HaptiMOL:
Interacting with large biomolecules using haptic feedback

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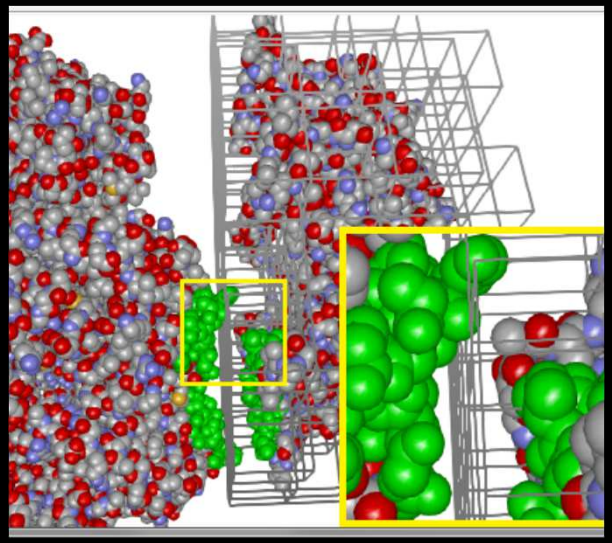

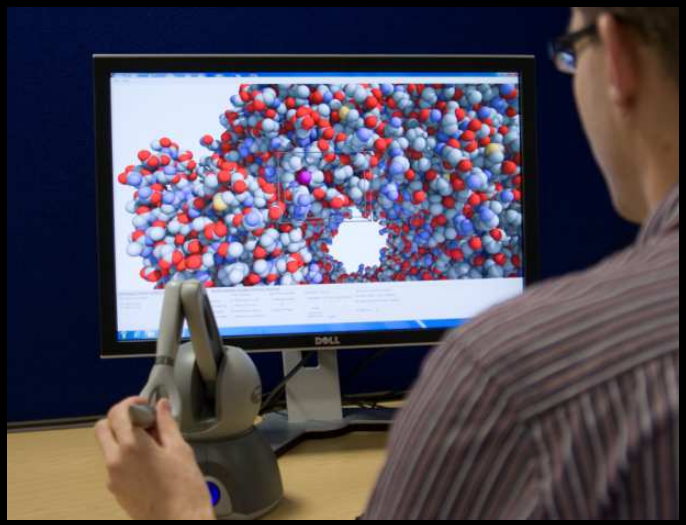

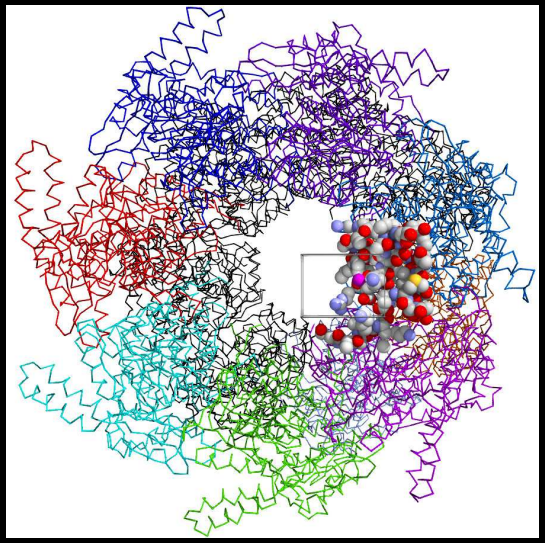

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What are the benefits of using a haptic device to interact with proteins?

