John M. Switlik   john.m.switlik@ieee.org   Google Scholar

Context: US Army (Aviation Material Readiness) ->

Vitro Labs (BAE) ->

Informatics, Inc. (Wikipedia) ->

Sperry Univac (Trilogy/Amdahl, Knowledge Systems Center) ->

Boeing (Military Aircraft Company, Commercial)

1st. AI and Truth (LinkedIn)

2nd. Recovery of 2003 talk at COE (Dassault's operators meeting, CATIA)

This presentation (following are slides and comments, PPT) covered some of the KBE work that was related to the Boeing 777 project which is the gist of coming articles.

At the time that KBE got started, CAD was still in the process of moving from 2+D to 3D with freeform surfaces. So, CAD with its analysis partner, CAE, were adapting to the new modeling schemes.

At the time KBE still had its KBS flavor with the major change of focusing on constraint satisfaction rather than rule processing. Hence, there was the underlying object model with its facility to handle static and dynamic characteristics as well as the new facilities of solid modeling.

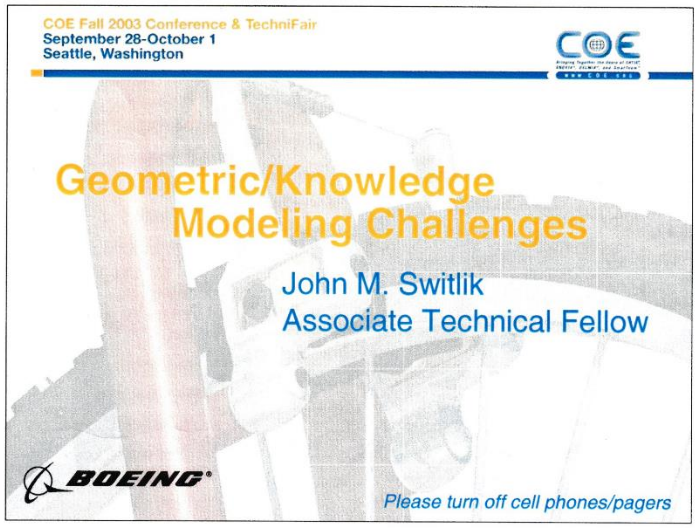
Jumping over details, one check of a solid entity was whether it could figure out its boundary closures. At the time, Boeing was going from the loft model with its basis in planar profiles to the more capable method of flexible shape handling. Needless to say, this was way early (later 1980s) compared with today (2024s).

All we have to do is start with the current view of KBE to see how things have changed. Much of KBE has gone off to other realms or to similar realms with different names.

The coming papers will look at those details.

Context: Operations Research -> Database Technology -> Expert Systems ->
Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



The presentation looks at some of the common issues related to computational modeling, in terms of geometry and knowledge.

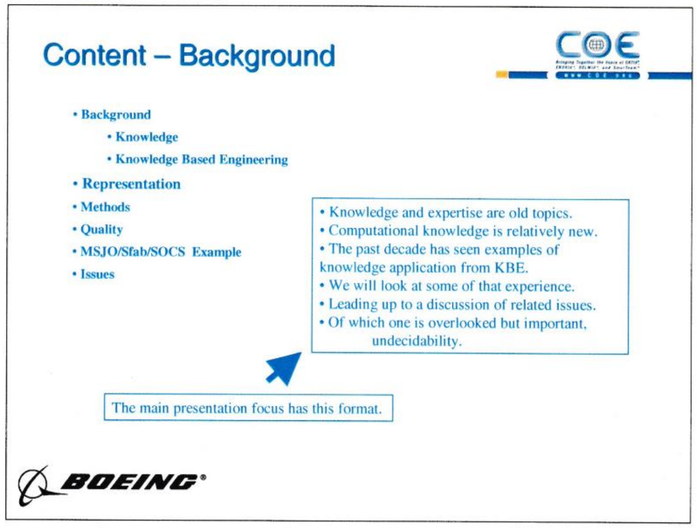
Background material includes a brief look at knowledge and at KBE which is the application of knowledge processing to Engineering.

Then, the discussion looks at Representation, Methods and Quality, followed by an example from MSJO/Sfab/SOCS, a project dealing with the knowledge of geometry.

The example provides details on the approach (Sfab/SOCS) that can handle problematic data (minimal, sparse, noisy, or originating from multiple sources).

As a conclusion, the presentation points to additional information related to the subject matter and lists open issues that will require continued and joint effort within the industry.

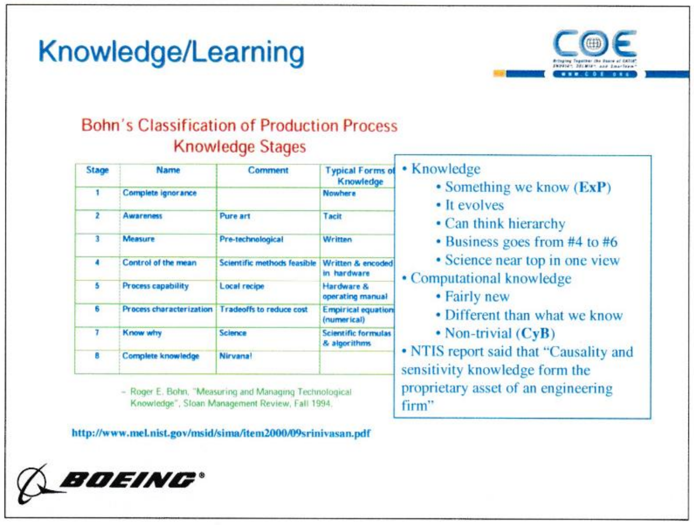
Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



Background material includes a brief look at knowledge and at KBE which is the application of knowledge processing to engineering domains.

