Direct Modeling:
in Search of a Silver Bullet

Dmitry USHAKOV
Director of Product Management
LEDAS Ltd.

Preamble

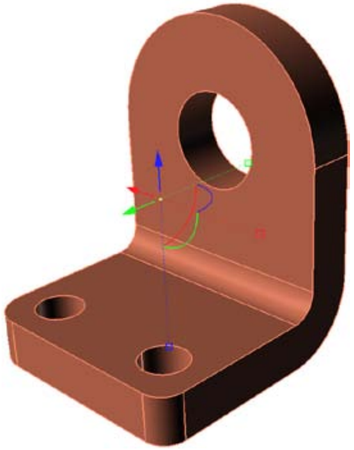
- Is it easy to make changes in 3D geometry?
  - If you spent a lot of money to buy a mainstream MCAD system...
  - Spent enough time to learn parametric feature-based modeling...
  - The geometry to modify was created in the same CAD system...
  - It was designed by a smart guy, who predicted the way you want to change it...
  - Then you are lucky! It is easy indeed.

- But what if at least one of the above conditions is false?
- **Do you think direct modeling will help?**

ledas

Direct Modeling Sugar

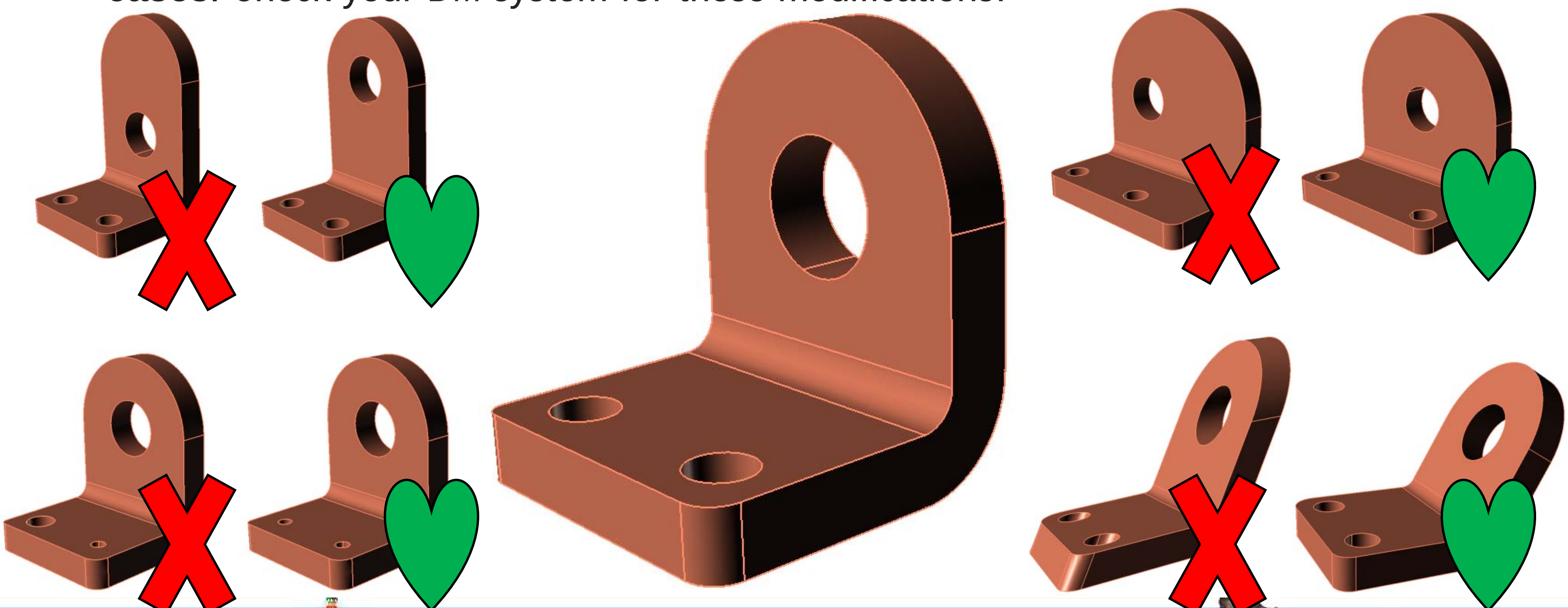
- In Direct Modeling (DM) systems you deal with geometry itself and not with a feature tree. This allows you to manipulate directly with boundary entities – faces, edges, vertices
  - You can move them
  - You can deform them
  - You can use driving dimensions to position them