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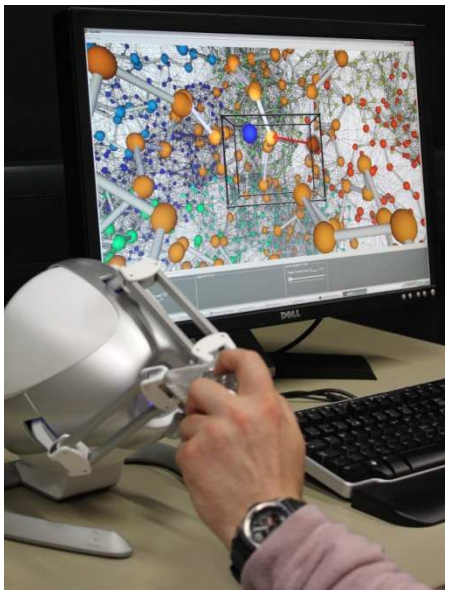
- Interact with three dimensional objects in 3D.
- Feel objects as the haptic probe interacts with virtual models.
- Apply forces to objects by pushing or pulling them.
- Obtain more insight into the three dimensional form of protein structure.
- Feel interaction forces during molecular docking



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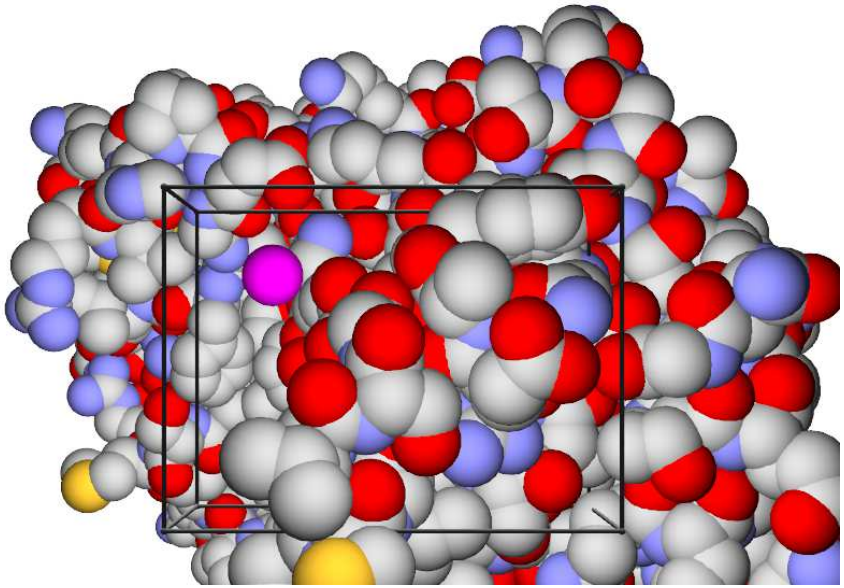
iSAS: Interactive Solvent Accessible Surface

To appreciate the 3D shape one can roll a sphere over the surface of complex structures.

The molecules are represented in space-filling mode and are rigid.



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iSAS: Interactive Solvent Accessible Surface

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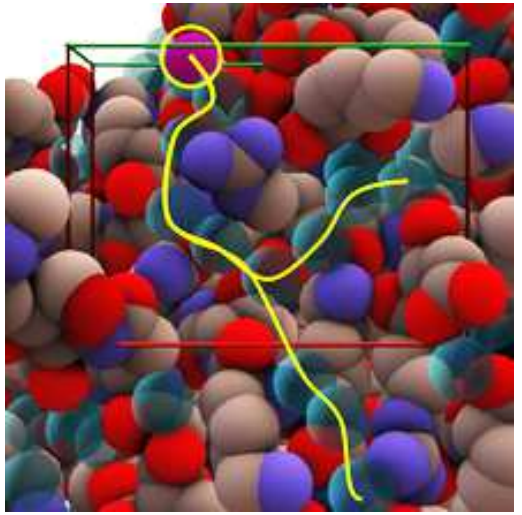
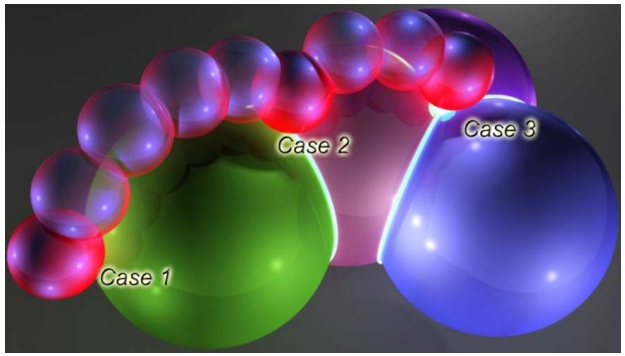
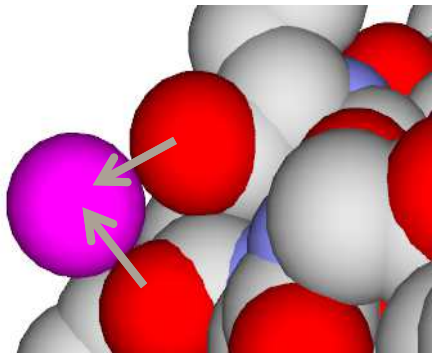
By guiding a sphere approximating a water molecule one can determine the solvent accessible surface.

