FireSim – A Virtual Firefighting Simulator

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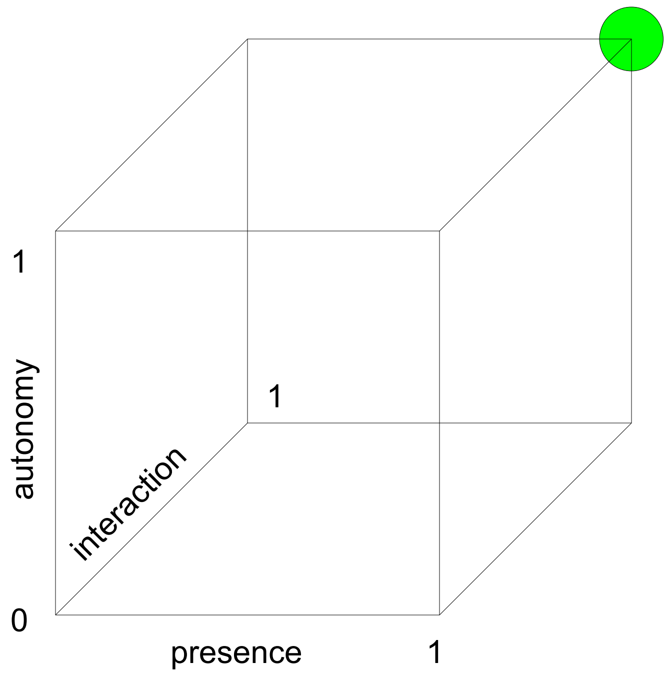
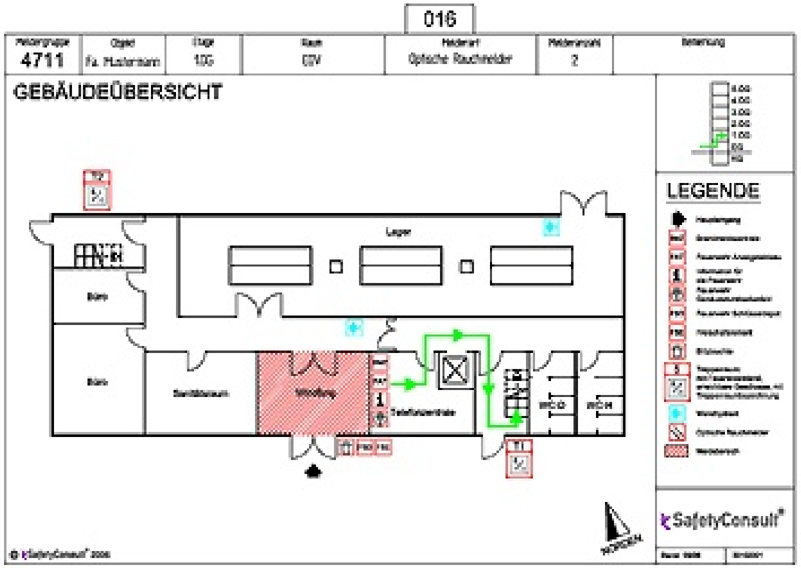
Concept

- physical and chemical laws apply to all processes
- simple models for selected scenarios
- important criteria for good simulation
  - appearance of simulation should be closed to reality
  - handling the simulation (interaction) should be “natural”
  - simulation must strictly follow physical and chemical laws



