Synthesizing Personalized Construction Safety Training Scenarios for VR Training

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George Mason University

(a) Virtual Construction Site

(b) Generate Navigation Mesh

(c) Generate Path Graph

(d) Define Hazard Candidates

(e) Synthesized Scenario for Personalized Training

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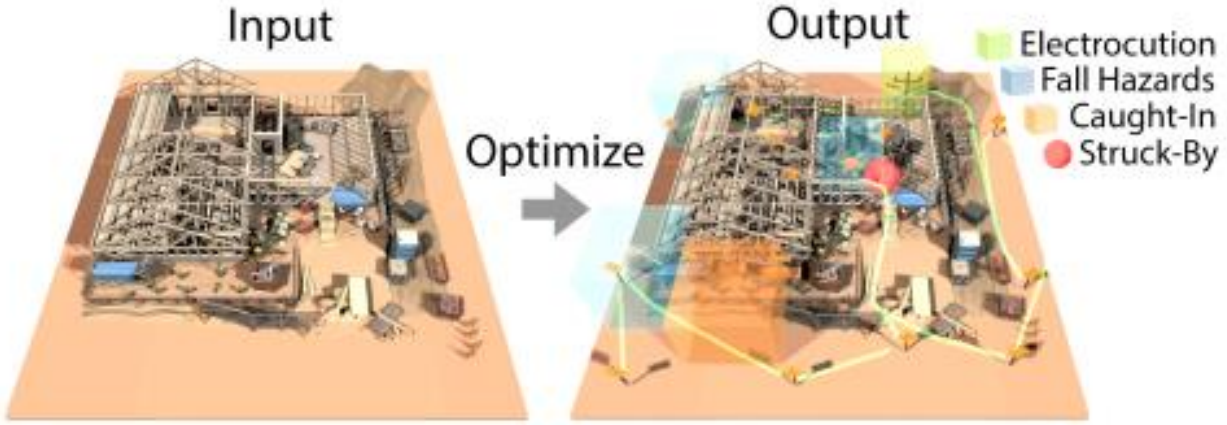
Overview of our Approach

