2 Related Work

Visualization domains that are related to our work can be categorized into molecular visualization, and occlusion management. We will focus mainly on occlusion management as this is also the focus of this paper. //After we present a short historic overview of the development of cutaway techniques we discuss more recent techniques.

2.1 Occlusion Management

**Object based approaches:**

Cutaway and ghosting techniques were first introduced by Finer & Seligmann in 1992 as an automated approach for generating illustrations that consider the occlusion of user defined objects. The authors introduced a set of algorithms that automatically identify and handle potentially obscuring objects which - enabled due to the introduction of the z-buffer to then modern graphics hardware.

In 2002, Diepstraten et al [diepstraten2002] picked up the technique again and defined a set of rules for computer-based rendering of technical illustrations to achieve a view-dependent transparency model that mimics the ghosting techniques of technical illustrations. They later extended these rules for interactive cutaway illustrations [diepstraten2003].

Analogous to the cutaways for polygonal representations, Weißkopf et al. developed an interactive clipping technique for volume rendering. [I don’t really know, which aspect to highlight in this paper…]

In 2004, Viola et al developed an automated approach for focus & context visualization for segmented volumetric objects. An assigned object importance determines the visibility priority for the segmented parts of the volume. Techniques such as opacity modulation, screen-door transparency, and volume thinning were applied to make occluded objects visible.  
Follow-up work focused on the definition of levels of sparseness and importance compositing for cutaway and ghosting calculations [importance driven feature enhancement]

In 2005, Viola et al. coined the term “smart visibility” as a collective term for cut-away views, ghosted views, and exploded views - to describe expressive visualization techniques that smartly uncover the most important features of the displayed data.

[which part of your phd thesis should I highlight?]

Krüger – neck dissect  
Krüger – clearview

li et al developed an approach that allows interactive exploration of complex models, e.g., mechanical or anatomical. the user has to rig each part of the respective model, so that the system knows, which type of cuts to apply. the cuts that their system produces adhere to a set of rules that were inspired by cutting conventions found in medical and mechanical illustrations. //for the dense molecular data that we are dealing with, a 1:1 implementation of this approach would not work. it would require some sort of segmentation that would yield objects that then can be rigged by the user. however, a segmentation of this type of data would already be a challenge of its own.

the approach by burns & finkelstein for view dependent cutaways inspired our aperture that is discussed in section Y. the cutaway shape is determined by the enlarged shape of the focus objects in the depth image. to preserve the information of the cut geometry, they apply shading & contouring/outlining of the cut surfaces, and ghosting of the cut geometry contours.

2011 Perceptual Evaluation of Ghosted View Techniques - baer, preim

Lidal et al. propose design principles for Cutaway Visualization of Geological Models. they promote boxes as ideal cutaway shapes for emphasizing the shape and depth of focus features in layered structures, such as geological sediments. Lidal et al further promote the use of illumination to effectively communicate the shape and spatial ordering inside the cutaway, as well as enhancing relationships between the focus features and the context. they define five design principles that we discuss in section X in relation to our approach. //our approach also supports box shaped cutaways but not exclusively. the cutting geometry corresponds to the coarse step in our approach - which will act as a window into the dense data. However, in order to achieve images that mimic manual scientific illustrations as they can be found in medical books, a cutaway geometry alone is not sufficient. the context around box acts as a frame of reference for the focus data. in our approach we also achieve this with the fine step - the visibility histograms.

Most recently, lawonn et al present a composite technique that combines flow visualization and rendering of volumetric/poly? structures. the structures (blood vessels) are cut to reveal the flow within. additionally, the structures visually encode the wall thickness as colored regions in order to preserve context information that is of relevance to the user. the also apply the depth image approach that was published by burns & finkelstein. //they use the depth image of the objects of interest — in this case the pathlines — to create the cutaway.

In **Transfer function based approaches,** the user assigns importances to materials/density values in the TF. Based on the TF, the ray that is cast through the volume then determines the importance of a point and whether the point should be cut/rendered transparent or not.