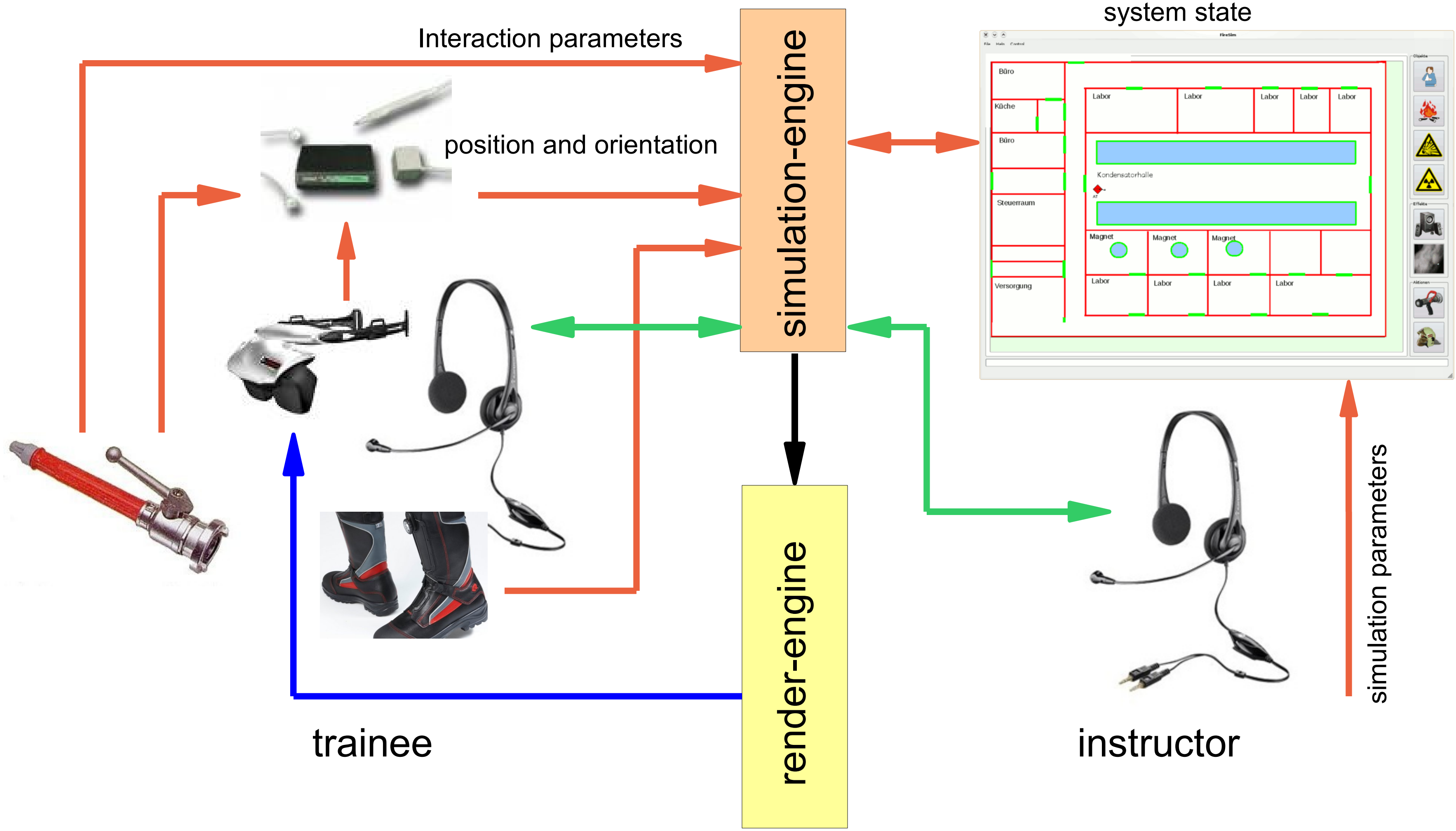
Virtual World

- static geomety
  - building, rooms, (passive) objects
  - CAD-drawings, operations sheet



- dynamic objects
  - state of object changes over time
    - location and condition of attack group, person, ...
    - location and state (e.g. activity) of radiation source
    - location and state of fire (e.g. current temperatur)
  - core of simulation
- user can move freely inside the virtual world