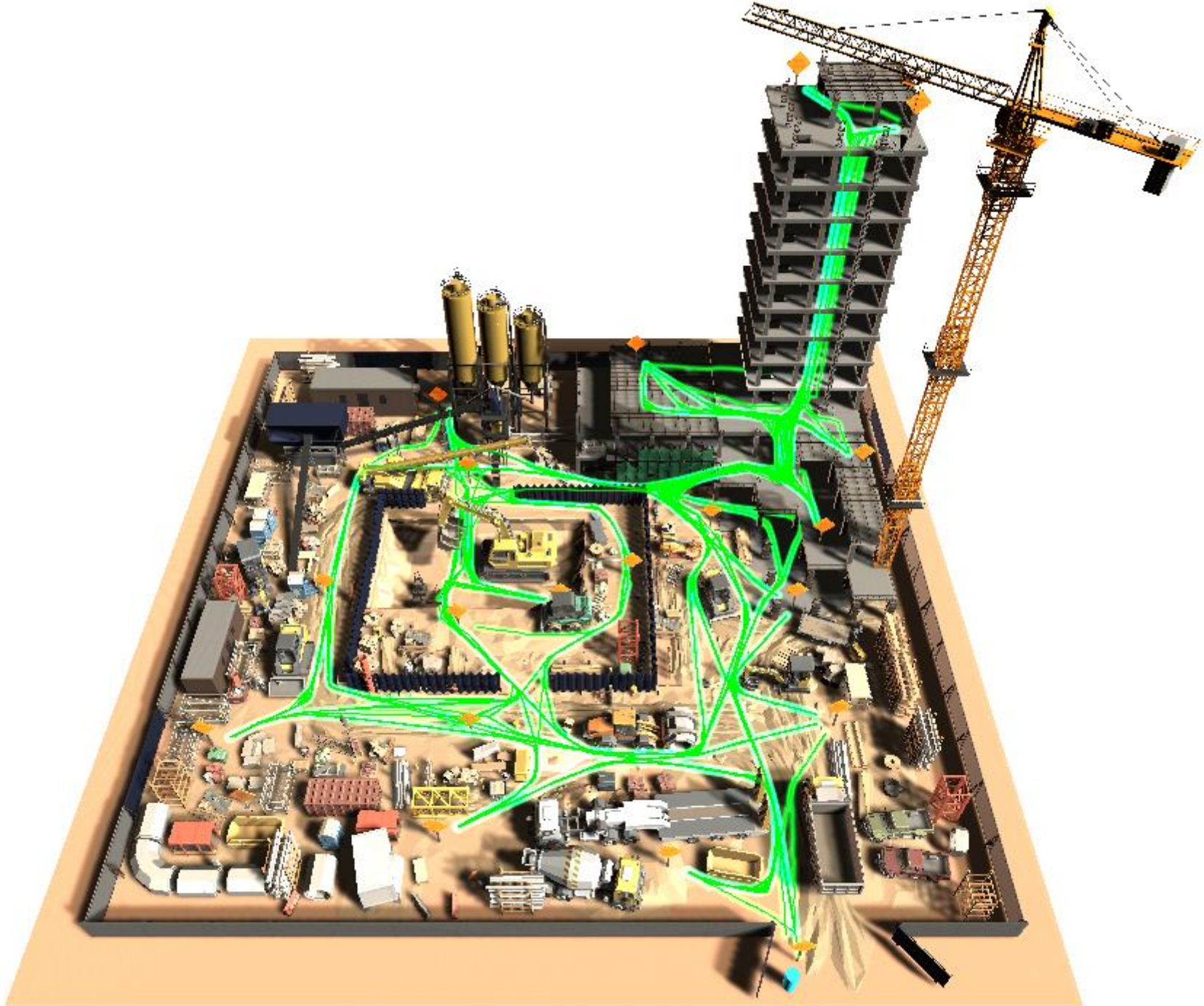
(a) Pre-evaluation

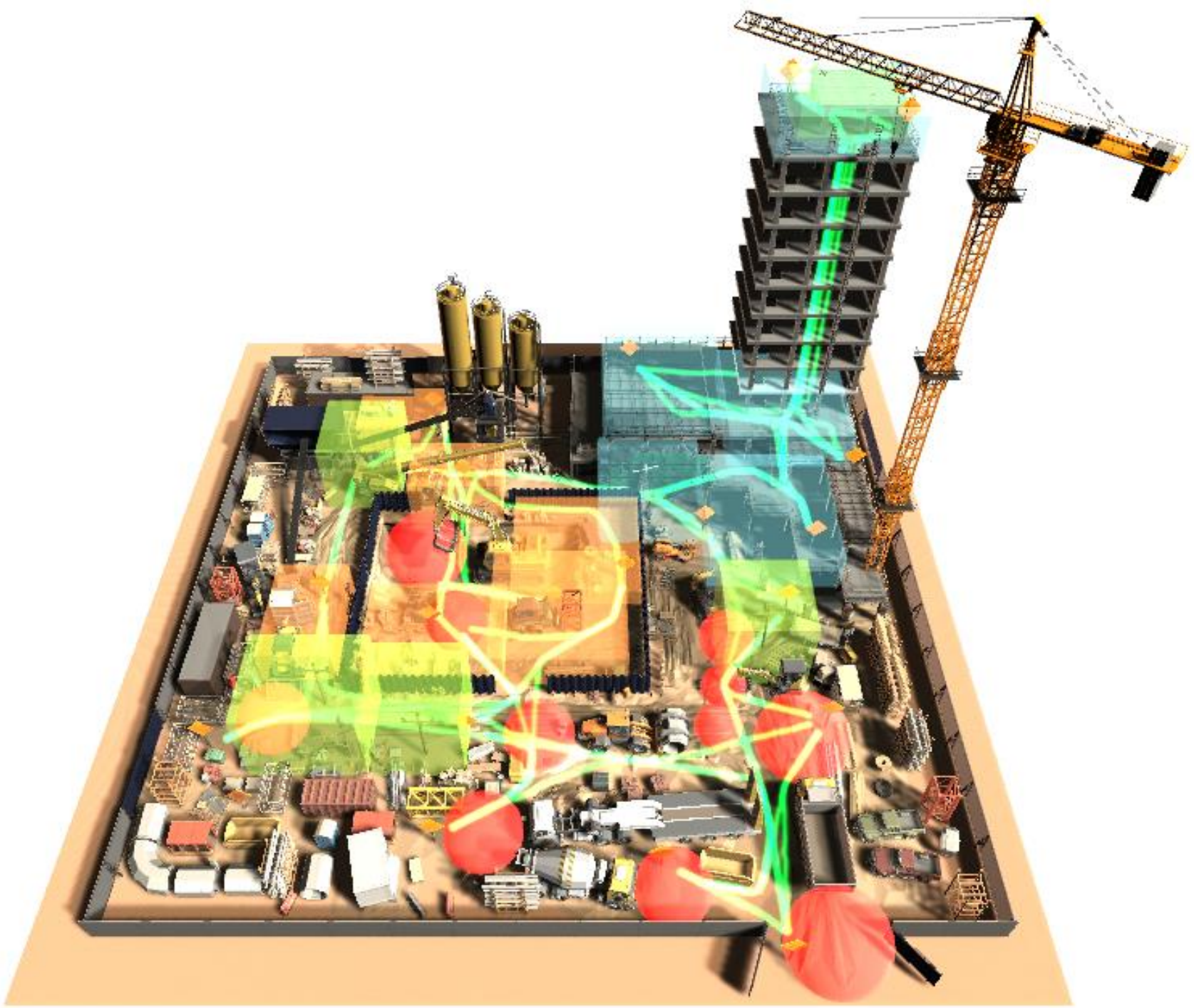


(b)Synthesizing Personalized Training Scenarios

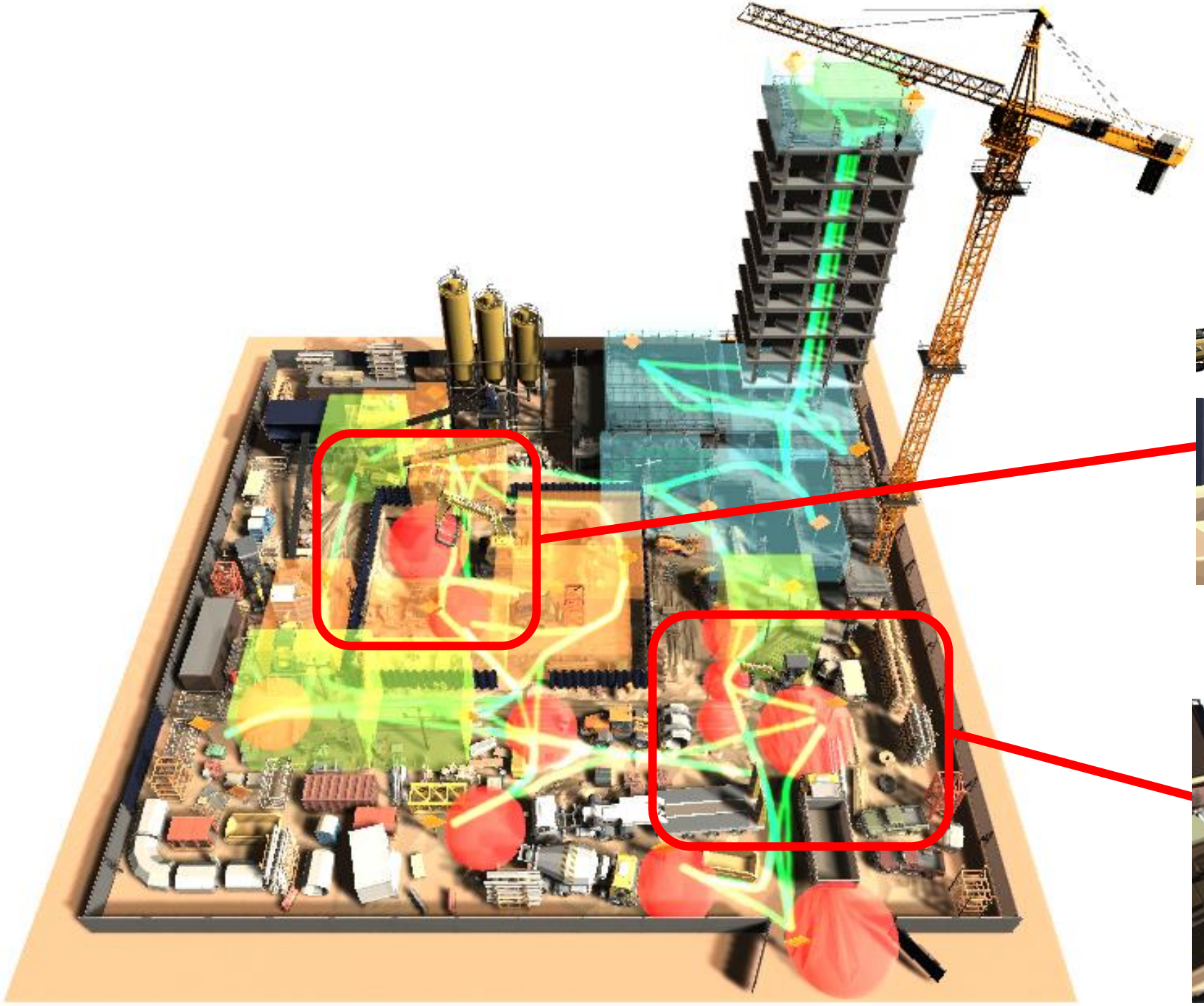
(c) Training in Virtual Reality

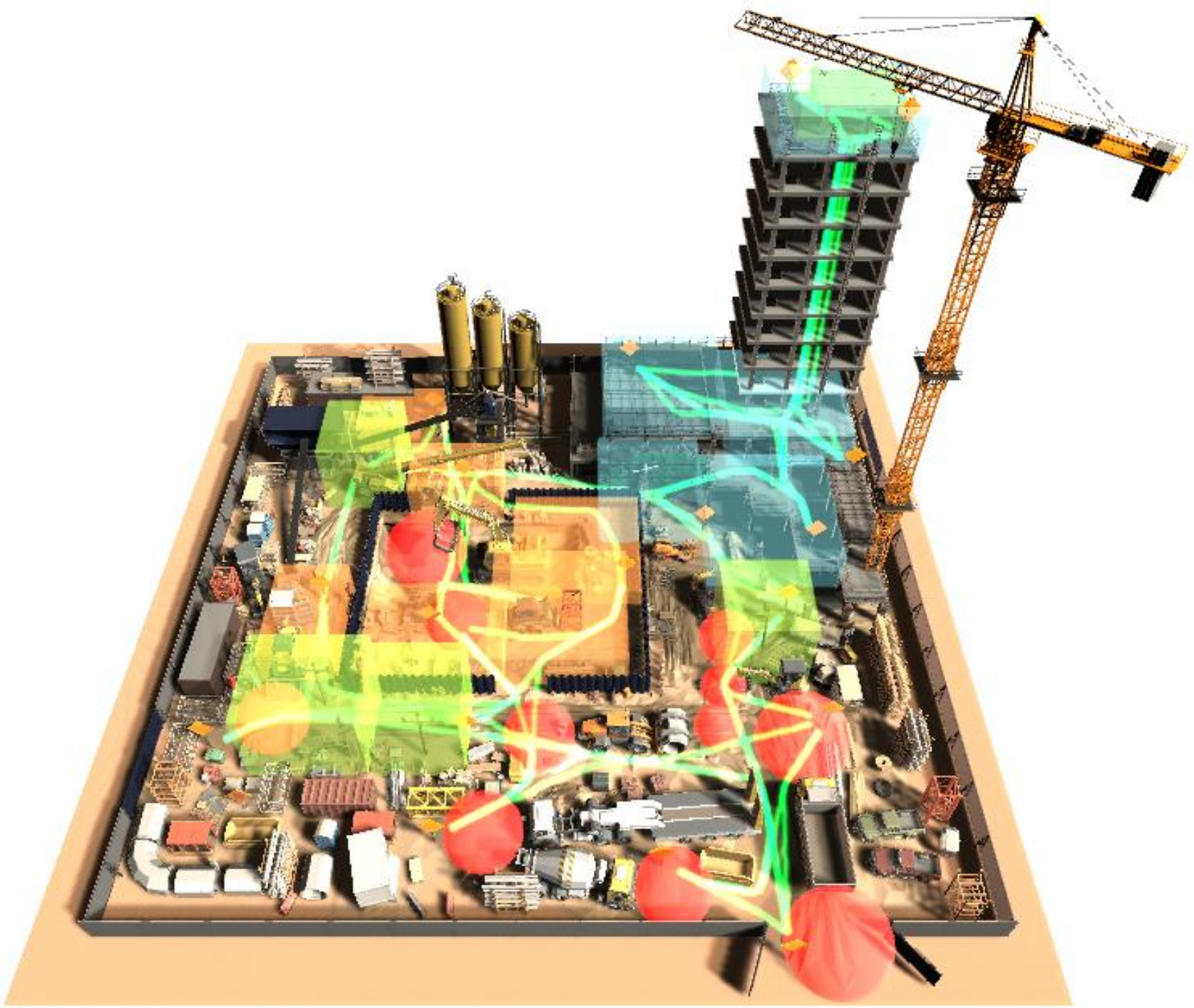
(d) Post-evaluation



