Towards Scenario-Based Simulations of Coupled Distributed System Response on a City-Scale

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Do we have the necessary tools to predict performance loss?

How much damage caused to components of the system?
Causes of pipeline damage
(inspired by Craig Davis)

Permanent ground deformations (PGD):
1. Fault movement (NOT dynamic)
2. Liquefaction and lateral spreading
3. Landslides

Transient deformation:
4. Urban scale wave propagation

Source: C. Davis, LADWP
Stochastic Sediment Velocity Model (SVM)

Approximately 1000 profiles: in-situ and non-destructive measurements of Vs

Shi and Asimaki (2018), SRL
Multi-axial cyclic plasticity model (Borja & Amies, 1994)

Wang & Sitar (2006)

Smooth evolution of nonlinear response

\( G/G_{\text{max}} \) only input for calibration
2. Ingredients of regional liquefaction risk

- Density (Vs30)
- Saturation (CTI)
- Shaking (PGA)

Liquefaction Vulnerability

Zhu et al (2015), Earthquake Spectra
Reducing uncertainty by modeling water cycle

also by Zhu et al (2017), BSSA
Reducing uncertainty by modeling water cycle

replace CTI...

Soil moisture - remote sensing

Precipitation

Leaf coverage

Global soil database

USGS Groundwater
Case study: Imperial Valley – M7.2 2010 El-Mayor Cucapah

Soil moisture (SMAP NASA database)

Mital et al (20XX), to be submitted

P-value: 0.20

Compound topographic index

P-value: 0.78
3. Emerging trends in landslide simulations

Hybrid large deformation simulations (MPM)

Distinct element method

Compute failure, velocity and runout

Creep-to-catastrophic failure
Earthquakes: Preparatory, triggering or both?

Repeated strain near-surface

Self-reinforcing phenomenon

Can we assess deformation probability and recurrence period?
4. Dynamic 3D pipeline-soil interaction (vs. quasi-static state-of-the-art)

- No contact elements
- No dynamic interaction
- No radiation damping
- No hysteresis

... very few experiments...

ASCE (1984), ALA (2005)
Physics via high fidelity computer simulations
Smooth Particle Hydrodynamics Demo
3D Dynamic macroelement for soil-pipeline interaction in transient deformation

Nguyen & Asimaki (20XX), ASCE JGGE
Conclusions...

- Summarized gaps in state-of-the-art performance assessment
- Essential elements in resiliency quantification of systems
- High-fidelity computing & experiments → simple models for practice

- There is still work to do on the component level
- System physics cannot be derived from up-scaling component physics