There is a lot that can be said about knowledge and KBE, but we'll only take a brief look.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



Stage	Name	Comment	Typical Forms of Knowledge
1	Complete ignorance		Nowhere
2	Awareness	Pure art	Tacit
3	Measure	Pre-technological	Written
4	Control of the mean	Scientific methods feasible	Written & encoded in hardware
5	Process capability	Local recipe	Hardware & operating manual
6	Process characterization	Tradeoffs to reduce cost	Empirical equation (numerical)
7	Know why	Science	Scientific formulas & algorithms
8	Complete knowledge	Nirvana!	

This chart is Bohn's view showing stages from ignorance to knowledge. The viewpoint originated in 1977.

> Bohn, R Measuring and Managing Technological Knowledge, IEEE Engineering Management Review, Winter 1977

The format shown in the Slide came from a NTIS report.

Of course, we would like to know as much as we can. But, acquiring knowledge has costs.

Business as a process bows out of the knowledge quest according to choice based upon several factors.

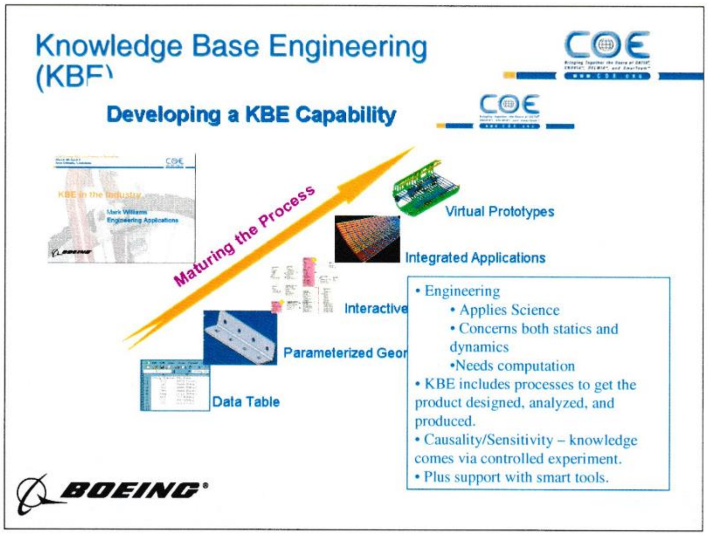
For IS/IT, the SEI/CMM is one process. SEI/CMM culminates at optimization (hopefully, #6).

Bohn's progression through science goes beyond optimization to truth.

Engineering applies science. With the advent of knowledge systems, we see an increasing role for computation in the process.

Therein lies the rub as we need to trust the computer as a role player in a process that can be fairly non-trivial.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



KBE represents engineering knowledge by computational models using a heavy emphasis upon part hierarchy and rules.

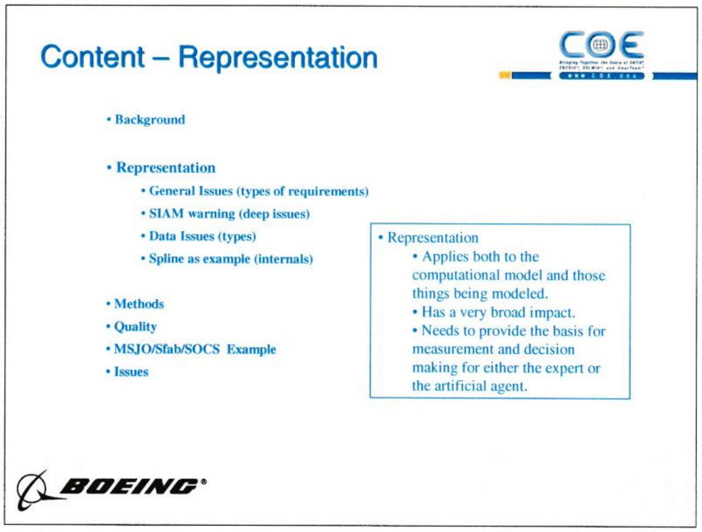
The KBE efforts have had measurable success for the past decade.

But, KBE can only as good as the formalization allows. The successful application of more automation to KBE will require several issues to be addressed.

For one thing, derivations via computational models do not necessarily accurately reflect the world. Even with a perfect model on the computer, it is separate from reality.

It is too easy to assume that modeling of causality via computation is sufficient to know all ramifications.

KBE will need to be able to predict behaviors as well as the statics.



Representation deals with technical concerns (for example, structure and parameter definitions).

Choices related to representation influence who can use data, how they can use data, and for what purposes.

Representation faces one hard fact dealing with the need for transformations to other representations; such manipulations of data are known by experience to be problematic.

Representation, in the KBE context, requires a broad mixture of structures in order to support more-smart processing.