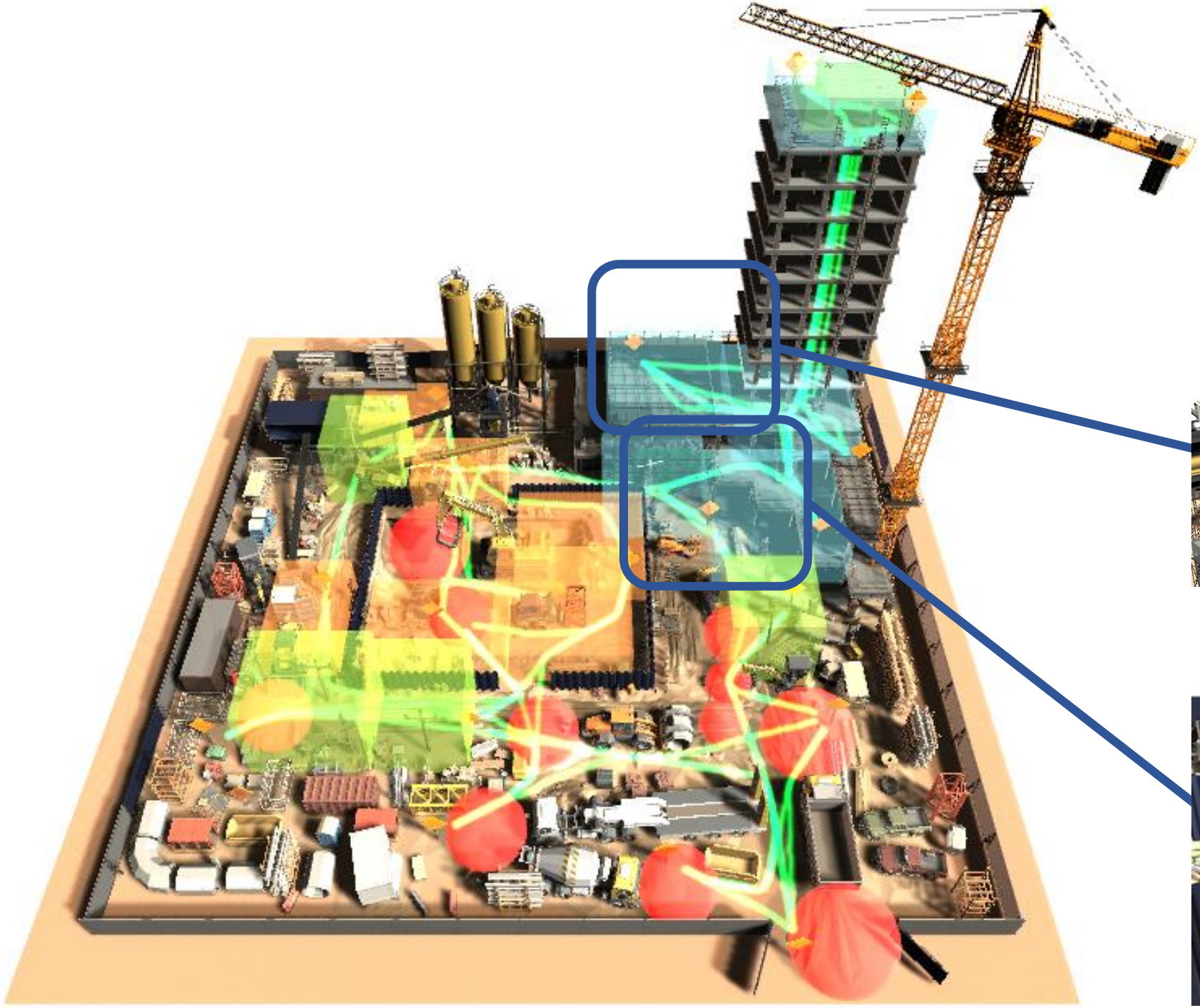


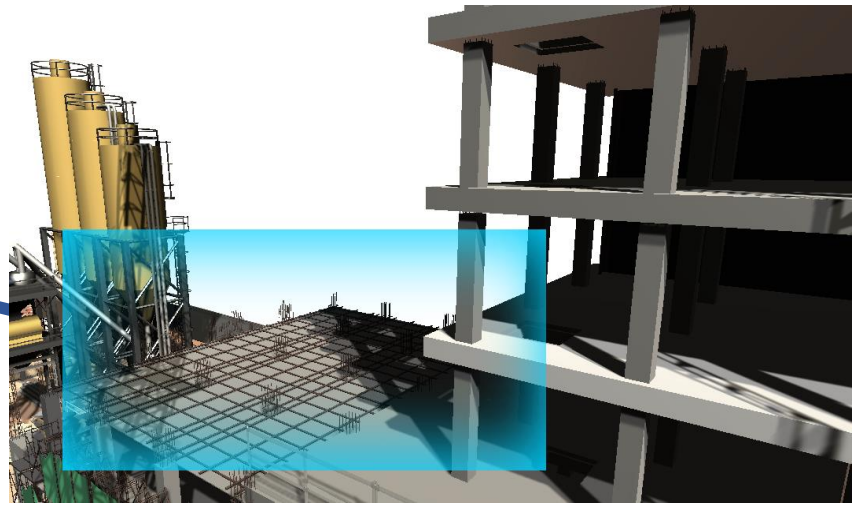
Struck-By

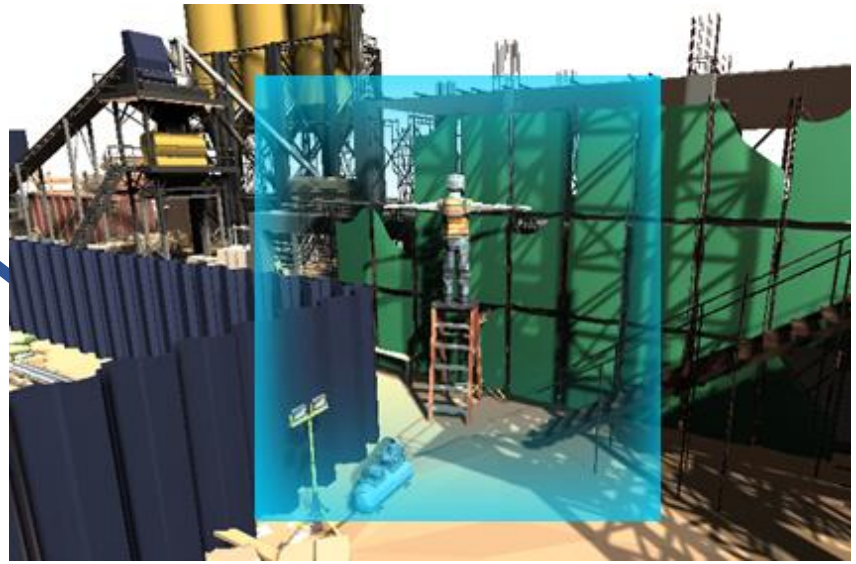


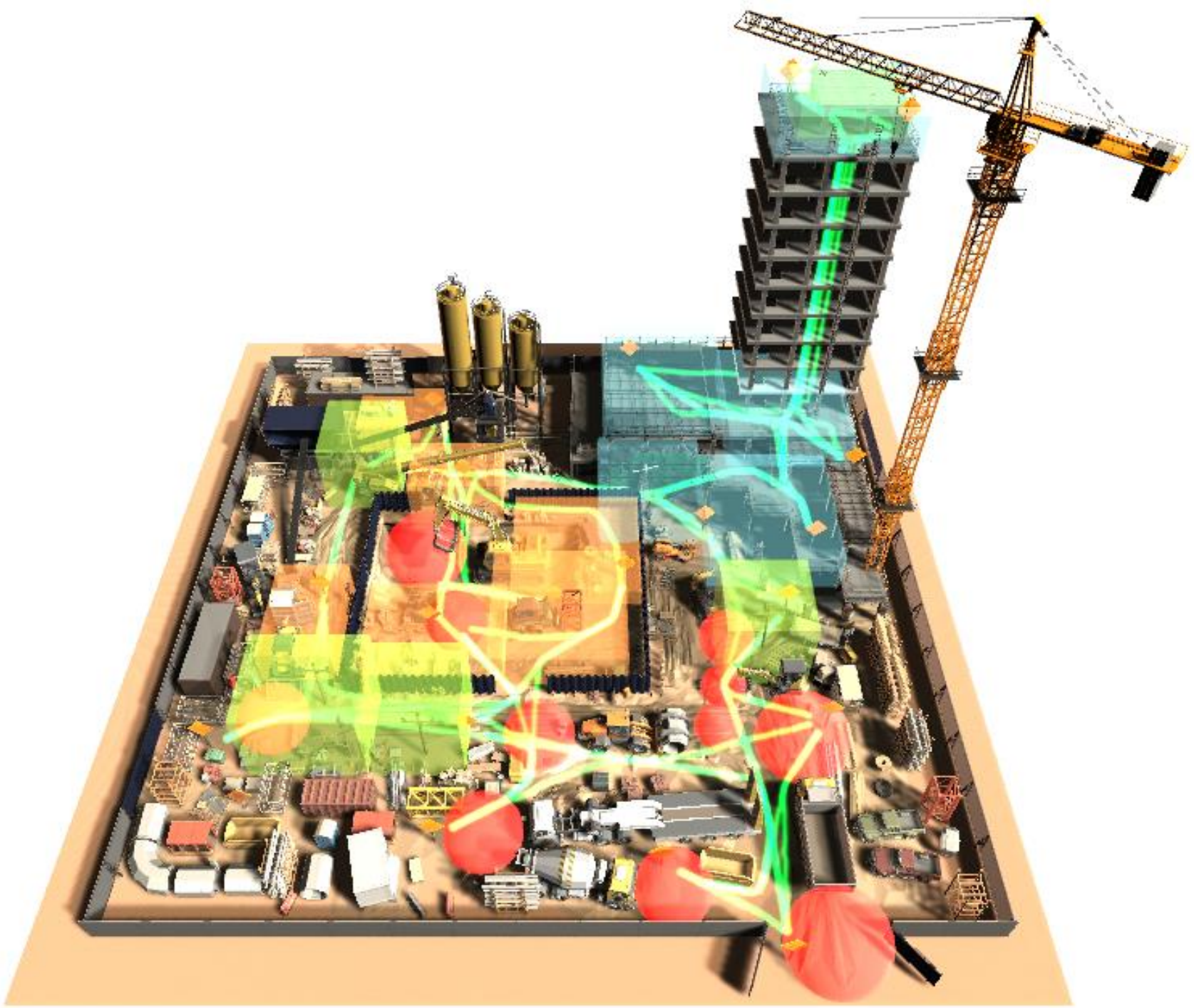


Fall Hazard

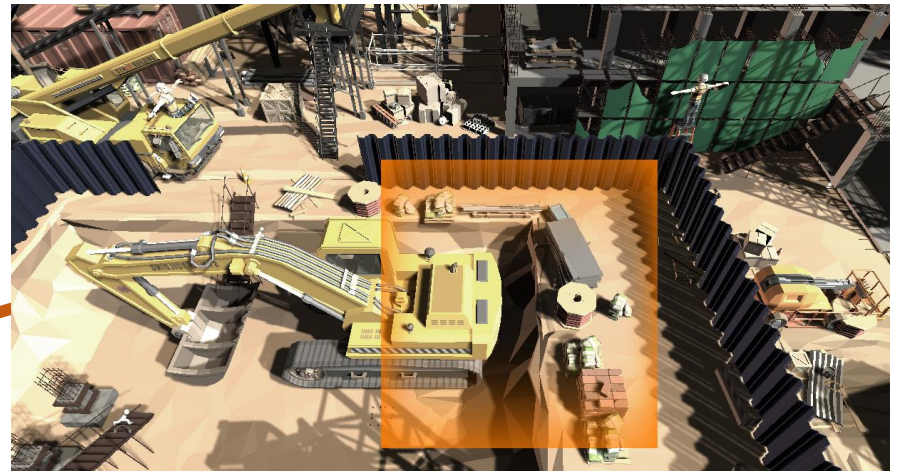


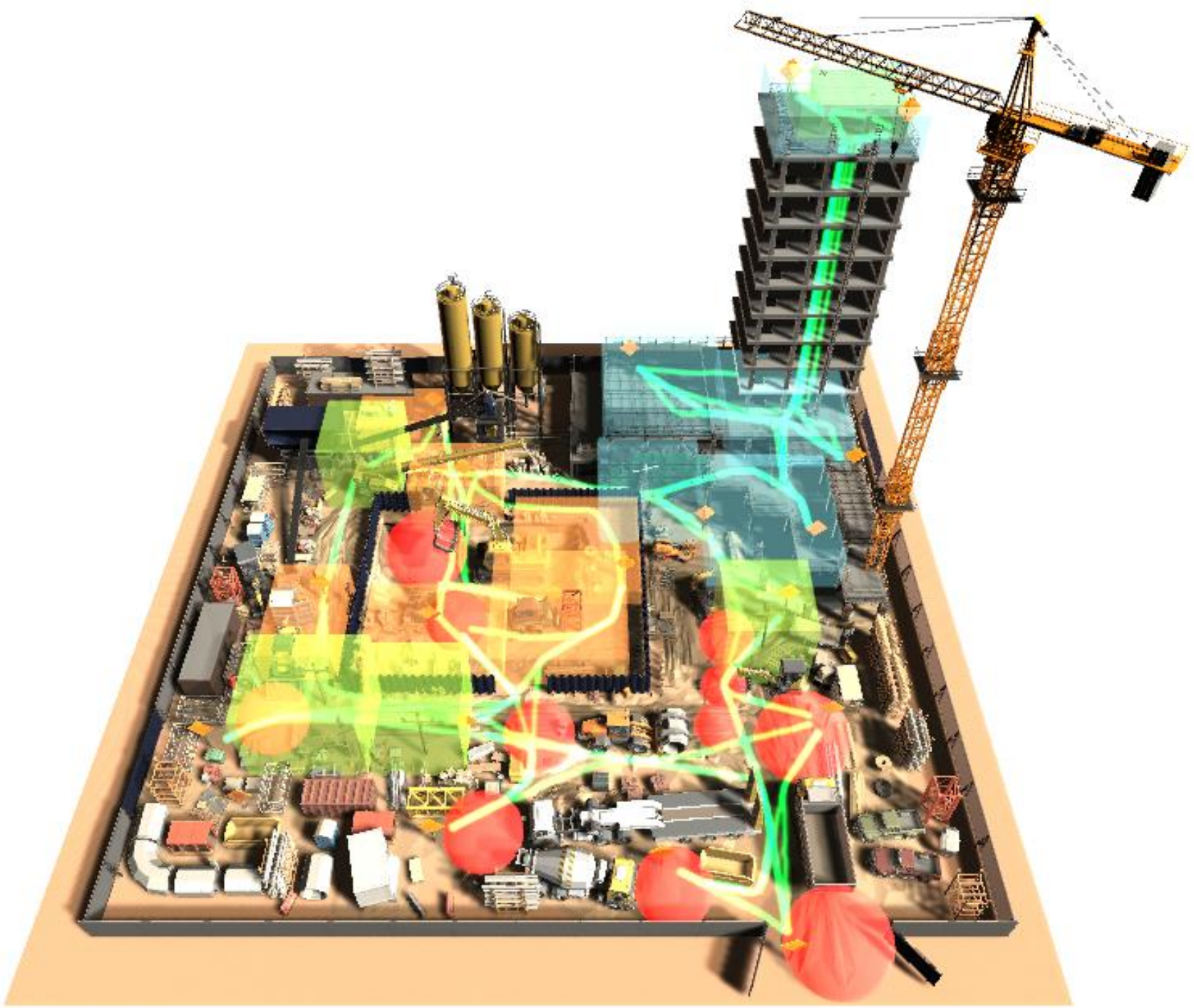




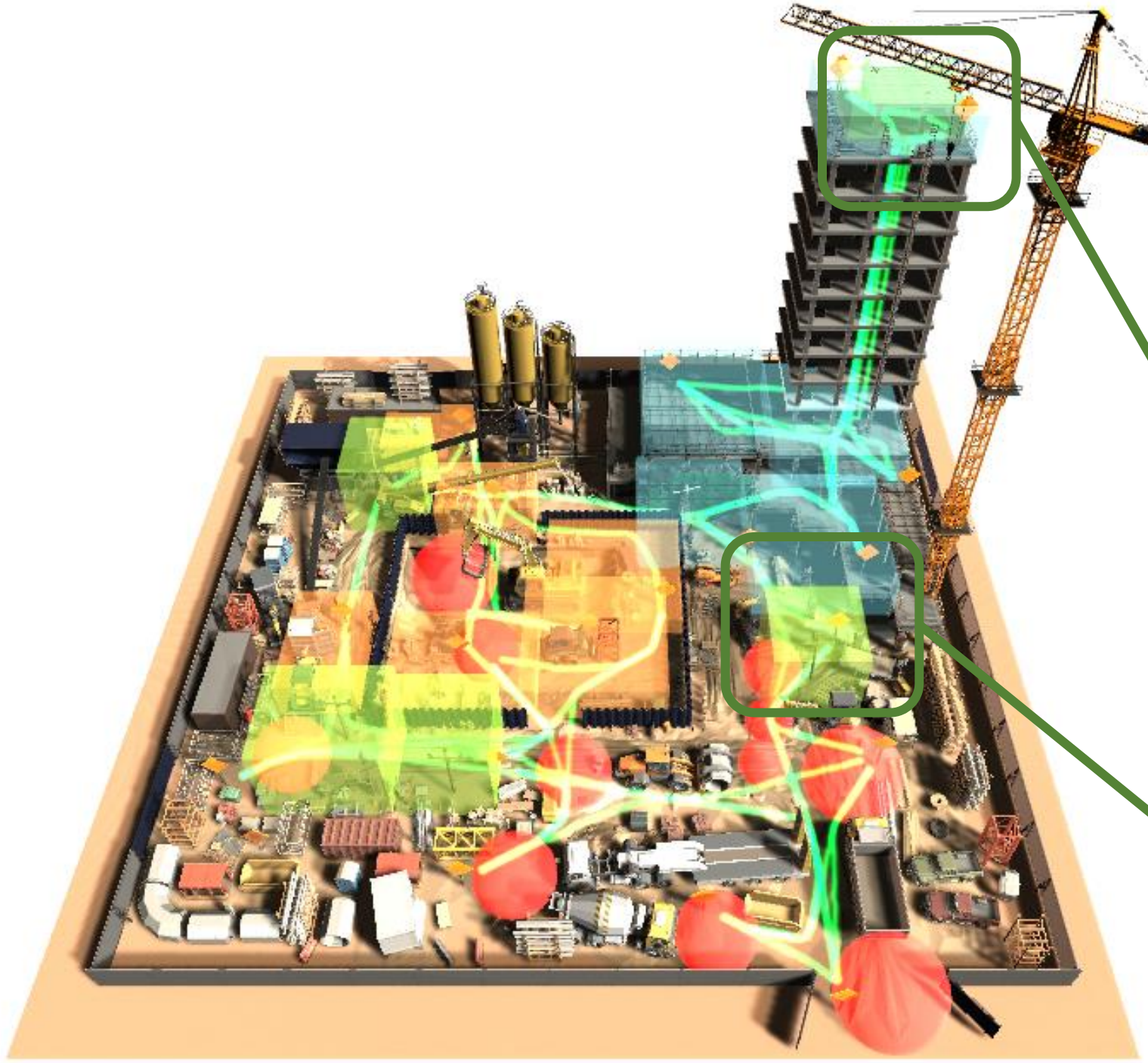