- Unleashed editing capabilities allow you to modify any geometry independently on its origin
- DM systems are significantly cheaper than mainstream MCADs
- You can still use features to create your model, but you do not need to think anymore how to build a proper feature tree
- Too much sugar? **No features means no design intent: almost any operation will modify your model in undesired way**

Design Intent in DM

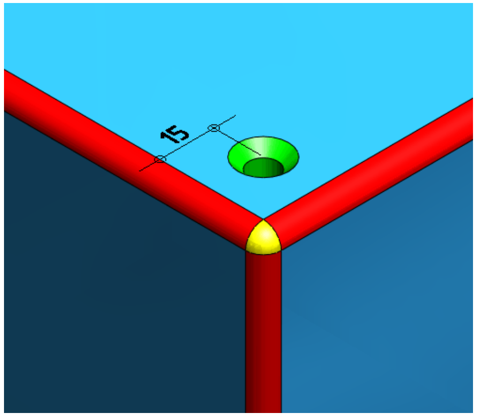
- To preserve design intent, any user modification should be supported by the modeling system in intelligent way – by moving and changing other elements
- Most DM systems are **not able** to address this issue, others support only **simplest cases**. Check your DM system for these modifications:



ledas

So what's a silver bullet?

- Existing approaches – step-by-step modification, multi-selection (with smart patterns) – do not help so much; they are error-prone
- A promising solution consists in **automatic recognition of design intent**, and converting it into a set of geometric and dimensional **constraints** between boundary elements of a featureless model
- Which constraints can be recognized automatically in 3D geometry?
  - Coincident, tangent, parallel, perpendicular, coaxial faces
  - Equal distances, radii and angles, symmetry
- More constraints can be added by the user
- All constraints are solved simultaneously; geometry is updated by moving its boundary faces
- We call this concept **Variational Direct Modeling**



ledas

Questions

- Do MCAD users really need this?
- Can constraints replace features?
- Is variational direct modeling easy in use?
- Is this technology robust and scalable enough to deal with complex mechanical models?
- Has this idea been implemented in any CAD?
- Visit Working Group #2 "**Intelligent Methods of Three-Dimensional Modeling in CAD**" to know how the approach of LEDAS answers these and other questions

Features+Constraints=?

- Constraints can be used to specify and control design intent, but users still need the ability to recognize features in history-free models – just to remove or copy some of them
  - holes, fillets, pockets...
- A powerful DM system should be able to:
  - recognize simple features that does not depend each other and allow users to remove/copy any of them
  - recognize geometric constraints and solve them each time the model is changed by the user

Is it easy to use?

- Constraints have no order and no dependency
  - Any (all) constraint can be removed at any moment – with no relation to the rest of the model
- The user creates only those constraints and driving dimensions, which are needed for parametric modification of the model
  - In most cases only few dimensions are enough
- If a new constraint contradicts with ones added previously, the system highlights the minimal overdefined subset, allowing the user to decide what to remove

ledas

Is it easy to learn?

- Constraints are not new for MCAD users who deal with them in parametric drawing/sketching and assembly design applications
- VDM is a logical and consistent application of the same concept for 3D geometry editing
- Geometric constraints represent basic geometric concept (parallelism, perpendicularity, tangency...) and don’t need to be explained
- Driving dimensions generalize the well-known notion of reference dimensions, and the users can learn them very fast

ledas

Is this technology is scalable?