The yellow lines indicate a set of crystallographic water molecules (ghost water) that you can see but not feel.



We developed a new haptic rendering algorithm for hard-sphere contacts.





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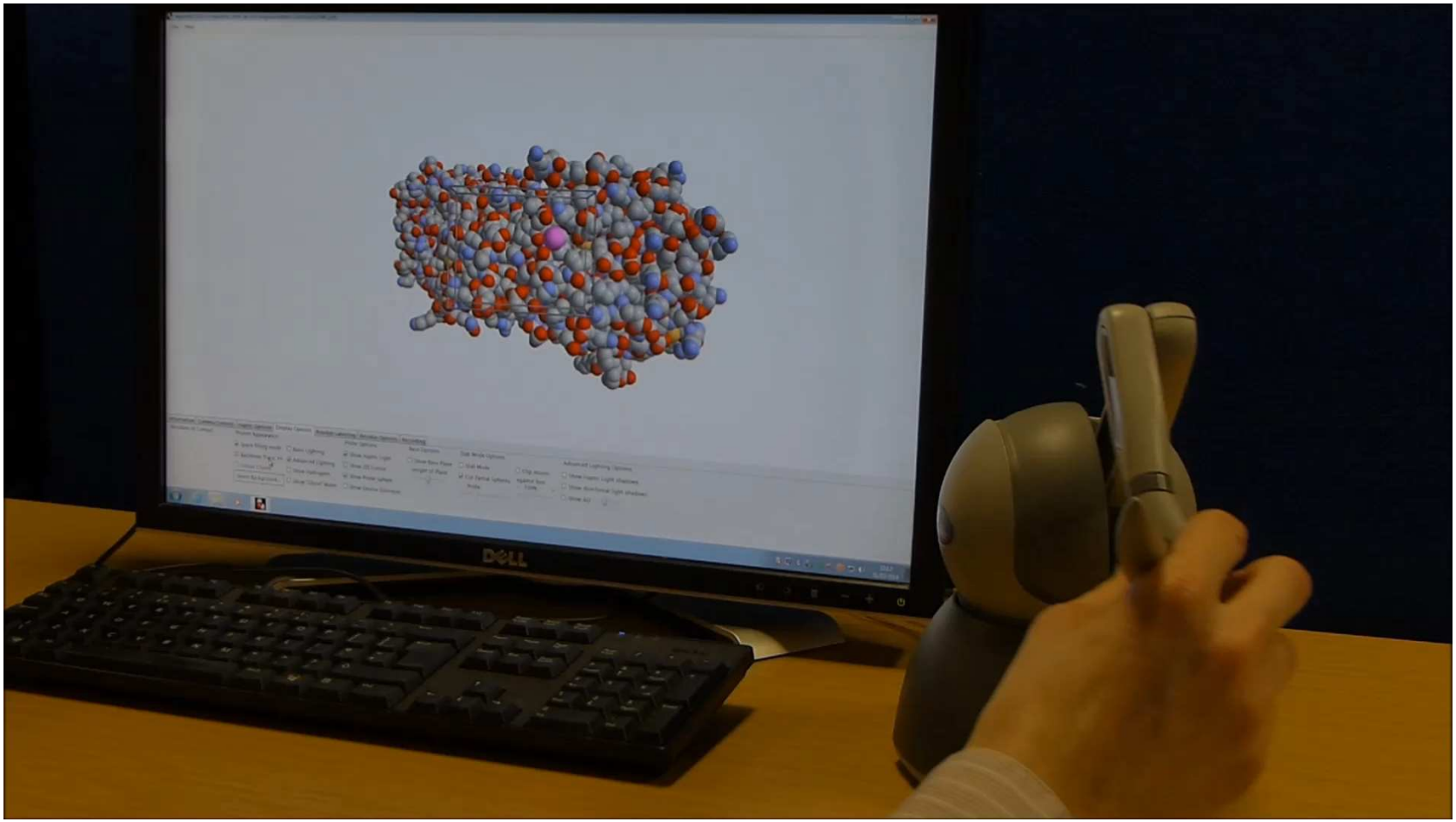
HaptiMOL iSAS