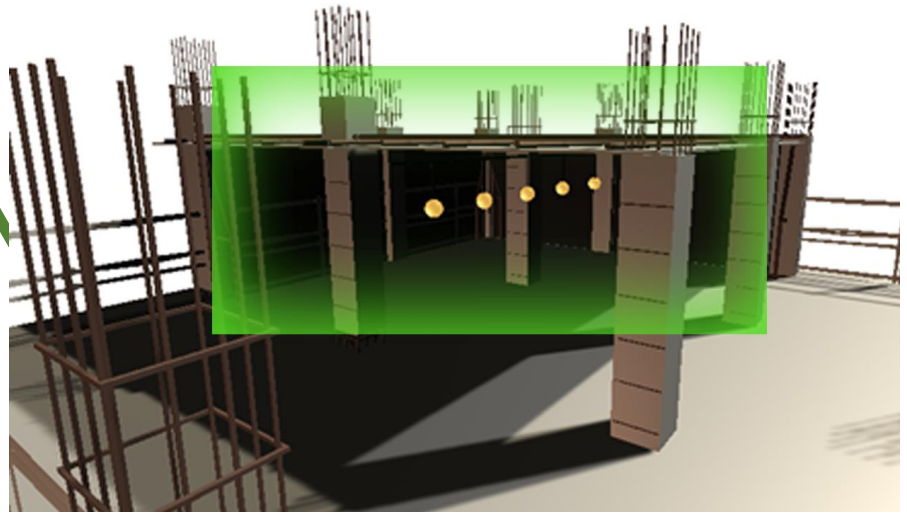
Caught-In

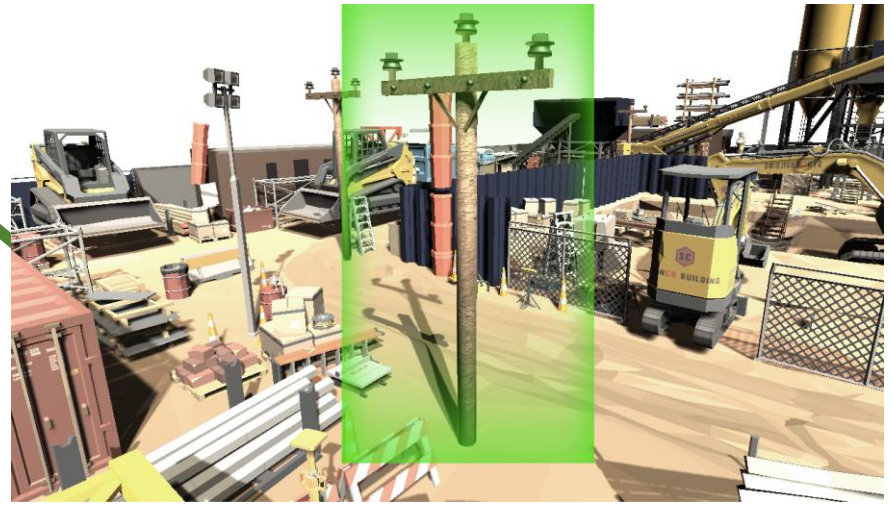




Electrocution







Minimizing Total Cost

Cost Functions

Overall Cost. $C_{\text{total}}(R,H) = w_{\text{D}}C_{\text{D}}(R,H) + w_{\text{S}}C_{\text{S}}(R,H) + w_{\text{T}}C_{\text{T}}(R,H),$