The context-preserving volume rendering model proposed by Bruckner et al uses a function of shading intensity, gradient magnitude, distance to the eye point, and previously accumulated opacity to selectively reduce the opacity in less important data regions. Contours of surfaces that would be removed due to opacity remain visible as the amount of illumination received is taken as a measure whether a point should be visible or not.

Burns et al propose a multimodal approach that combines CT scan data and realtime ultrasound data. Importance driven shading is used to emphasize features of higher importance that have been revealed through the culling/ghosting.

Ruiz et al. propose atomatic transfer functions that calculate a divergence as measure of distance between the target and the actual distribution of... they use the rendered image to minimize the distance between desired and rendered…. leibler distance for defining this asymetric metric

Correa et al.

**[conclusion of the occlusion sub-section]**

Transfer function based approaches are well suited for volumetric data that contains segmentable structures, such as the organs or bones in a medical scan. For molecular data this only holds partially true, as some types of molecules do indeed form solid structures that could be made visible with a TF (membranes, nucleus). On the other side, within these structures there is a more noise like distribution of these molecules.

since the obstructing information is cut away - most modern approaches have something in common in alleviating this inherent shortcoming: they try to preserve the structures that have been cut, in some way or another.

due to the data type & how we handle it, our approach is fundamentally different from existing cutaway approaches. in our approach, (partial) occlusion of individual objects is not an issues as the data does not contain large singular entities such as polygonal or segmented volumetric objects where each single one has a semantic meaning.

instead there are thousands of instances of a couple of dozens molecule types. objects are never partially cut - just removed or not. not based on a density function as in TFs in volume rendering or on specific objects of interest - but based the combination of those two aspects: clipping object(s) & a visibility function/histogram for each molecule type.

still, principles from existing cutaway algorithms can also be applied to our approach.

2.2 Molecular Visualization

//TODO

3. Overview

3.1 Data

our data according to the Elmqvist taxonomy:

* high object density
* high object interaction:
  + high proximity: hundreds of thousands (millions?) of molecules of dozens of different types, densly packed
  + high enclosure: some molecules form structures that enclose other types of molecules, e.g., nucleus, cell membrane
* object complexity:
  + low, from a cutting perspective: since objects are either entirely cut or not
  + high, from a visual perspective: they are complex structures that consist of dozens or hundreds of atoms
  + partial occlusion of individual molecules is not an issue since there typically are many instances of each type visible at the same time

X Discussion

X.1 Elmqvist’s taxonomy for occlusion management

elmqvist et al described a taxonomy of occlusion management techniques. the techniques can be grouped into five different design patterns that support different tasks and are suitable for different data types. the visibility equalizer (VE) falls into the virtual x-ray technique that applies transparency or object removal - which is the most suitable method for the dense molecular data that we are dealing.

virtual x-ray techniques such as cutaways make discovery trivial & facilitate access. They have very high disambiguation strength –which means they can handle dense data (high proximity) with enclosement, containment, .. they support view dependent and static approaches to occlusion handling.

inherent downsides:

* weakens occlusion depth cues => decrease in depth perception, makes spatial relation difficult. However, this can be tackled with special cutting conventions & illumination / shading. And also other special approaches: [=> refer to fuzziness section]
* transparency (ghosting): yields additional visual complexity, more cognitive load  
  [=> mention ghosting/contours if we implement them]

the user task according to the taxonomy: all three tasks are somewhat relevant in our context

* target discovery: know where specific molecule types lie in the cell
* target access: retrieve graphically encoded info: not on a single instance level - however on a per-type level - how big is the volume of the type
* spatial relation: which types are enclosed by which, where do they lie, how is the distribution?

other techniques such as multiple view, tourplanners, volumetric probes, and projection distorter would not be well suited to gain the desired insight into the dense molecular cell data

* multiple viewports, tour planners: the cell data is dense => multiple view ports would still suffer from occlusion. Cutaways &transparency necessary acts as a window into this dense data
* probes, projection distortion: we do not want to distort the data since the organic / anatomical / cellular structure needs to be preserved

X.2

Related techniques can be grouped into techniques that..

* OOI based vs TF
* polygon vs volume representation
* automated vs interactive specification of the cutaway