Thermal Modelling of Soldiers: Human Thermal Simulation & Camouflage Applications

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Why perform simulation-based human signature analysis?

- Systems can be evaluated under any circumstances
- Repeatable, cost-effective, safe
- Measured inputs can be used to validate models
- Optimization can be automated
Human Thermal Simulation Workflow

Geometry

Human Thermal Physiology

Texture Map

Thermal Solution

Radiance Prediction

Human Simulation Workflow
Human Geometry Creation

Human Animation Software
(Poser Pro 2010)

3D Scanning Device
(Artec 3D)

FEA Meshing Software
(ANSА)

Geometry
Human Thermal Simulation Workflow

- Geometry
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- Texture Map
- Thermal Solution
- Radiance Prediction
A simple thermal model (e.g. set $T_{\text{core}} = 37^\circ \text{C}$) is NOT sufficient for human simulation.
Accurate human signature predictions require accurate, localized skin and clothing temperatures

TAIThermIR’s segmental Human Thermal Module is capable of sophisticated \textit{thermoregulatory simulations} that capture regional “hotspots” caused by radiation, heterogeneous garment insulation, etc.
TAIThermIR Human Thermal Module

- Human Thermal Module:
  - Multiple (20+) body segments
  - Multiple tissue types per segment
Human Thermal Modelling

- Human Thermoregulation: Maintaining constant internal body temperature independent from the environment
  - Metabolic heat generation
  - Convection due to blood flow (blood perfusion)
  - Conduction from tissue to tissue
  - Vasodilation, vasoconstriction
  - Sweating, shivering, respiration
  - Evaporation
  - Clothing thermal resistance
  - Radiation/convection/conduction with environment
Human Thermal Model Inputs

- Model Inputs
- Shell element surface mesh
- Clothing thermal properties
- Activity level
- Anatomical description
Human Thermal Model Outputs

- **Model Inputs**
  - Shell element surface mesh
  - Clothing thermal properties
  - Activity level
  - Anatomical description

- **Model Outputs**
  - Clothing & Skin temperatures
  - Core body temperature
  - Thermal Sensation & Comfort (local and whole body)
  - Blood pool temperature
  - Interior tissue temperatures
  - Local & whole body heat fluxes
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Texture Mapping

Texture Maps are used to apply optical properties ("paints") to geometry at a sub-element level.

Sandford-Robertson BRDF renderings incorporate texture-mapped paints into radiance predictions.

- Paint 1: Black
- Paint 2: Dark Green
- Paint 3: Light Green
- Paint 4: Tan
Texture Mapping: Examples

- Texture mapping is performed via other tools
  - e.g. Blender, Rhino
- Texture map is imported into TAI ThermIR
  - User selects unique “paint” for each color in texture map

Dingo-2
Meshed Geometry with Texture Map

German Shepherd
Meshed Geometry with Texture Map
Optical Properties for Texture Mapping

Spectral Emissivities of Various Surface Colors

- Black
- Dark Green
- Light Green
- Tan
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Radiance Prediction
TAIThermIR predicts the impact of natural environment on human thermoregulation.
Human Thermal Model Validation

- Human subject tests performed by Stolwijk and Hardy
  - Core and skin temperatures were measured on humans sitting quietly in:
    - 82.4°F (28°C) for 60 minutes
    - 118.4°F (48°C) for 120 minutes
    - 82.4°F (28°C) for 60 minutes

- TAITherm simulation used the same environmental temperatures, activity level, and clothing as human subject test
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Texture-Mapped Rendering Examples

- Rendering utilizes ray-tracing from sensor to scene
  - Calculates spectral radiances from Visible to LWIR wavebands
  - Uses MODTRAN for ATM effects
Camouflage Rendering Examples

Various Sensor Wavebands and Times

Visible
Near Infrared
SWIR
MWIR
LWIR
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Scene Simulation Overview

- Scene simulation: Creating realistic synthetic EO/IR scenarios
  - Buildings and faceted terrain (DEMgs)
  - Moving vehicles (including engine/exhaust heating & thermal interaction with terrain)
  - Moving sensor platforms, transient weather
  - Animated humans (changing poses)
Animated Soldier IR Signature Video

- Night-time IR animation from perspective of moving sensor
Thanks for your attention!

- **http://www.thermoanalytics.com**
  - TAIThermIR
    - Thermal, Human and Radiance Simulation
  - MuSES
    - Exported-controlled
    - Advanced features

- **https://support.thermoanalytics.com**
  - Software Downloads
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