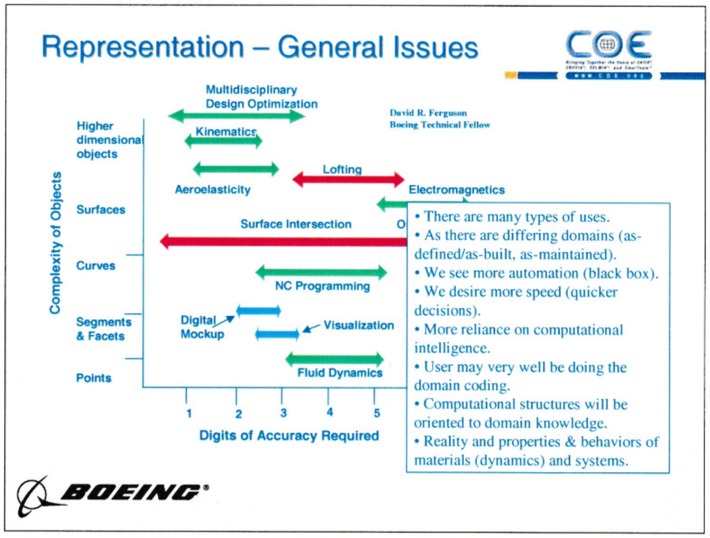
One requirement, that results from the growing use of knowledge approaches and the increased level of education, will be end user access to deep data issues, such as structure.

Algorithm/heuristics are sensitive to representation.

KBE utilized a human-in-the-loop framework to overcome some of the computational uncertainty.

For the more automated decisions needed for autonomy, representation must resolve a long list of issues.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



This chart by Dave Ferguson, Technical Fellow, Phantom Works pulls together the several types of uses for models. Practice shows that no one representation is sufficient, by itself.

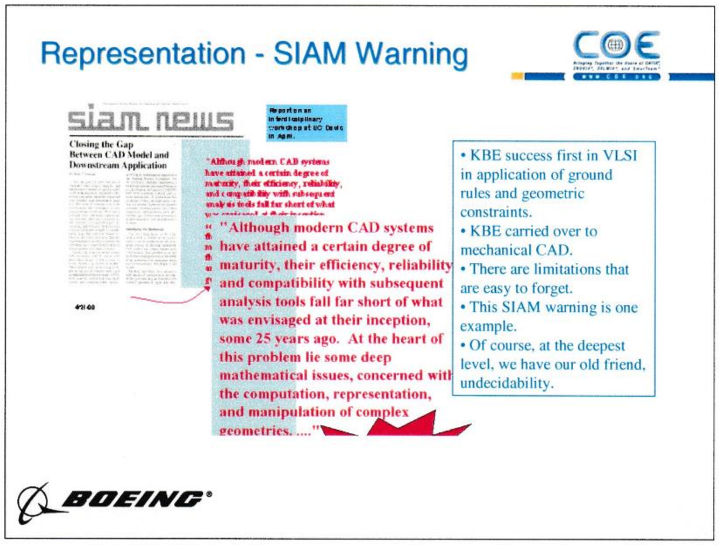
Lean goals of reductions in time and effort imply computational assistance with non-trivial properties.

The human element will bear the brunt of the knowledge challenges. Fewer heads will be resolving problems that will not abate in complexity.

Both the basis for knowledge in terms of the underlying scientific framework and in terms of modeling techniques and capability will be growing.

Issues of fidelity bring up this question: Does representation strive for the highest requirement everywhere thereby incurring the highest cost?

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



Success builds confidence to venture further. But, at its core, the CAD/CAM/CAE mix can be problematic.

These issues also can plague KBE.

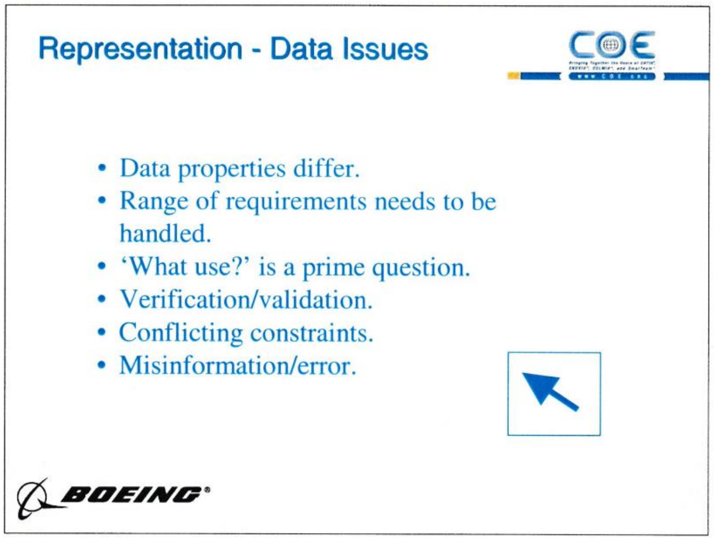
Many limitations have been overcome with workarounds.

Such efforts may continue to be the modus operandi while the appropriate theories are bolstered.

Actually, the requirement for workarounds could very well be a set of greater magnitude and velocity than realized.