- All constraints of one model (defined by the user and recognized automatically) have to be solved **simultaneously**
- A naïve approach consisting in solving a system of nonlinear equations does not work even for moderate-size model
- Fortunately, in most cases a constraint problem can be decomposed into a set of smaller ones – solving them one by one, we can find the solution to the initial large problem
  - It works in less than 1 sec for models with 1,000 constraints

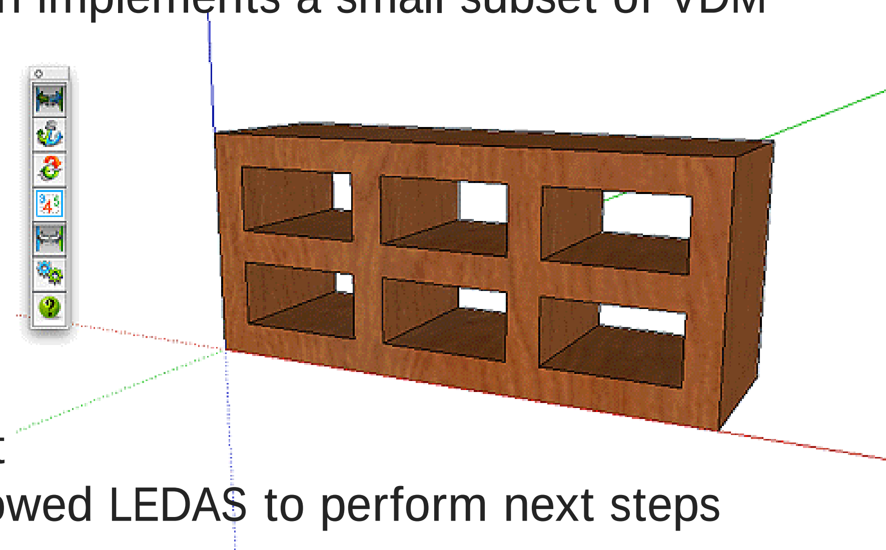
What is needed to implement VDM?

- The core of VDM is a geometric constraint solver – a software component that is able to solve large-scale constraint problem very efficiently
- An important part of VDM functionality is the ability to recognize geometric relations between model elements and convert them into a non-contradictory set of constraints (this should be tuned by the user)
- The third part of VDM is a geometric modeling kernel, which is needed to modify BRep after all constraints are solved

ledas

VDM first success story

- LEDAS started to develop its own variational constraint solver (LGS) in 2001
  - Since 2004 it was licensed by dozen of CAD/CAM/CAE vendors to implement parametric drawing, assembly design, and motion simulation applications
- In 2008 LEDAS released a first implementation of VDM as a plug-in for Google SketchUp, a popular 3D modeling application
- Called "Driving Dimensions", this plug-in implements a small subset of VDM
  - Constraints are not recognized automatically
  - Instead users have to specify driving dimensions manually
- Almost 25,000 SketchUp users downloaded the plug-in from www.DrivingDimensions.com
- Experience accumulated in development and promotion of end-user software allowed LEDAS to perform next steps



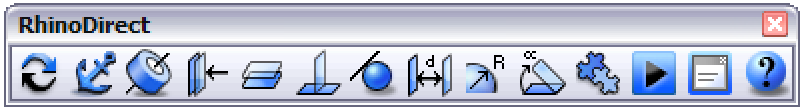
ledas

RhinoAssembly

- Faced with serious limitations of SketchUp geometric modeling kernel, LEDAS decided to implement the full-scale VDM in Rhino
  - Developed by Robert McNeel&Associates (RMA) since 1992
  - Costs below EUR 1,000
  - More 150,000 users worldwide
  - Advanced functions for freeform surface modeling
  - Based on the OpenNURBS open-source format
- LEDAS choose the following tactics to enter the market of Rhino plug-ins:
  - First, to develop a plug-in for bottom-up assembly design and kinematic simulation
  - To put it on the market and establish strong relationships with end users, resellers, RMA team
  - Then to develop a VDM plug-in on top of it

RhinoDirect

- LEDAS released first public beta-version of RhinoDirect plug-in in January 2010
- Current version (0.4) supports parametric modification of solids, which boundaries composed of planar, cylindrical and spherical faces



- Users can apply geometric constraints and driving dimensions (distance, radius, angle) to change the shape
- RhinoDirect automatically recognizes design intent and generates additional constraints

Conclusion

- Variational Direct Modeling technology is supposed to solve the main problem of Direct Modeling – managing design intent
- VDM technology is still under development, but LEDAS has already entered in partnership with some vendors interested in applying this technology in their CAD applications
- We are ready for collaboration with all CAD developers!