System Design

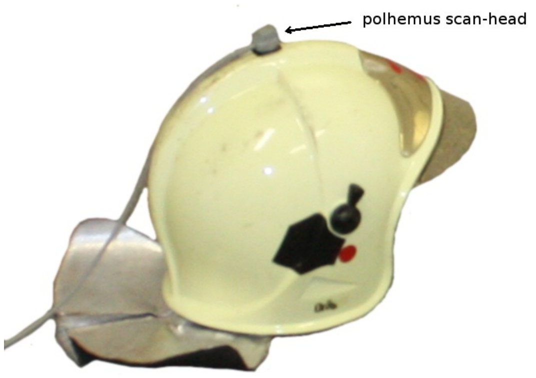


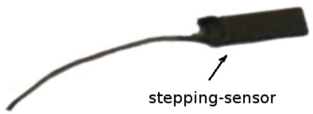
System Setup

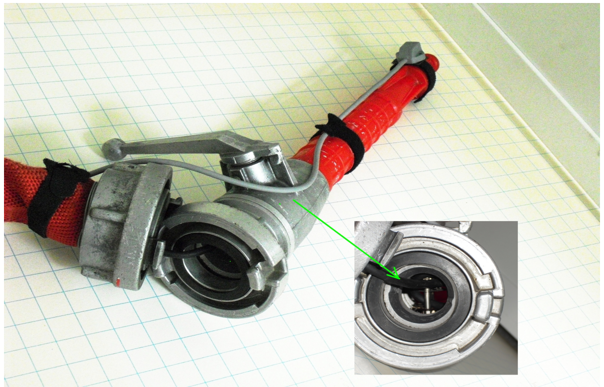
- PC, mid-range graphics card, soundcard, Linux OS
  - 2 * quad-core AMD, nVidia Quadro FX 3700
- tracking system
  - Polhemus Patriot
- display system
  - head mounted display (eMagin Z800)
  - big-wall back-projection, stereo
- data acquisition (control interface)
  - Vellemann K-8055 USB experimental board
- head-set
- “gadgets”
  - modified C-size nozzle, Teleprobe FH40G dummy, ...

Interaction and Simulator feed-back

- position in the virtual world
  - tracking system (height and orientation)
  - virtual walking model (stepping sensor)
  - collision detection
- input devices
  - natural handling
  - modified C-size nozzle
  - Teleprobe FH40G dummy
  - process control
    - radio communication
    - extinguishing agent supply
- visual, acoustic and haptic feed-back