Report from http://www.siam.org/meetings/cadcfd99/ workshop.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering

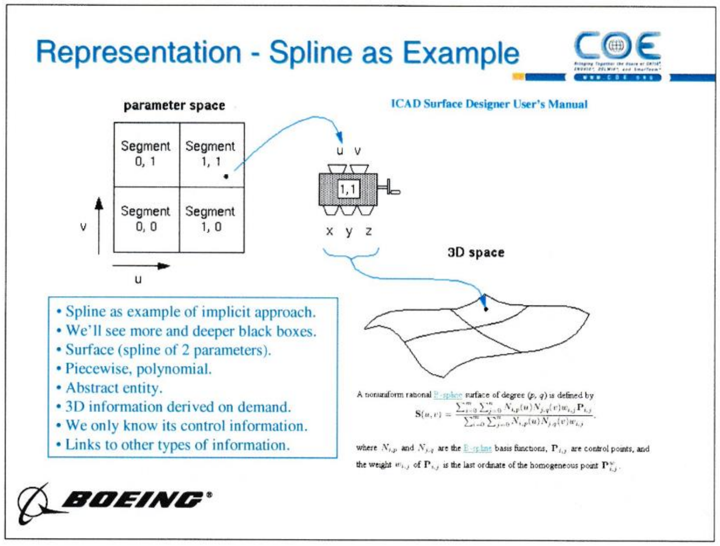


Data fitting covers a lot of different requirements.

As we will see with Quality, fidelity of the model to the data is important.

But, another part of the cost is acquisition. Smart data handling ought to be able to handle problematic data, such as misinformation and error.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



How we represent the data can have widespread influence. Splines are implicit, abstract entities.

http://mathworld.wolfram.com/NURBSSurface.html

The surfaces that form the faces of a solid are represented by spline. Methods used in this representation will be operations on abstractions. The very large set of 3d points that form the screen image, do not exist, except in computer memory.

Being mindful of representation can help methods work.

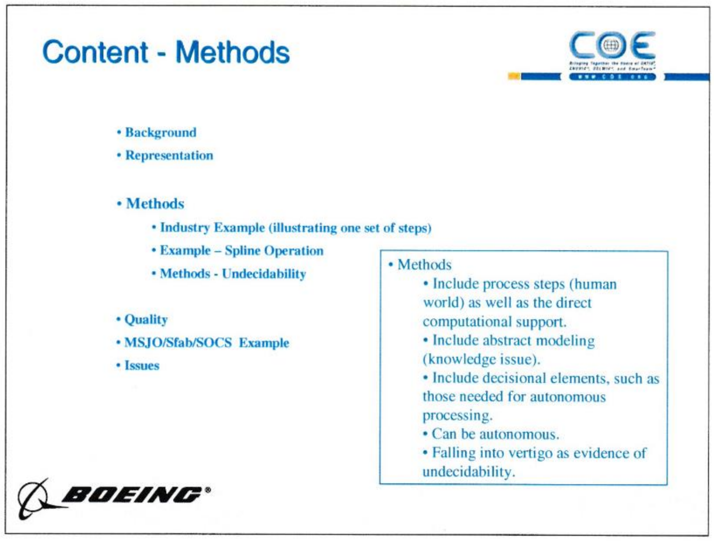
In actuality, the spline technology was a big step forward. Fairly complicated elements can be modeled and managed in a robust and simple manner. The experience of the past 15 years and the current generation of software attest to the growing power.

But, splines are a very good example since they are implicit. In general and in many domains, advances in modeling are accompanied by similarly implicit modes. The success of computing makes things look easy.

It's easy to forget the bases and assumptions that are pushed out of sight. A diminishing of a necessity set (at least, the awareness thereof) can lead to thinking that the sufficiency side is stronger than it really is. The chains might look like this (large necessity >> small necessity <<<>>> sufficiency, where <<<>>> denotes a propensity toward a 'duality' mode).

And, leads to incorrect notions of causality.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



Methods are of many types:

- Manual or automated
- When automated, of an evolutionary or optimization bent (heuristic and algorithm mixes)
- From external and internal expertise
- Domain or interdisciplinary or system
- Trustworthy or not
- Of continued capability through time.

A knowledge method has both human and computer based components.

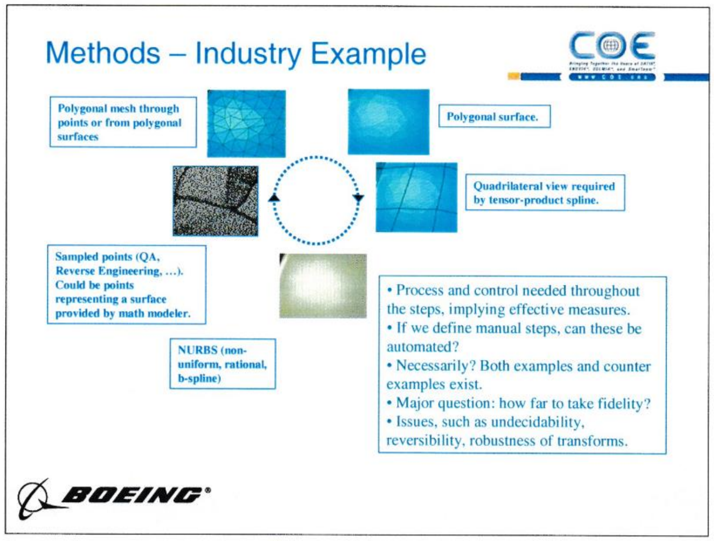
The source of the expertise or systems can be COTS or in-house.

Trust issues concern the veracity, and supporting basis, of the associated knowledge.

Capability involves an effective mix of procedures, algorithms, and heuristics.