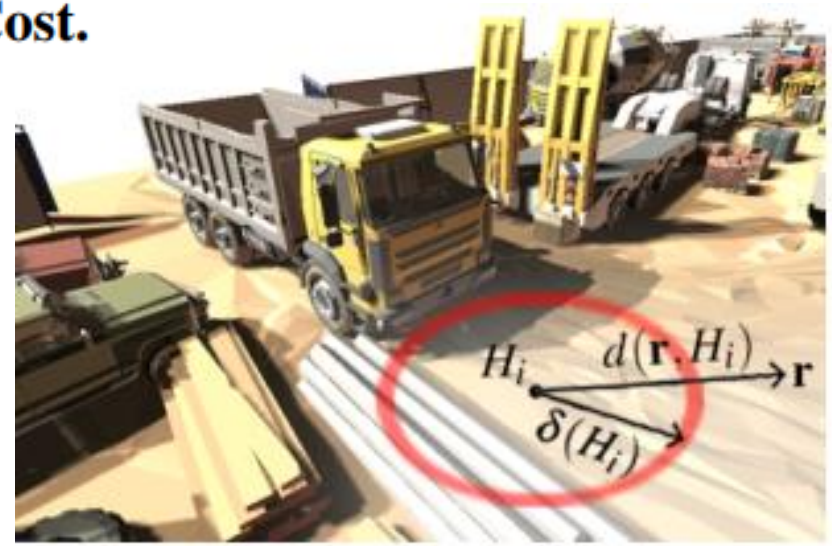
Cost Functions

Overall Cost. $C_{\text{total}}(R,H) = w_{\text{D}}C_{\text{D}}(R,H) + w_{\text{S}}C_{\text{S}}(R,H) + w_{\text{T}}C_{\text{T}}(R,H),$

Dynamic Hazard Cost.

$$C_{\text{D}}(R,H) = 1 - \exp\left(-\left(\frac{D(R,H) - \rho_{\text{D}}}{\sigma_{\text{D}}}\right)^2\right),$$

$$D(R,H) = \frac{k}{|R|}\sum_{i=1}^{|H|}\int_R \Pr(H_i | d(\mathbf{r},H_i) < \delta(H_i))\mathrm{d}\mathbf{r}$$



$$\Pr(H_i | d(\mathbf{r},H_i) < \delta(H_i)) = \frac{T_{d(B_i,H_i)<\delta(H_i)}}{T_{d(B_i,H_i)<\delta(H_i)} + T_{d(B_i,H_i)\geq\delta(H_i)}}$$

Cost Functions

Overall Cost. $C_{\text{total}}(R,H) = w_{\text{D}}C_{\text{D}}(R,H) + w_{\text{S}}C_{\text{S}}(R,H) + w_{\text{T}}C_{\text{T}}(R,H),$

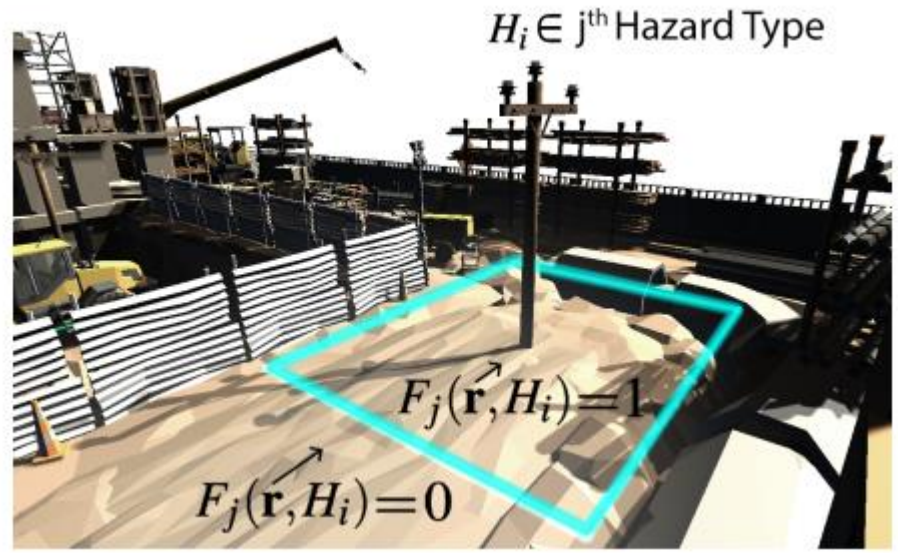
Cost Functions

Overall Cost. $C_{\text{total}}(R,H) = w_{\text{D}}C_{\text{D}}(R,H) + w_{\text{S}}C_{\text{S}}(R,H) + w_{\text{T}}C_{\text{T}}(R,H),$

$$C_{\text{S}}(R,H) = 1 - \exp\left(-\left(\frac{S(R,H)}{\sigma_{\text{S}}}\right)^2\right),$$

$$S(R,H) = \frac{1}{M}\sum_{j=1}^{M}\left(\frac{k}{|R|}\sum_{i=1}^{|H|}\int_R F_j(\mathbf{r},H_i)\,\mathrm{d}\mathbf{r} - \lambda_j\right)^2$$

Static Hazard Cost.



Cost Functions

Overall Cost. $C_{\text{total}}(R,H) = w_{\text{D}}C_{\text{D}}(R,H) + w_{\text{S}}C_{\text{S}}(R,H) + w_{\text{T}}C_{\text{T}}(R,H),$

Cost Functions

Overall Cost. $C_{\text{total}}(R,H) = w_{\text{D}} C_{\text{D}}(R,H) + w_{\text{S}} C_{\text{S}}(R,H) + w_{\text{T}} C_{\text{T}}(R,H),$

Training Time Cost.

$$C_{\text{T}}(R,H) = 1 - \exp\left(-\left(\frac{T(R,H) - \rho_{\text{T}}}{\sigma_{\text{T}}}\right)^2\right),$$

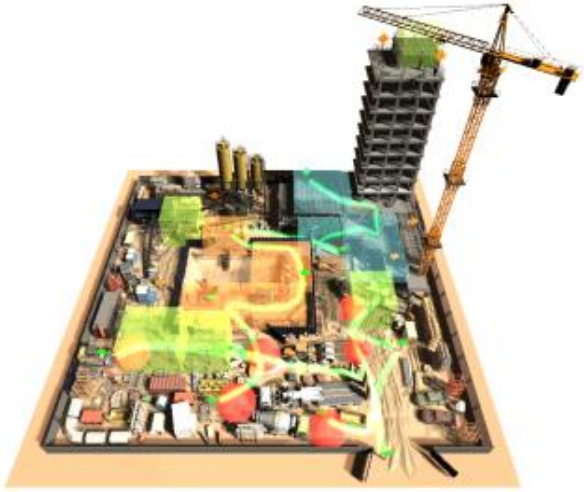
$$T(R,H) = k_1 \frac{1}{v} \int_R \mathrm{d}\mathbf{r} + k_2 \sum_{i=1}^{|H|} T(H_i)$$

Optimization

(a) The 1st iteration.

(b) The 100th iteration.

(c) The 200th iteration.



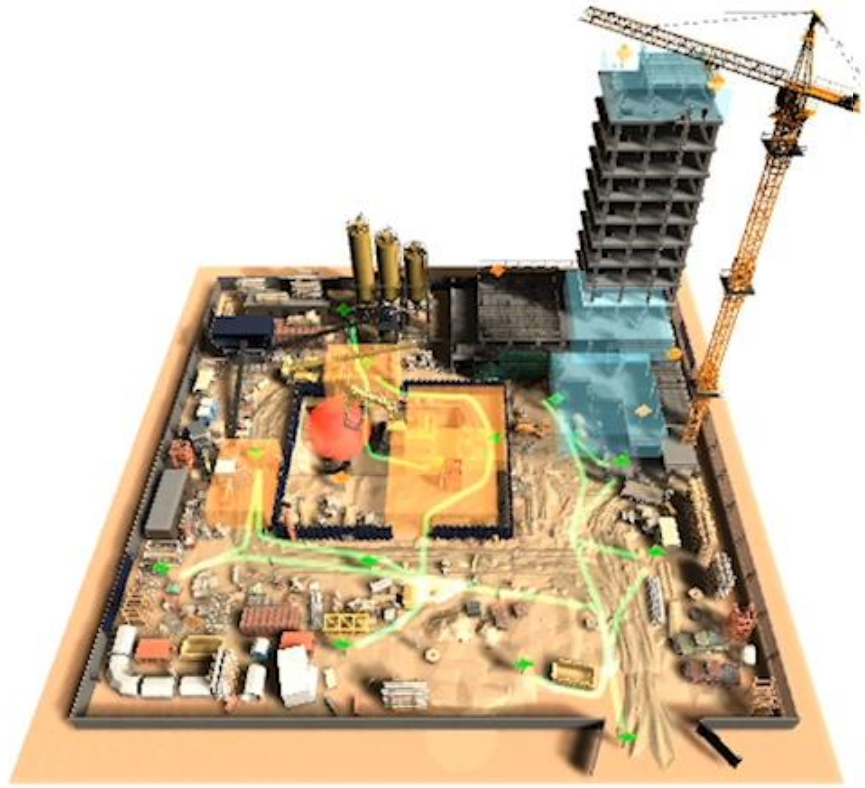
(d) The 500th iteration (Result).