http://www.haptimol.co.uk/movies/isas_v3.wmv

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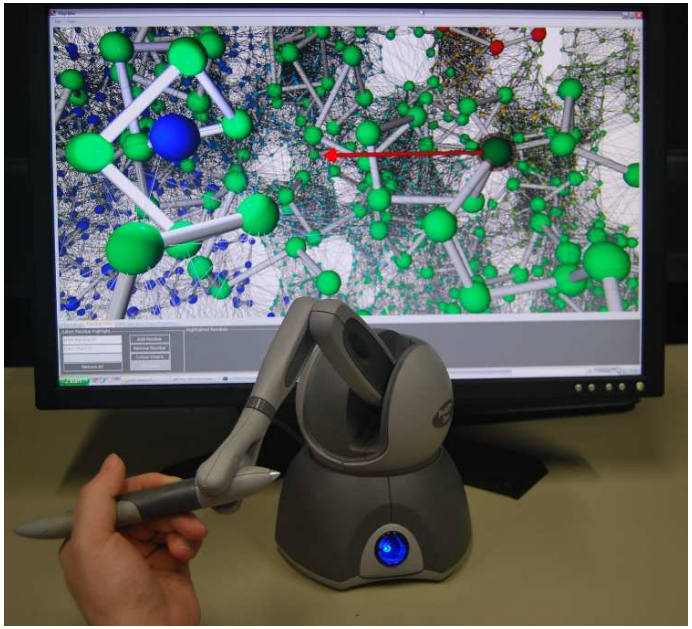
Elastic Network Models

- HaptiMOL ENM enables users to apply forces to atoms in an elastic network model and to observe the resulting deformation.

- The user can apply forces to individual C_α atoms on the backbone by selecting them with the haptic device.