Increases in computational features lead to increases in interrelationship and complexity properties, thereby necessitating that we manage 'truth' in a multi-faceted form.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



This is an example of a method that has both manual and automated components. The premier implementation of this method utilizes an interactive seat with fairly sophisticated software.

It shows 5 steps starting from a collection of points to a set of surfaces. At each of the steps, there are choices the user makes.

Through time, the system get more capability to do each steps better. The automation components cover more of the trades.

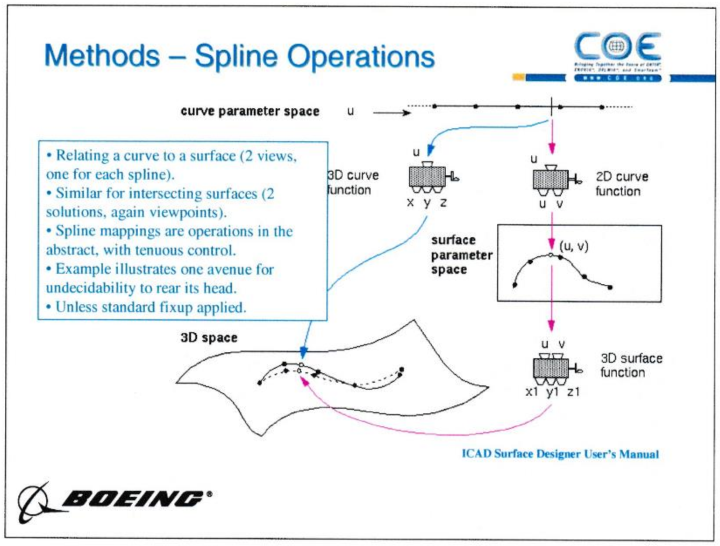
This general process can apply to points from any source whether points from a physical measurement device or points from an already existing set of surfaces (abstractions).

Several areas are still very much open. Converting from the polygonal surface to the quadrilateral surface has several bottlenecks.

The trades on fidelity are being studies. The requirement for continuity still needs to be clarified.

The manual approach assumes that a smart user can resolve conflicts. As the approach gets more toward automation, several other problems come to fore, such as undecidability.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



Operations on surfaces (splines) which are abstractions occur in the abstract.

For instance, mapping a curve to a surface means that their abstractions get related.

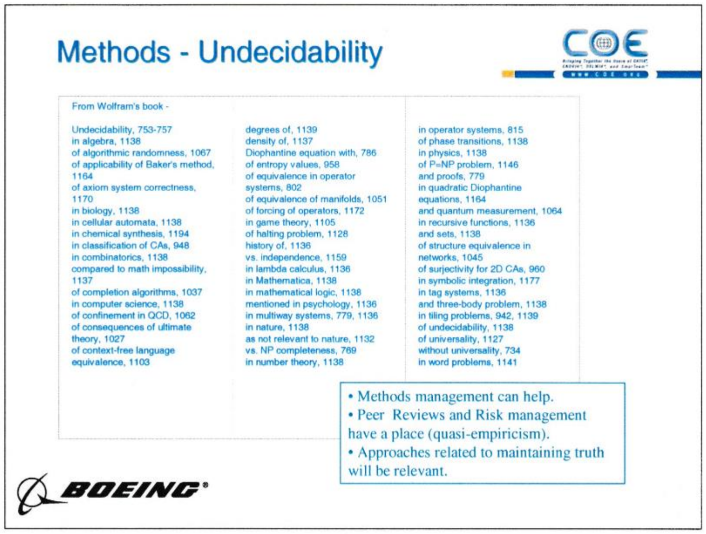
If two surfaces are intersected, the result will be two curves. There will be a curve for each surface that is exact. That is, each surface sees the result from their perspective.

This conflict can be handled by several ways. One approach assumes one curve that has a known delta with the other surface. Another might produce an average curve that has deltas from either surface.

Techniques for minimizing the error exist but take time.

It is undecidable, prior to computing the solution, to know what the intersection and maximum error will be.

Context: Operations Research -> Database Technology -> Expert Systems -> [Knowledge Based Systems -> Knowledge Based Engineering] -> Truth Engineering



What is "undecidable" and how is this concept applied?

Wolfram has provided a reasonable list in his recent book. Wolfram's view is that this subject has not received the proper attention in Mathematics, for several reasons.

http://www.wolframscience.com/nks/index/u.html

Wolfram described two types of undecidability that he deals with in Mathematica.

- The time constraint helps limit the Turing machine non-termination problem.
- An iteration constraint handles neighborhood issues related to problems like a fixed point search.

There are many other types that need to be considered in KBE.

For instance, a solution might be a converging series rather than an instance. Generally, some choice can be made between otherwise equivalent entities in the series.

But, such choices have topological factors about which there may have been erroneous assumptions made.

This term will become important as knowledge processing expands in scope and capability, as there are higher-order types of undecidability.

Undecidability is handled via decision, however the choices will less than optimal.