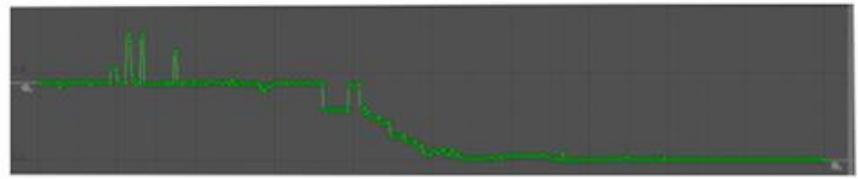
Add a Vertex
Remove a Vertex
Modify a Vertex

Add a Hazard
Remove a Hazard
Modify a Hazard

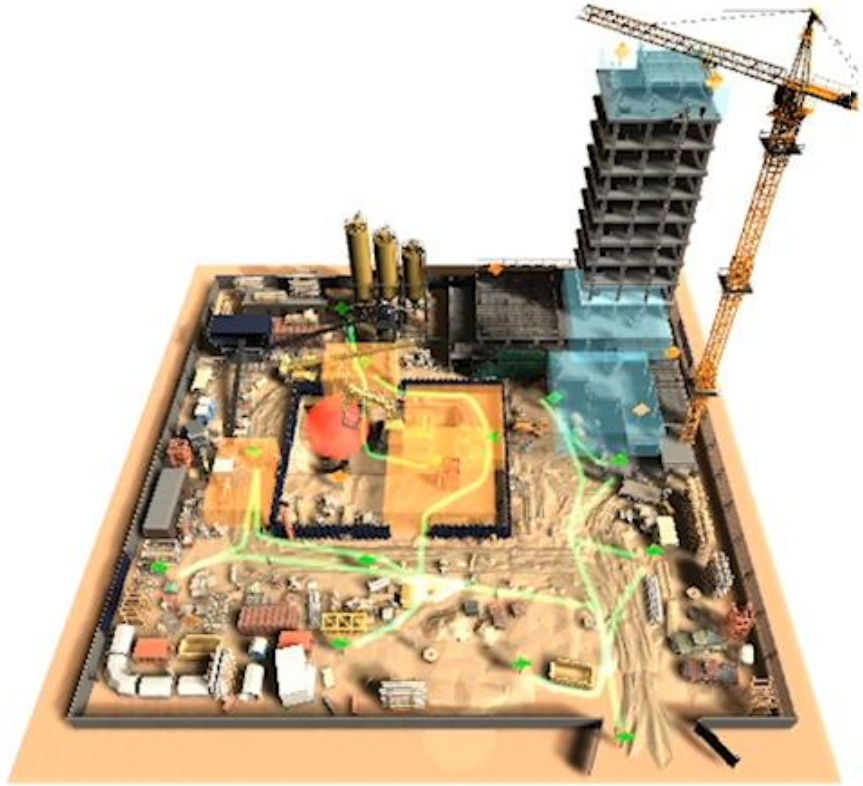
$$\Pr(R', H' | R, H) = \min(1, \frac{f(R', H')}{f(R, H)}),$$