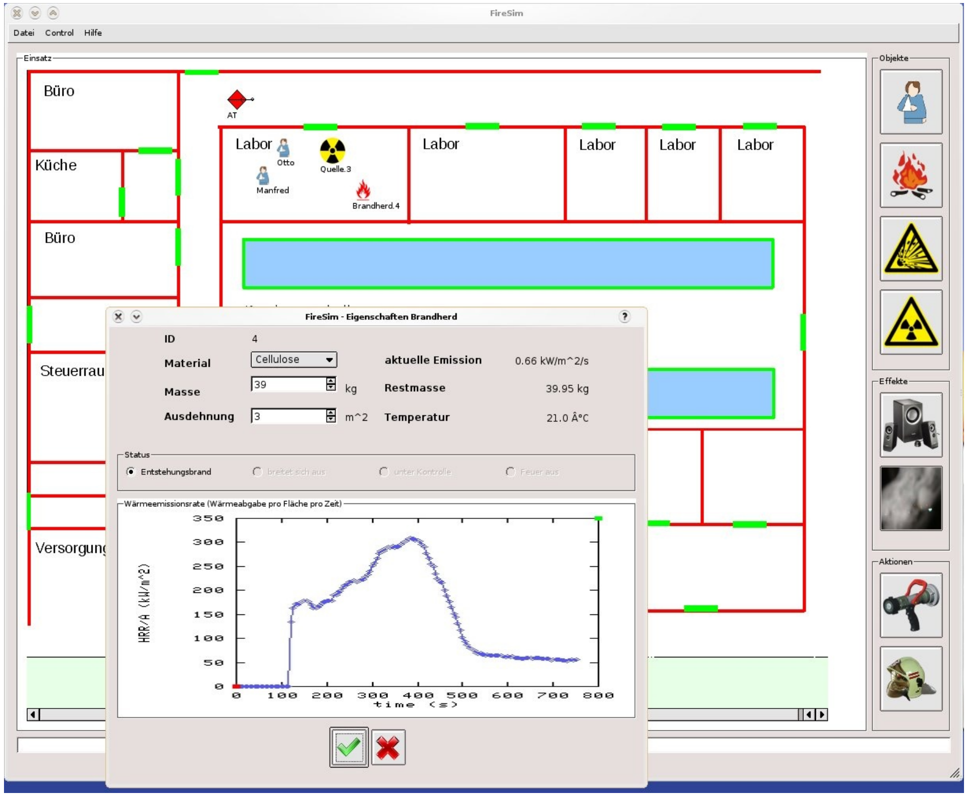






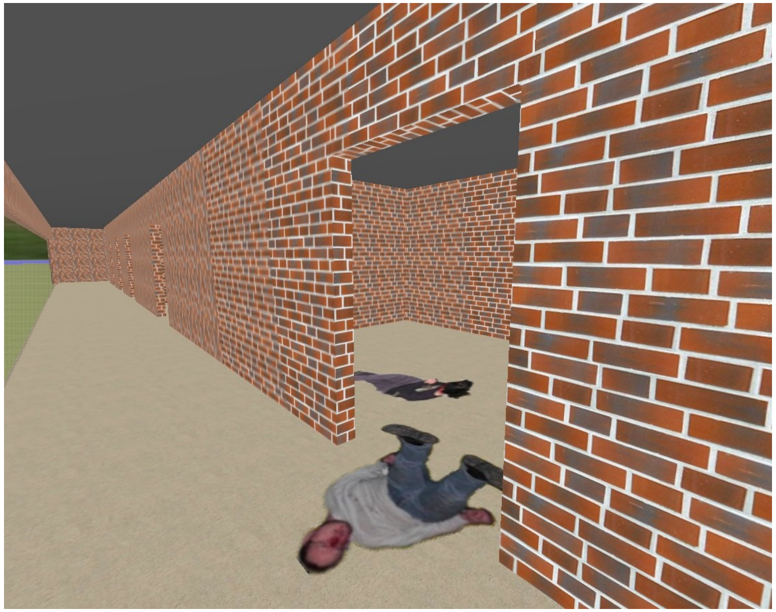
Engagement

- define scenario
  - combine different types
- place order
- arm trainee
- accomplish
  - logging
    - decisions
    - radio traffic
    - system parameters
  - interaction by instructor
  - (immediate) replay
- analysis

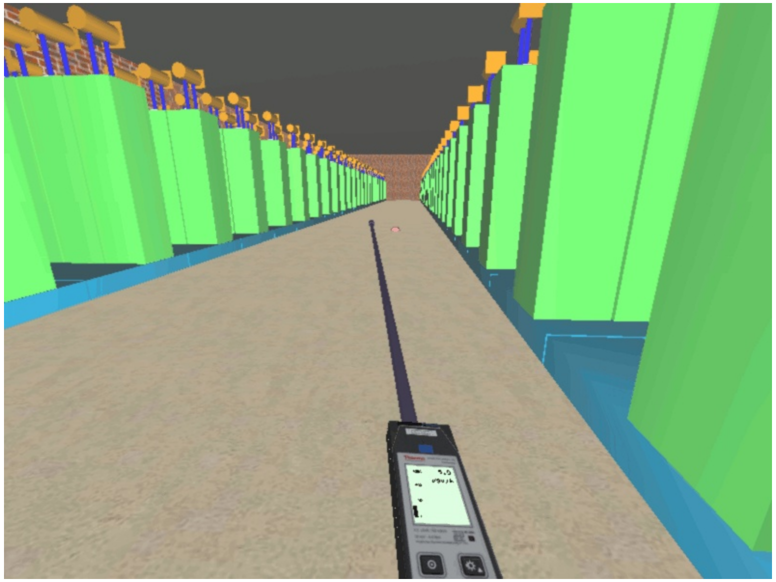


Search & Rescue

- objective:
  - locate and rescue (insured) person
- modeling person
  - mobile/immobile/on the run
    - mobile person not implemented yet
  - condition (NAD, unconscious, ...)
  - degree of insury
- representation
  - texture (image of real person)
  - acoustic: (crying, moaning, coughing, ...)
    - sound level depends on distance to person



Radiation Protection

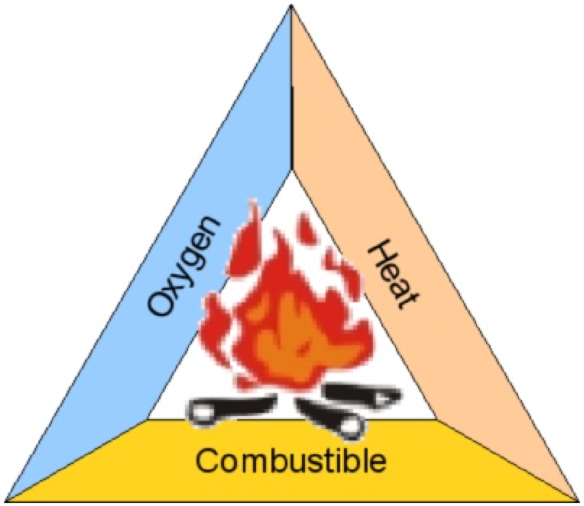


- objective:
  - determine dirty area
  - locate and isolate radiation sources
- measure dose rate (equivalent dose over time)
- source defined by isotope and activity *[Bq]*
- conversion into dose rate via dose conversion factor (DCF)
  - depends on isotope, $0{,}45 \cdot 10^{-8}$ .. $350 \cdot 10^{-8}$ *Sv/Bq*
  - more general $2{,}2 \cdot 10^{-8}$ *Sv/Bq*
- superposition of different sources

$$H = \sum DCF_i \cdot \frac{A_i}{\left\| \underline{x}_S - \underline{x}_i \right\|^2}$$