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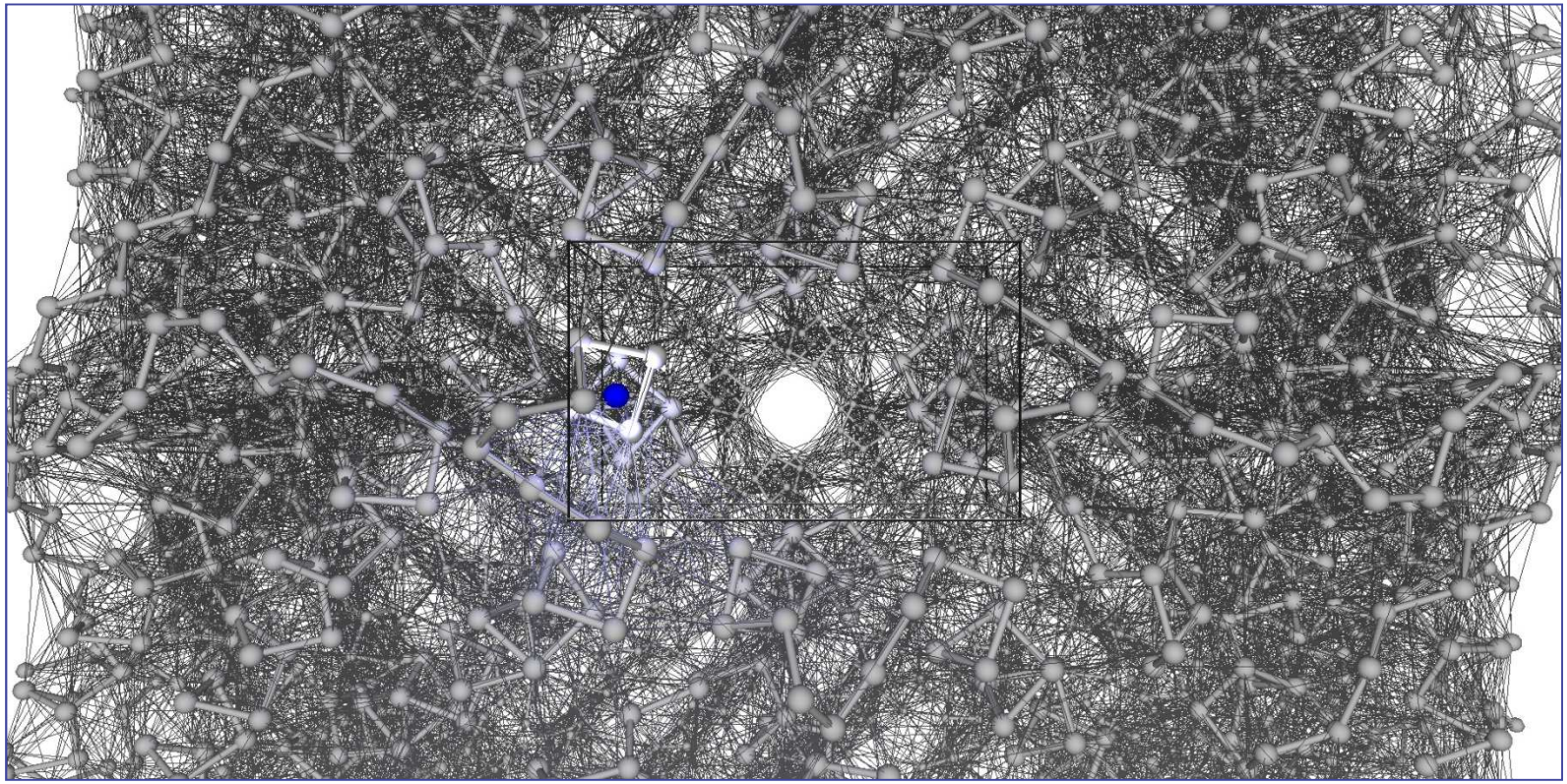
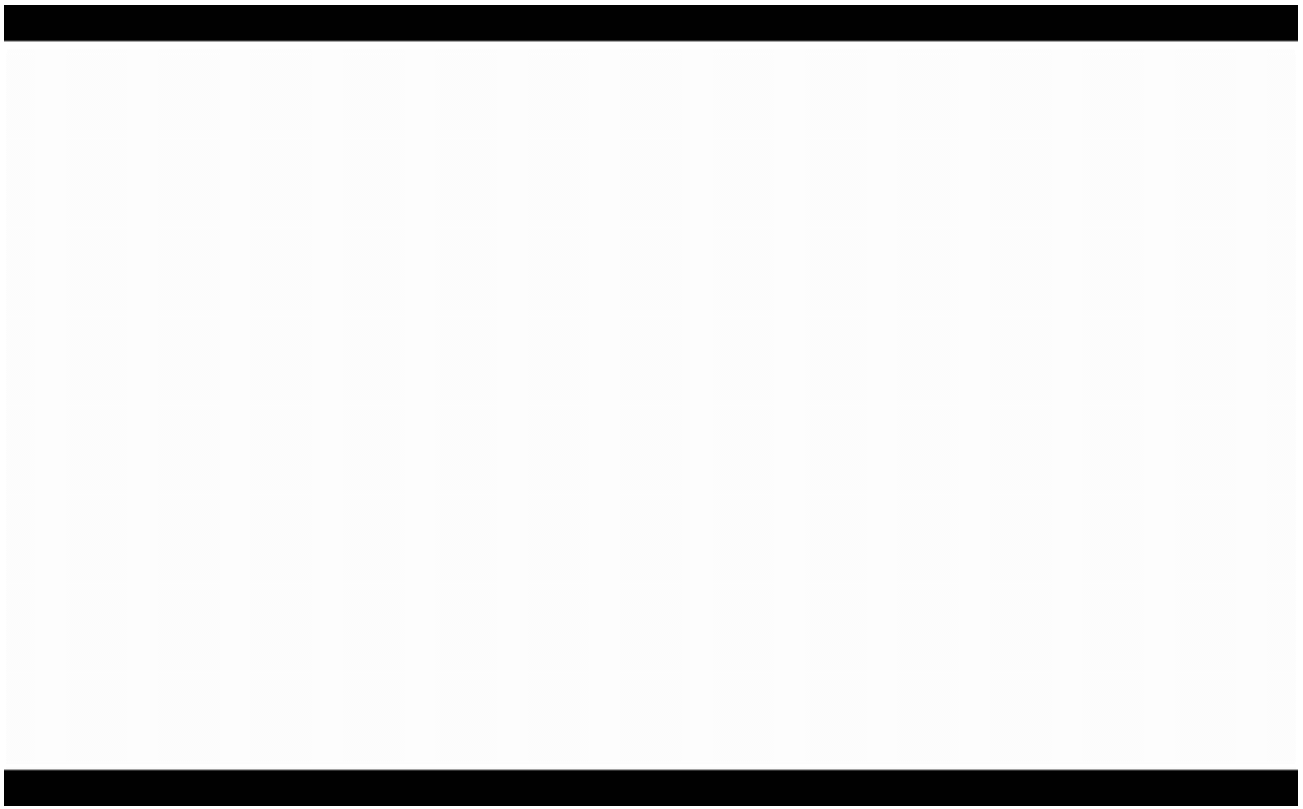
Elastic Network Models