$$f(R, H) = \exp(-\frac{1}{t} C_{\text{total}}(R, H))$$



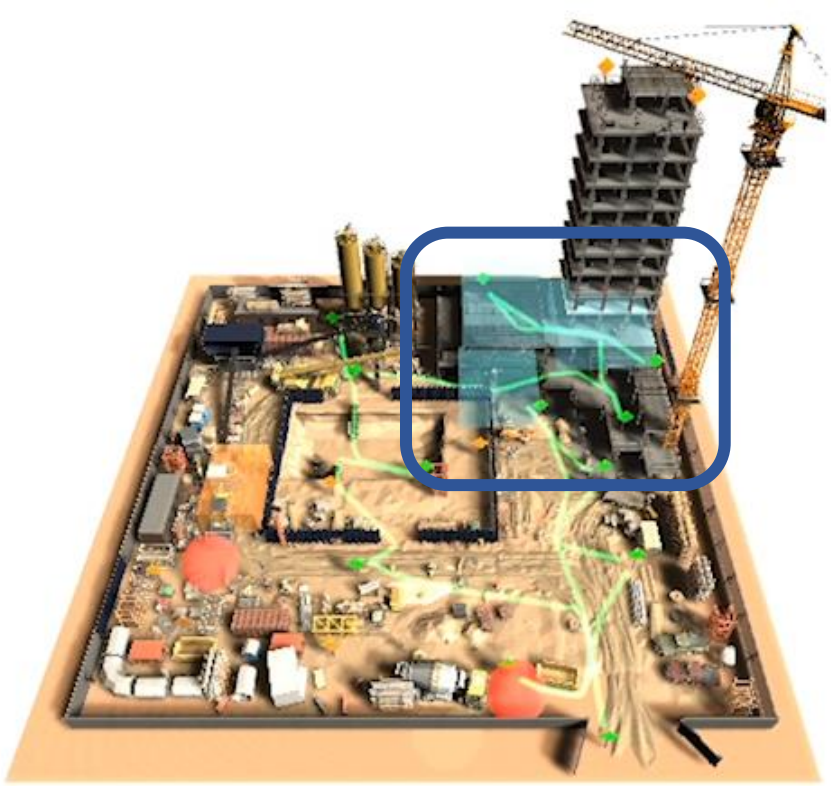


Fall Hazard

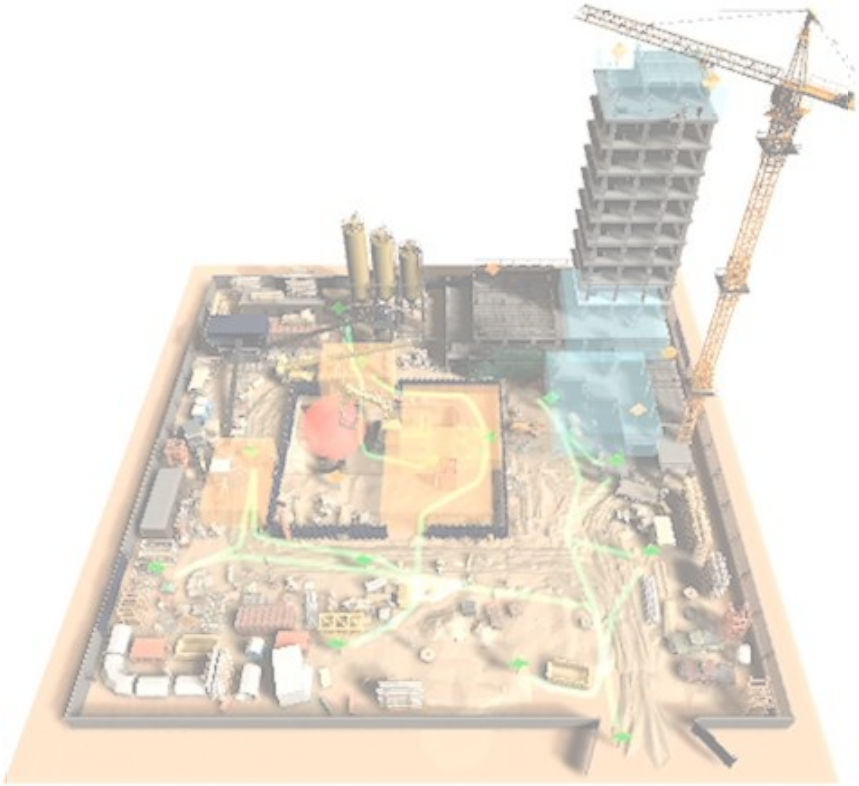


Caught-In

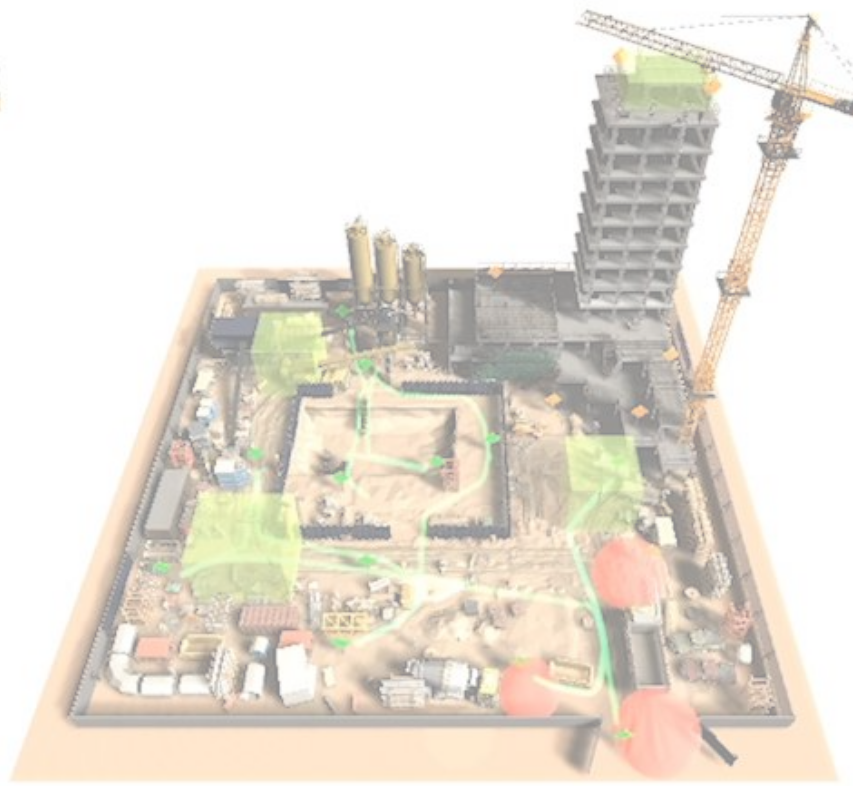
Electrocution



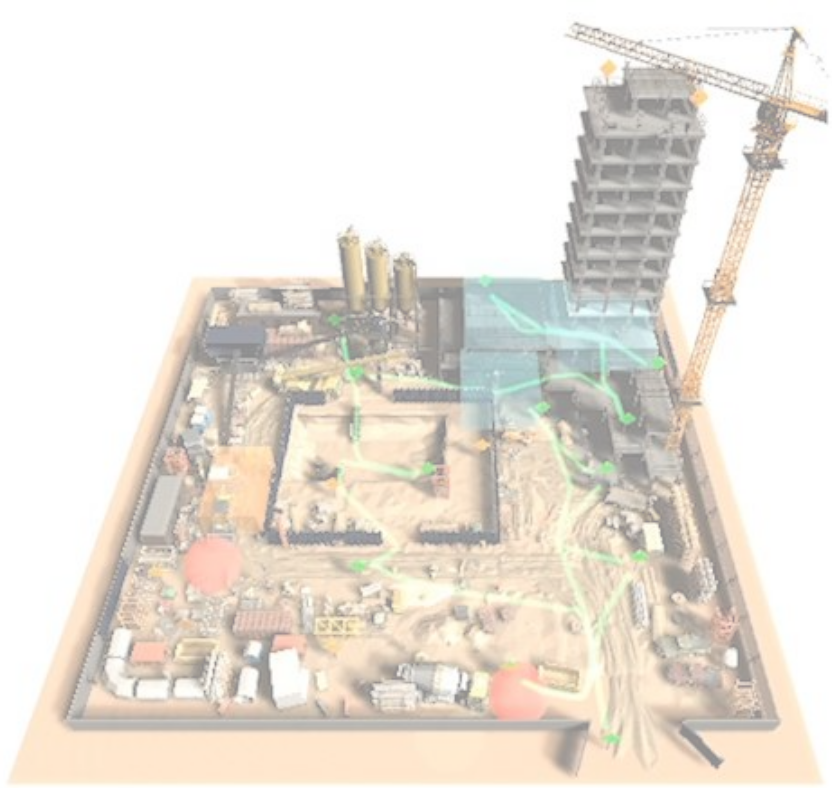
Fall Hazard



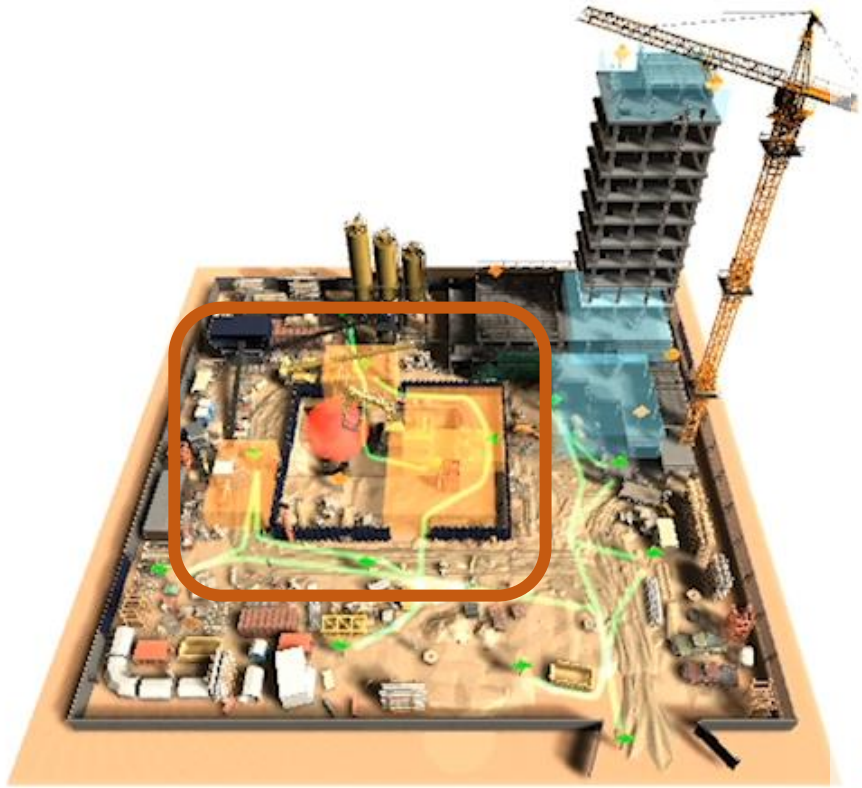
Caught-In



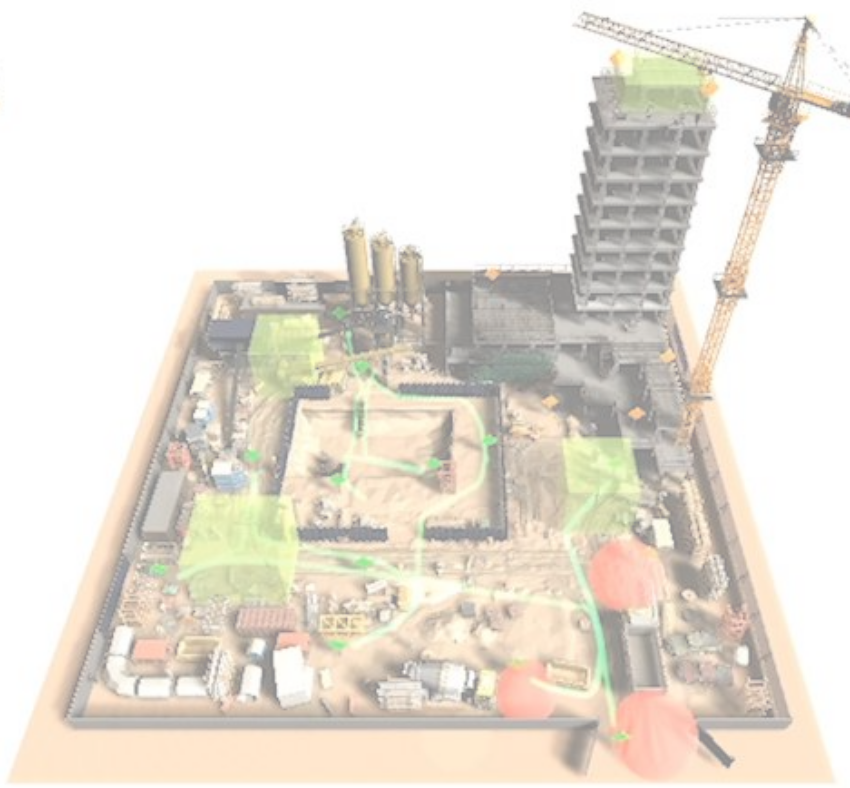
Electrocution



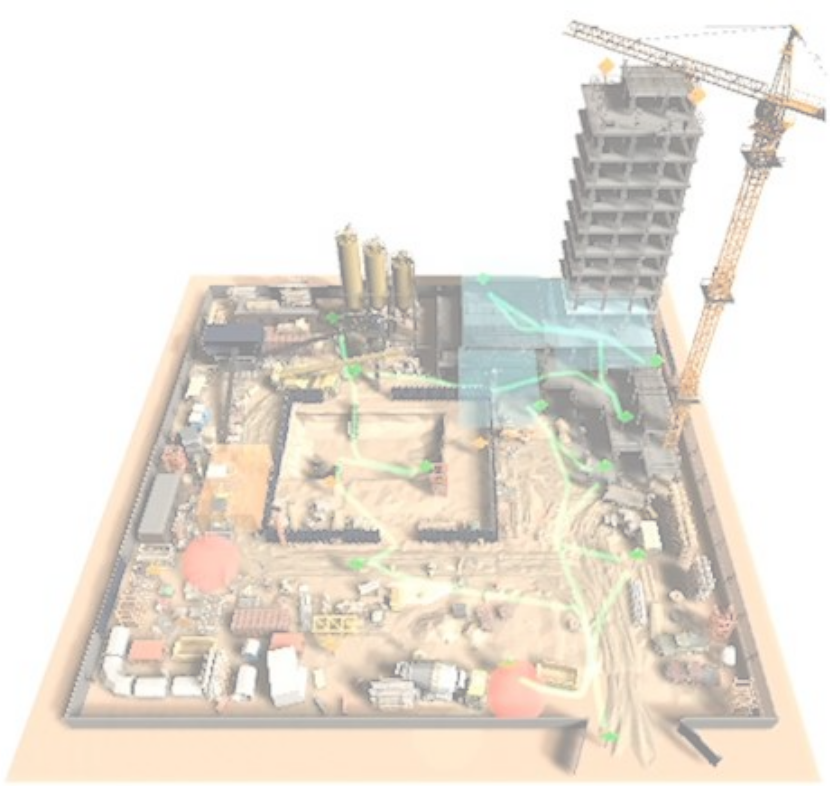
Fall Hazard



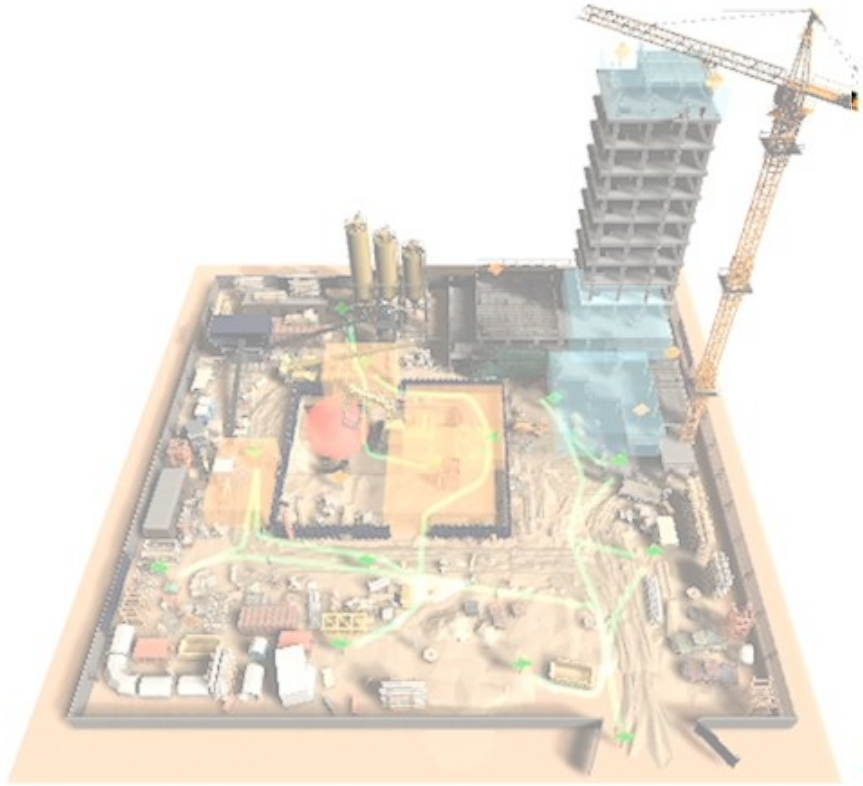
Caught-In



Electrocution



Fall Hazard

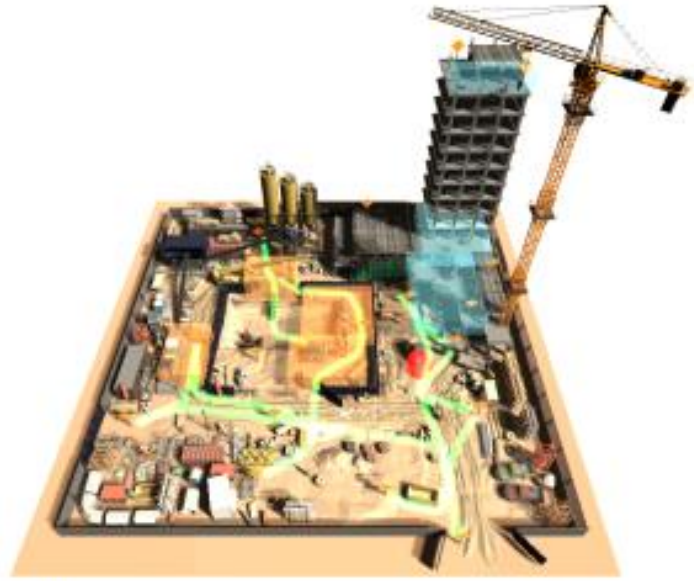


Caught-In

Electrocution

(a) Synthesized route with fewer hazards.