Fire-Fighting

- objective:
  - locate fire source
  - attack fire (extinguish)
- apply fire physics (combustion triangle)
  - extinction by cooling
- visual representation
  - simple: 2D texture on bill-board
    - sophisticated: multi particle system
  - 2D might by sufficient in areas full of smoke
- smoke
  - visibility depends on the height above ground (the lower the better)
  - simple model: linear smoke density (0..100 %), ~ $(1.0\text{-}height/h_s)$
    - assume “standard” height $h_s = 1.80\ m$

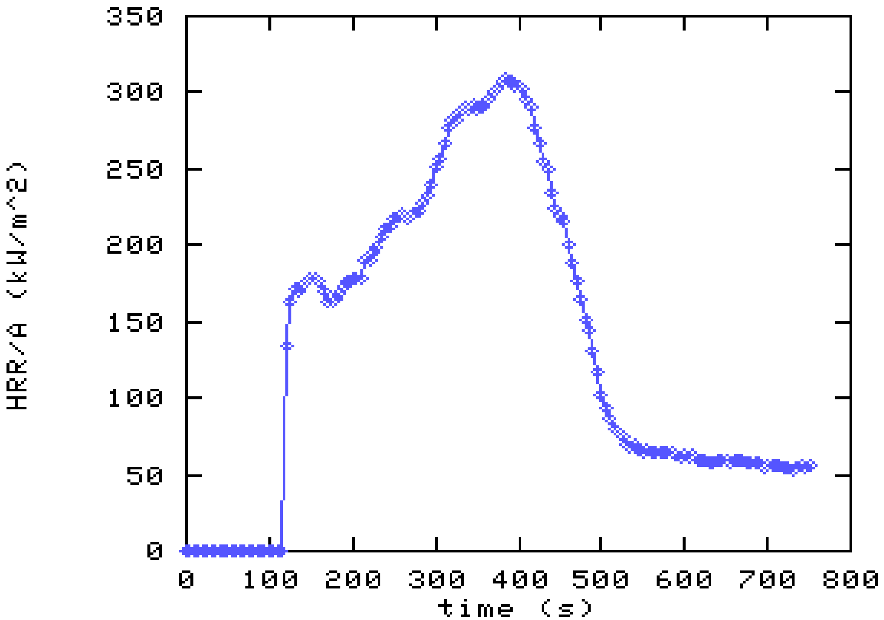


Fire-Fighting – Simple Combustion Model

- fire physics
  - complex model (dynamic process of compressible gas)
    - NIST FDS – Fire Dynamics Simulator
  - large computing times (10 min, app. 8 h processor time on two cores)
  - simplification:
    - heat release rate
    - mass loss rate
    - simple energetic approach