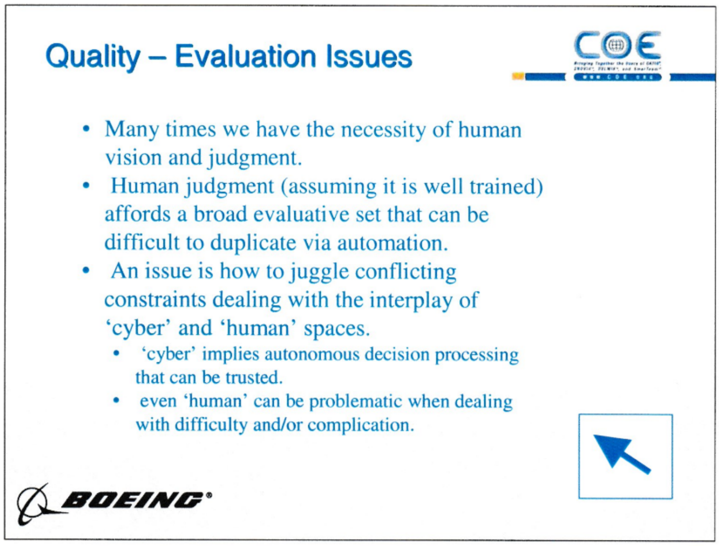
Adaptive approaches may have a different favor of undecidability than we see with the human-in-the-loop framework.

Quality varies by context, is driven by data usage and measurement capabilities, and affects representation and methods.

There are many examples of classic trades that exist between some quality criteria.

One good example would be trades for a curve or surface (fit, continuity, and footprint).

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



Quality, in the sense of this presentation, is going to be a core issue for decision processing for both the human-in-the-loop and the more autonomous element.

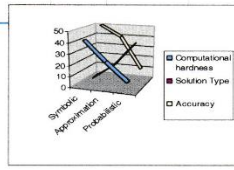
In the computational era, quality of methods imply management of external and internal entities. One ongoing debate concerns the openness of a system to review.

The types and kinds of openness of an external system will be clarified and defined further.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering

Quality – Computational Issues

Method	Example technique	Computational hardness	Solution Type	Accuracy	Other
Symbolic	quantifier elimination	high	simple to medium	exact	assumes complete knowledge
Approximation	branch and bound	medium	medium to complex	close	requires a priori information about solution space
Probabilistic	statistical learning	low	complex	guess	requires a priori information plus solution is probably approximately correct, at best



- Computational approaches vary.
- Symbolic methods, when available, are highly desirable.
- Approximations have been the main game.
- New methods will allow mixing symbolic and approximations.

Peter Dorato "Quantified Multivariate Polynomial Inequalities"
IEEE Control Systems Magazine, Oct 2000

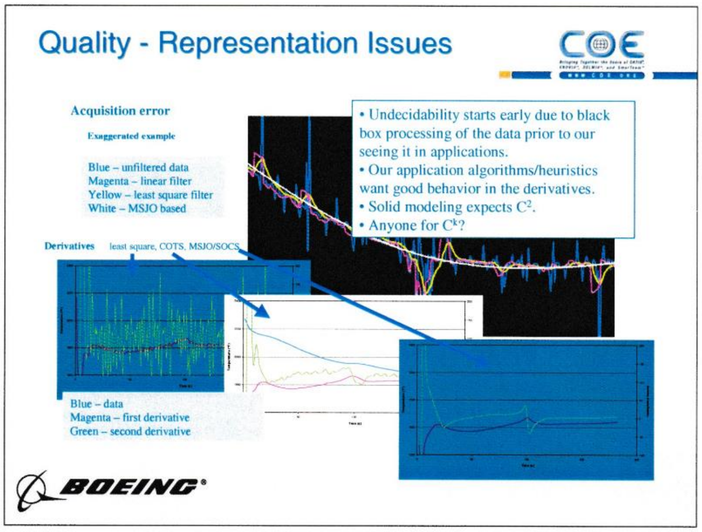
BOEING®

Quality must deal with computational issues.

There is no guarantee that internal systems are open, in the sense that the understanding of a system is not limited only by how it is expressed or controlled.

That is, domain expertise embedded in an intelligent system may be both difficult (deep understanding) and complicated (breadth and depth); this characteristic cannot be managed away.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



The capture/acquisition step has a direct tie to Quality.

One key element will be lifting to awareness the processing that data goes through, especially if the data represents real, physical phenomena.

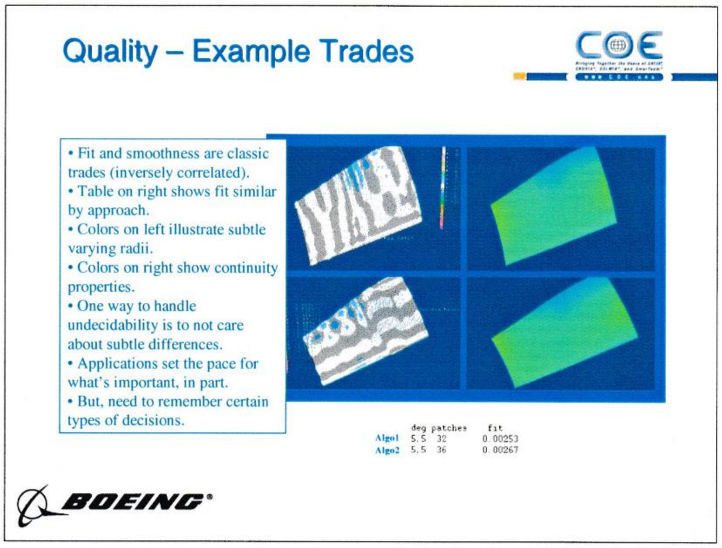
In this example, the derivative charts (especially the 2nd derivative – green) show improvement from left to right (least square, COTS, MSJO/SOCS). Transitions in the 2nd derivative from the MSJO/SOCS example (rightmost chart) indicate real physical occurrences.