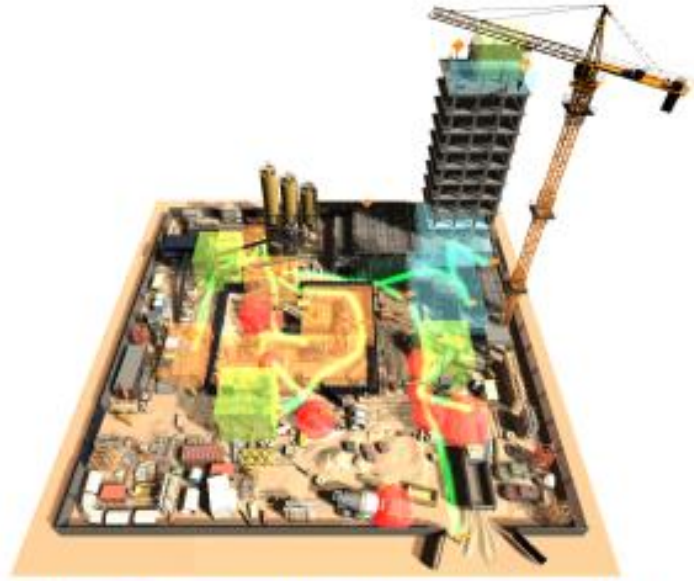
(b) Synthesized route with more fall hazards.



(c)Synthesized route with more caught-in/between hazards.

(d) Synthesized route with more electrical hazards.

(e) Synthesized route with more struck-by hazards.



(f) Synthesized route with all types of hazards.

User Study

Slides Group

FE-VR Group

PG-VR Group

Slides Group

FE-VR Group

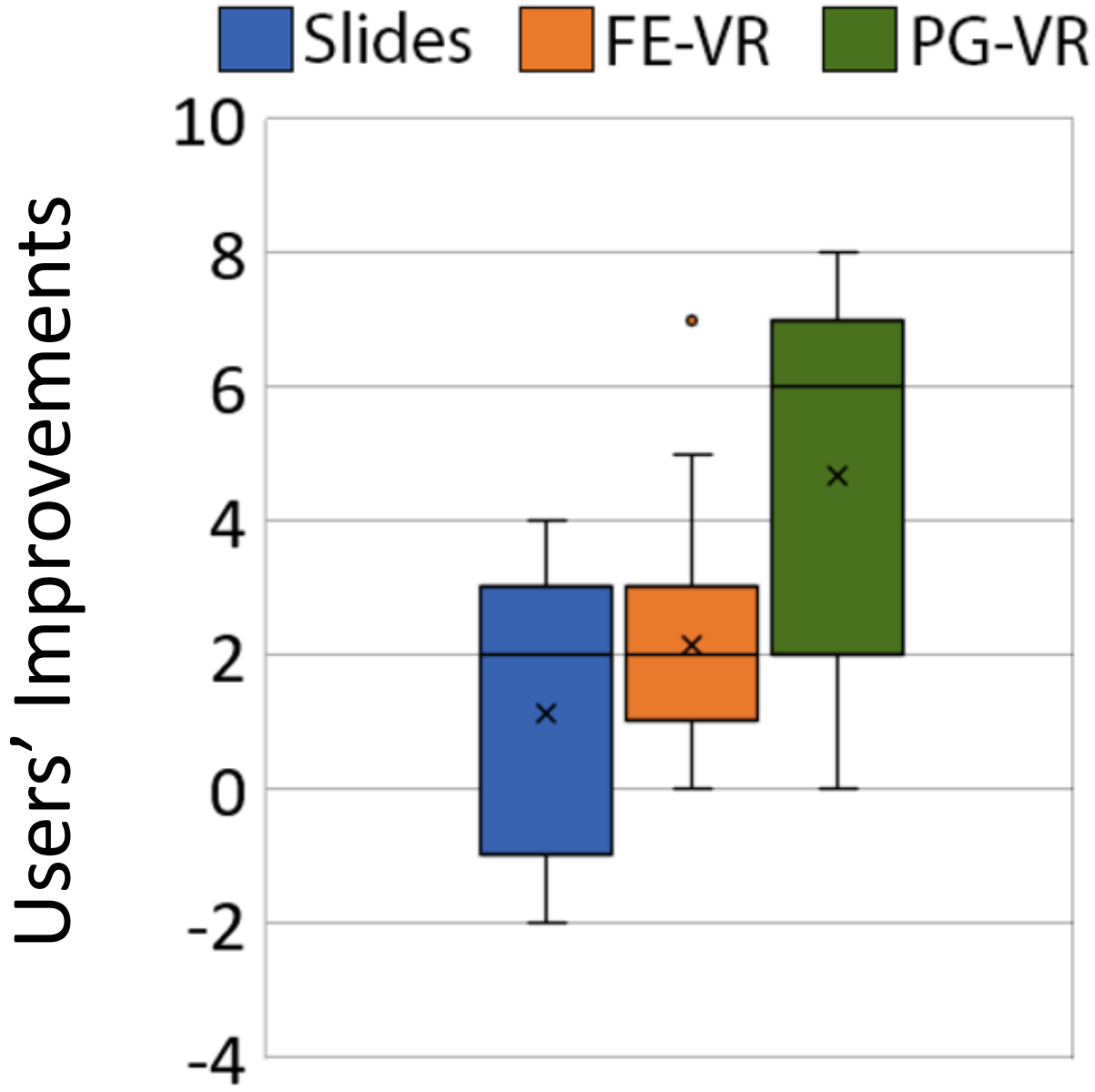
PG-VR Group

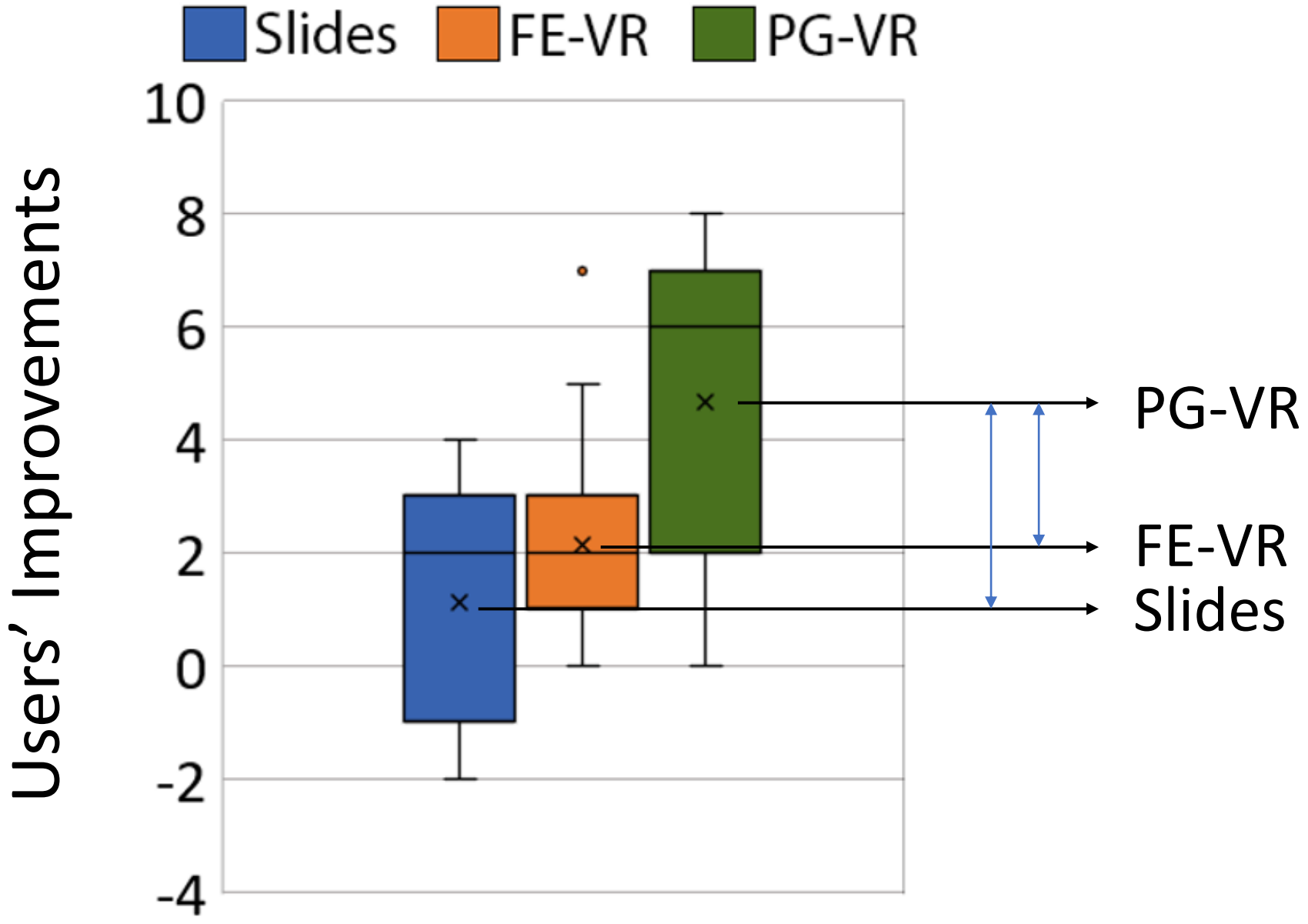
Slides Group

FE-VR Group

PG-VR Group

Result


Slides
FE-VR
PG-VR
Users' Improvements
10
8
6
4
2
0
-2
-4


Slides
FE-VR
PG-VR
Users' Improvements
10
8
6
4
2
0
-2
-4
PG-VR
FE-VR
Slides

Thank you for watching.