- HaptiMOL ENM enables users to visualise the connections forming the elastic network.



HaptiMOL ENM



http://www.haptimol.co.uk/movies/enmv1_movie.wmv

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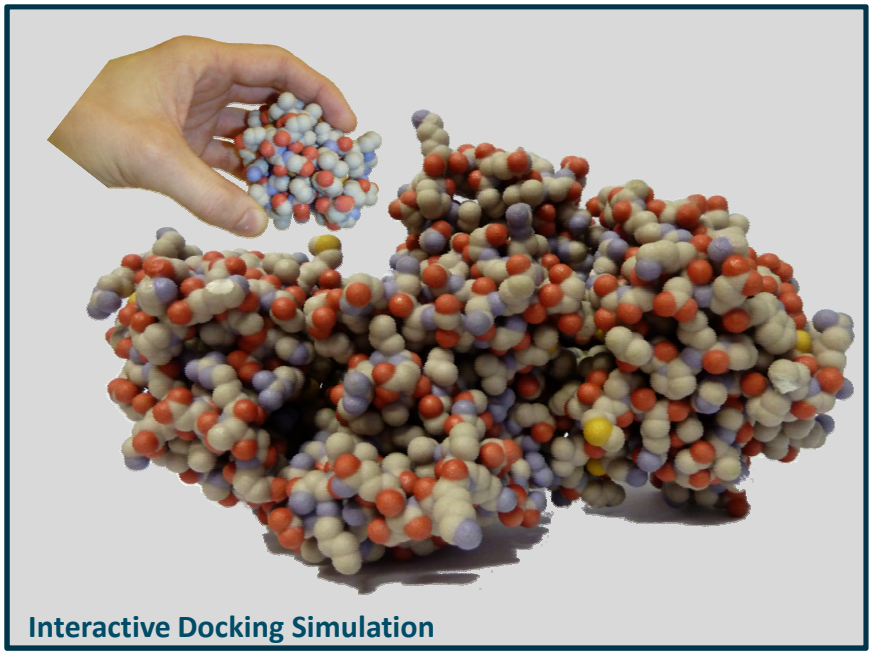
Haptic-Based Molecular Docking