Quality can be driven by the representation and method requirements.

Methods based upon manifold processing require at least C2 continuity. Lesser continuity can cause problems with algorithms/heuristics.

The MSJO/Sfab/SOCS approach provides C^k continuity. The method also allows outlier points to be dropped thereby producing a much better set of statistics.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



One good example would be trades for a curve or surface (fit, continuity, and footprint).

Being 'faithful' to real-world data many times means a discontinuous representation that can have an influence on methods.

If continuity is the goal, then the fit to the data needs to relax.

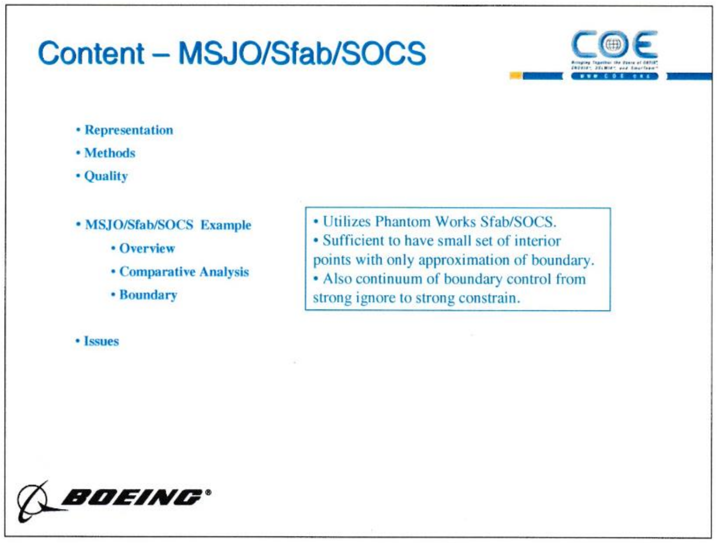
Given the quality measures for analysis and supporting decisions, there are techniques/data patterns that can be uncovered/exposed that help to more significantly organize the system.

The net effect is a much less random, more constrained/solution based state.

There needs to be a balance between the relationship of surface fit tolerance to overall data noise, segmentation to overall continuity, and curvature rates/values to boundary conditions.

Having a large constraint set can raise difficulties. One practice removes what's called non-trivial differences from scope. However, at any point, the 'trivialness' can change, thereby throwing undecidability into the picture.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



MSJO works with several types of data requirements which included:

- design/analysis models at several stages in the life-cycle;
- sampling/measuring models/techniques related to representing physical parts;
- experimental models associated with calculating physical properties (materials).

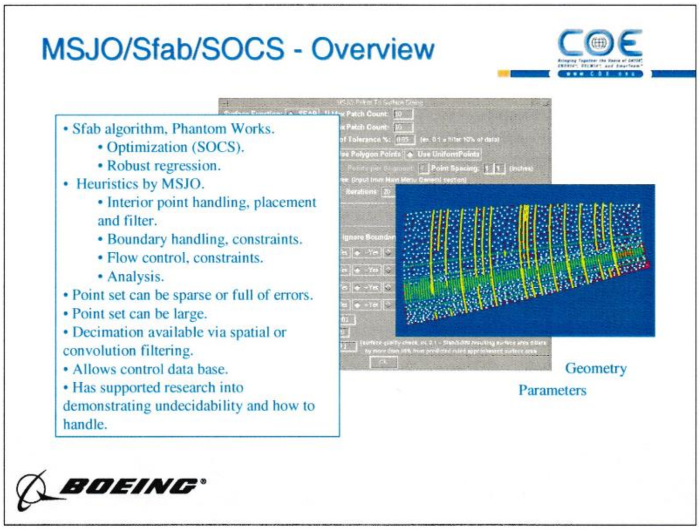
MSJO integrates the Phantom Works Spline Toolkit with rules expressed using ICAD in the CATIA v4 environment.

Work has started to apply CATIA v5 Knowledgeware in the KBE process.

This MSJO example uses optimization at its core.

Additional work has been done to apply the evolutionary approaches, such as genetic algorithms.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



One of the Methods slides showed a process of stepping from points to NURBS using intermediate geometry. A mesh is built to points. The mesh is then converted to a polygonal surface. This surface is then converted to the appropriate quadrilateral view.

This example shows going from points bounded by curves without the intervening steps. There are many cases where this approach might be preferred.

MSJO/Sfab/SOCS can handle data that has either noise or error.

MSJO/Sfab/SOCS implements control using SOCS.

A technique also allows points that are out of tolerance to be dropped out of the solution search. This facility removes outliers from the problem and provides a more accurate set of statistics.

The setup may provide a set of boundary curves that may or may not be accurate and interior points.