$$\dot{q}_F = \dot{m} \cdot \Delta H_c$$

$$Q_F(t) = \int_0^t \dot{q}_F \, dt = \int_0^t \dot{m} \cdot \Delta H_c \, dt$$

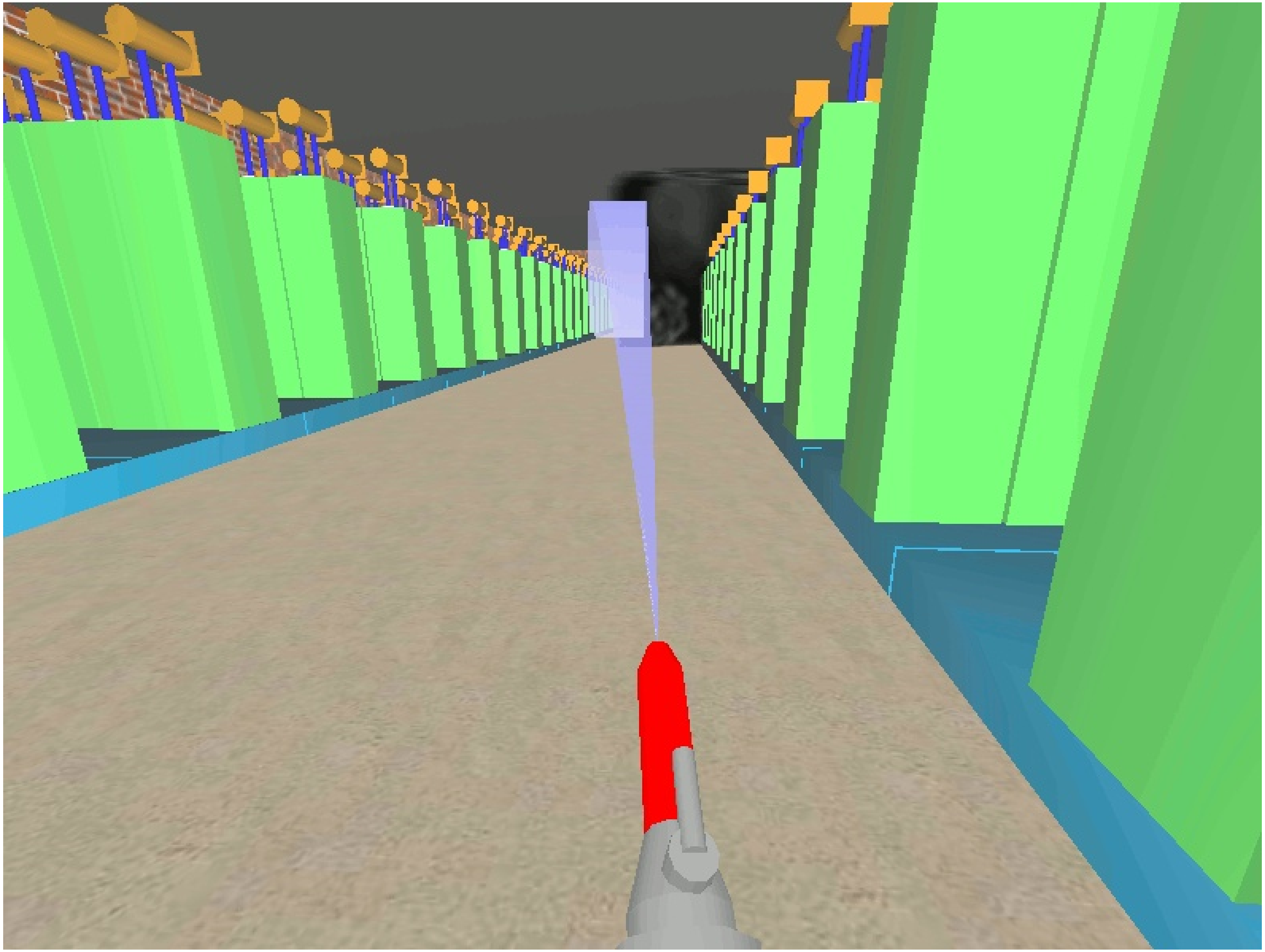


Fire-Fighting – Simple Extinguishing Model

- extinction by cooling
- model trajectory of extinguishing agent
  - attack angle, pressure (velocity), form of beam (air resistance)
- amount of agent effective on fire source
  - volume stream: $I_L(t)$; take foam expansion rate into account
  - $S_F(t)$: ratio between overlapping area (A_{FL}) by target area (A_L)
  - constant effectiveness (e.g. depends on drop size): S_L
  - heat capacity+evaporation heat of agent: C_L (water: *2,6 MJ/kg*)

$$\dot{q}_L(t) = C_L \cdot S_L(t) \cdot S_F(t) \cdot I_L(t); S_F(t) = \frac{A_{FL}}{A_L}$$

$$\Delta Q = Q_F - Q_L = Q_F(t) - \int^{t} \dot{q}_L\, dt - Q_{CTR}$$



Pros and Cons of Virtual Training

- advantages
  - cost efficient
  - usable any time, no complex preparation necessary
  - safe
  - replay, immediate correction of faults possible
- disadvantages
  - realistic models are complex and not easy to develop
  - different effects can not be represented properly
    - temperature, shock waves, ...
- nowadays used for: training of mission control and tactics
  - LFS Hamburg, LFS Celle, FKS Rheinland-Pfalz, FS Kärnten, BF Frankfurt, BF Berlin, BF Hamburg
  - Virtual Fires (tunnel fire simulation)
  - Pompiers de Paris - WearIT@Work

Outlook

- integration of NIST FDS
- improved rendering
  - switching to standard render-engines like Ogre
- extensions
  - shielding effect with radiation protection missions
  - autonomous person
- other standard missions
  - device handling (pumps, ...)
  - car crashes
- other virtual devices
- roll-out