- Aim: To create an immersive virtual docking environment.
  - The user interacts with the virtual molecules
  - The user senses the interaction forces
  - Can guide the molecules to their binding pose via a knowledge-guided search and selection

Haptic Device



Interactive Docking Simulation

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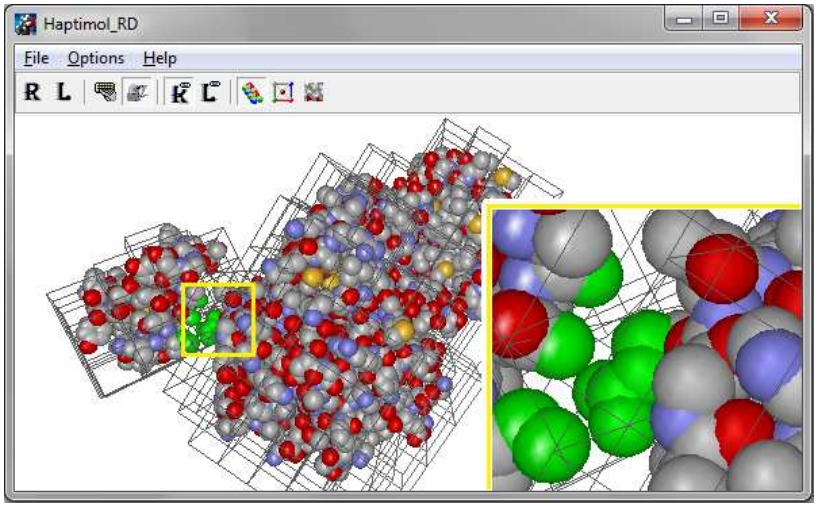
Main Issues

- Compute forces in real time, within 2ms
- Accommodate large molecules
- Support molecular flexibility

$$\vec{F}_{Tot} = \sum_{i}^{N} \sum_{j}^{M} \left(\left[12 \frac{A_{ij}}{r_{ij}^{13}} - 6 \frac{B_{ij}}{r_{ij}^{7}} + \frac{q_i q_j}{4\pi\varepsilon\varepsilon_0 r_{ij}^{2}} \right] \hat{\vec{r}}_{ij} \right)$$

We investigate Spatial Partitioning approaches on the CPU and GPU to compute the interaction pairs within a cut-off distance.



