, relating, or associating models

Table 2 and Figures 37–47 show eight thinking (communicating, remembering, deciding, solving, or learning), relating (selecting, matching, or transforming), or associating (selecting, matching, or transforming) models.
**Table 2**  User feelings about objects

<table>
<thead>
<tr>
<th>Feature</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elegant</td>
<td>-</td>
<td>Ordinary</td>
<td></td>
</tr>
<tr>
<td>Simple</td>
<td>-</td>
<td>Complex</td>
<td></td>
</tr>
<tr>
<td>High tech</td>
<td>-</td>
<td>Traditional</td>
<td></td>
</tr>
<tr>
<td>Luxurious</td>
<td>-</td>
<td>Basic</td>
<td></td>
</tr>
<tr>
<td>Beautiful</td>
<td>-</td>
<td>Plain</td>
<td></td>
</tr>
<tr>
<td>Unique</td>
<td>-</td>
<td>Common</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 37**  Design elements of objects (see online version for colours)
The communicating model in Table 2 and Figure 37 uses selected words to communicate information about objects. The selected words are used to communicate user feelings about objects and design elements of objects (Smith and Smith, 2012).

**Figure 38** A framework for creating information models

The remembering model in Figure 38 uses a framework and information models to define, store and recall information about objects. The framework uses translation methods, comparison methods and integrating methods to translate information about objects into ontologies, compare ontologies to information requirements, integrate ontologies into information models and use information models to define, store and recall information about objects (Taisch et al., 2011).

**Table 3** A survey

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>4</th>
<th>7</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Elegant</td>
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<td>Ordinary</td>
</tr>
<tr>
<td>Simple</td>
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<tr>
<td>Unique</td>
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<td>Common</td>
</tr>
</tbody>
</table>

*Figure 39* A semantic space

\[
M_v = T S D_v' 
\]
The deciding model in Table 3 and Figure 39 uses surveys, semantic spaces and matching methods to make decisions about objects. The surveys use terms to describe customer needs. The semantic spaces use term-by-design matrices $\{M\}$, term matrices $\{T\}$, scaling factor matrices $\{S\}$ and design matrices $\{D\}$ to describe designs. The matching methods use the surveys and semantic spaces to create customer need vectors $\{M_v\}$, project customer need vectors $\{M_v\}$ into semantic spaces $\{T, S, D\}$ and match projected customer need vectors $\{D_v\}$ to projected design vectors $\{D\}$ in semantic-spaces $\{T, S, D\}$ (Smith and Smith, 2012).

**Figure 40** An object

![Image](image1)

**Figure 41** A disassembly sequence structure graph

The solving model in Figures 40–41 uses a graph-searching algorithm to create disassembly plans for objects. The graph-searching algorithm uses disassembly sequence structure graphs and constraint matrices to model objects and the relationships between parts in objects. The graph-searching algorithms use rules to search the disassembly sequence structure graphs and constraint matrices to create disassembly plans for objects (Smith et al., 2012a).
Figure 42  A sequence-learning algorithm

Figure 43  A task related to objects (see online version for colours)

Figure 44  Circulatory system responses for flight safety simulations
The learning model in Figures 42–43 uses a sequence-learning algorithm to learn tasks related to objects. The sequence-learning algorithm uses sensors, an agent and a planner to capture signals, set goals, choose actions and learn tasks related objects (Rohrer, 2007).

The selecting model in Figure 44 uses environmental conditions (pressures, accelerations and forces) and differential equations to select circulatory system responses (pressures, flows and volumes) for flight safety simulations (Hardy et al., 1982).

**Figure 45** Molecular theory principles

![Molecular theory principles](image)

The matching model in Figure 45 uses molecular theory principles to match induced environmental conditions to molecular movements in molecular structures (Nji and Li, 2010).

**Figure 46** Atomic theory equations (see online version for colours)

![Atomic theory equations](image)

The transforming model in Figure 46 uses atomic theory equations to transform natural environmental conditions (atomic charges and distances) into atomic movements in atomic structures (Smith and Yen, 2010).

### 3.2.3 Five acting, responding, or organising models

Figures 47-51 show five acting (speaking, grasping, or moving), responding (generating, or modifying), or organising (creating, or modifying) models.

The speaking model in Figure 47 uses a speech processing programme to transform speech into synthesised speech for speaking tasks. The speech processing programme uses mel-cepstral analysis, a hidden Markov model (HMM) encoder, a hidden Markov model (HMM) decoder and a mel-log spectrum approximation (MLSA) filter to
transform and encode speech into pitch, phoneme sequence and state duration vectors or decode and filter pitch, phoneme sequence and state duration vectors into synthesised speech for speaking tasks (Tokuda et al., 1998).

**Figure 47** A speech processing programme

![Speech Processing Diagram](image)

**Figure 48** A motion planning programme (see online version for colours)

![Motion Planning Diagram](image)
The grasping and moving model in Figure 48 uses a motion planning programme to plan motions for grasping and moving tasks. The motion planning programme uses search trees, dynamic programming algorithms and trajectory generation algorithms to plan motions for grasping and moving tasks (Kuffner et al., 2003).

Figure 49 A bio-signals programme

The generating model in Figure 49 uses a bio-signals programme to generate electrocardiograms (ECGs), electromyograms (EMGs) and electrodermal activity signals (EDAs) for biometric identifications. The bio-signals programme uses stored electrocardiograms (ECGs), electromyograms (EMGs) and electrodermal activity signals (EDAs) to generate electrocardiograms (ECGs), electromyograms (EMGs) and electrodermal activity signals (EDAs) for biometric identifications (van den Broek, 2010).

Figure 50 An ergonomic effects programme (see online version for colours)
The creating model in Figure 50 uses an ergonomics programme to create ergonomic models for ergonomic analysis tasks. The ergonomic programme uses personal attributes (nationalities, genders, weights and statures) to create ergonomic models for ergonomic analysis tasks (Demirel and Duffy, 2007a, 2007b; Jung et al., 2009; Wu et al., 2011; De Magistris et al., 2013).

Figure 51 An anthropometrical models programme

The modifying model in Figure 51 uses an anthropometrical models programme to modify anthropometrical models for clothing design tasks. The anthropometrical models programme uses 3D laser scanner measurements and anthropometrical landmarks to modify anthropometrical models for clothing design tasks (Lu et al., 2010).

4 Conclusions

This study describes digital human models. This study also describes trends in digital human models, shows that the most important trend in digital human models is integrated digital human models, shows that integrated digital human models are frameworks and models and describes frameworks and models that can be used to create digital human models.

The results show that digital human models are models, programmes, or devices, theoretical, analytical, or physical models and behavioural, functional, or structural models which can be used to study, analyse, or duplicate human behaviours, functions, or structures. The results show that digital human models are integrated or individual models which consist of frameworks and models or models.

The results can be used to describe, select, or create digital human models. The results can be used to describe, select, or create integrated models. Therefore, the results can be used to describe, select, or create frameworks and models. The results can also be used to describe, select, or create individual models. Therefore, the results can also be used to describe, select, or create models.
References