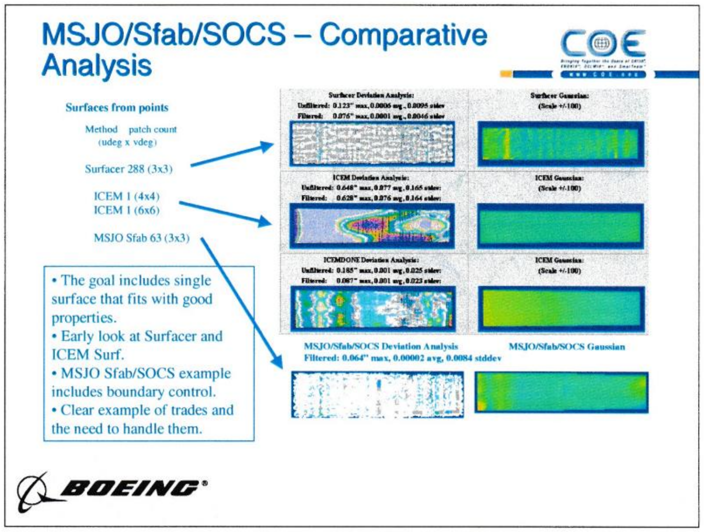
Parameters can be applied to both the boundaries and the points.

MSJO/Sfab/SOCS iterates point-parameter pairs through the optimization using SOCS reverse communication feature.

Details available upon request.

http://www.boeing.com/phantom/socs/

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



Many reverse engineering goals can have multiple constraints, such as the following:

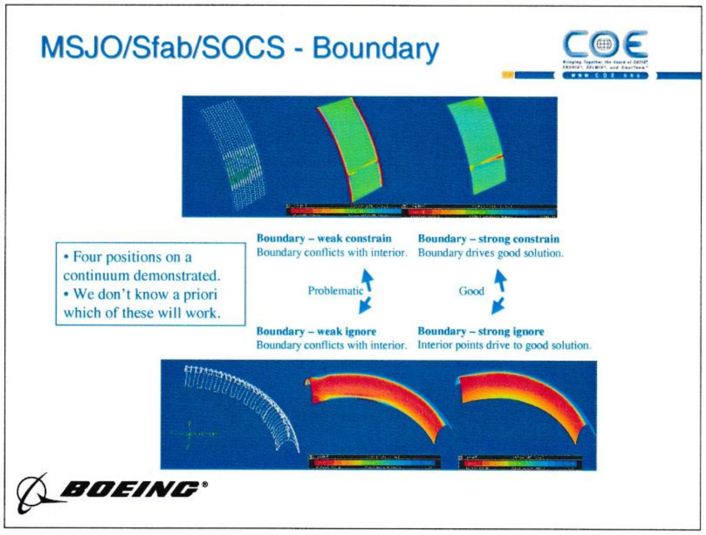
- •single surface (or minimal set of surfaces)
- •minimal deviation relative to the filtered points
- •no curvature reversals
- •minimum segmentation
- •less than 0.001 inch position continuity and
- •less than 0.05 degree tangent continuity between adjacent patches/segments.

Shown for this case is one solution by Surfacer, two by ICEM Surf, and an MSJO/Sfab/SOCS fit.

Each of these solution is an example of the effects of the related trades.

Balancing multiple quality-criteria will continue to be the norm in geometry and knowledge processing.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



In the context of using points with bounding curves, all the data might not have the same weight in fidelity.

MSJO/Sfab/SOCS allows the option of either constraining the boundary or relaxing the boundary, by degree.

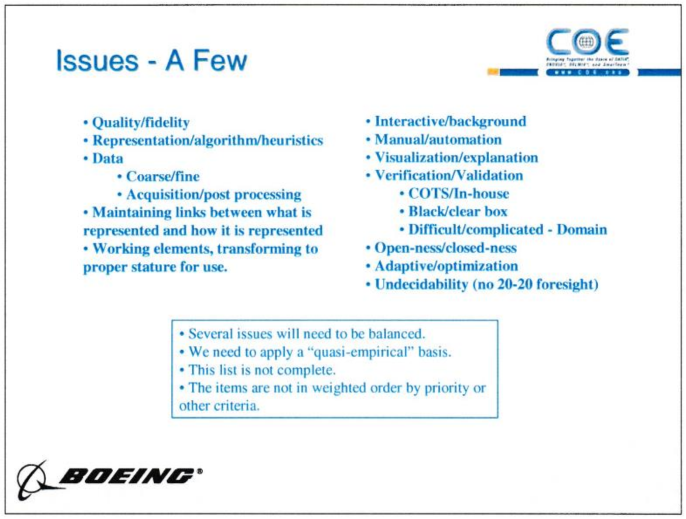
When the data is good, then constraints are in order.

If the interior data is believed over the boundary, the boundary needs to be ignored.

These two examples are illustrative of a much larger set, dealing with boundary versus interior information.

Some trades can be known a priori and played out. Others are only known at run time.

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering



The presentation looks at Background, Representation, Methods, Quality, and one example from MSJO/Sfab/SOCS.

At several points, there are references to related issues. This slide pulls these together.

In the operational mode, issues can be handled using trades. That implies the making of decisions by resources.

Issues raise costs. They are particularly troublesome in computing.

An automated process trying to eliminate issues must deal with undecidability.

The prowess of the computer to guide itself will be become increasingly interesting.

Our work will be to determine the appropriate amount that will be necessary for us to apply for control of the situation.

http://www.wolframscience.com/reference/notes/1136d

Context: Operations Research -> Database Technology -> Expert Systems -> Knowledge Based Systems -> Knowledge Based Engineering -> Truth Engineering