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HaptiMOL RD

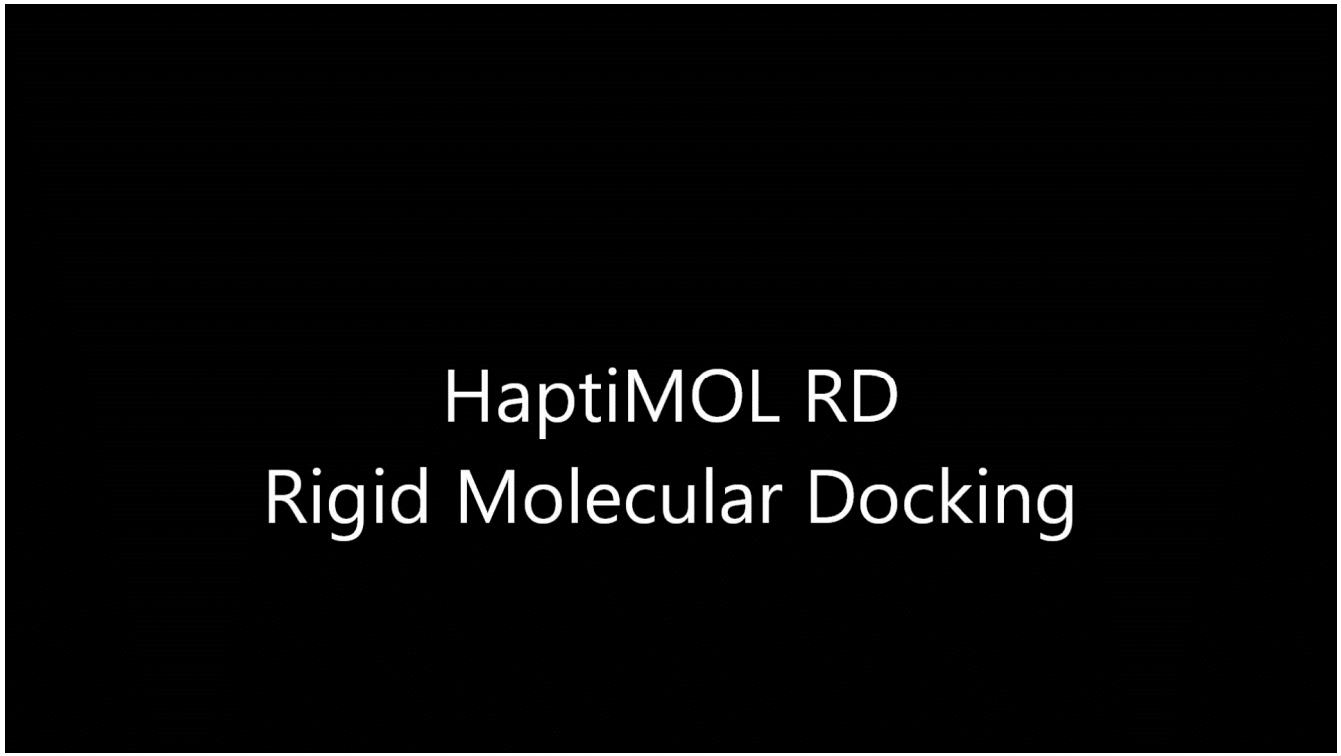
CPU mode

- Rigid Docking for molecules up to 7000 atoms each
- Potential support for flexible docking for molecules up to 1400 atoms each

GPU mode

- Rigid docking for molecules comprising more than 200,000 atoms each
- Potential support for flexible docking with
  - RECEPTOR - comprising more than 200,000 atoms
  - LIGAND - comprising up to 3400 atoms (regular grid)

HaptiMOL RD



http://www.haptimol.co.uk/movies/rd.wmv

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References

- Iakovou, G., Hayward, S. and Laycock, S.D., "Adaptive GPU-accelerated force calculation for interactive rigid molecular docking using haptics", Journal of Molecular Graphics and Modelling, 2015.
- Iakovou, G., Hayward, S. and Laycock, S.D., "A real-time proximity querying algorithm for haptic-based molecular docking", Faraday Discussion 169, 2014.
- Stocks, M.B., Laycock, S.D. and Hayward, S., "Applying forces to elastic network models of large biomolecules using a haptic feedback device", Journal of Computer-Aided Molecular Design, 2011.
- Laycock, S.D., Stocks, M.B. and Hayward, S., "Navigation and exploration of large data-sets using a haptic feedback device", ACM Siggraph: Posters, 2010.
- Stocks, M.B., Hayward, S. and Laycock, S.D., "Interacting with the biomolecular solvent accessible surface via a haptic feedback device", BMC Structural Biology, 9:69, 2009.