Intro to Metaballs

[Paul Heckbert](#) comp.graphics, 9 Nov 92

[Marco Pugliese](#) writes:

> *In the No. 1 (sept./oct. 1992) of Tech Images Internationales, they talk about "meta ball", a unique primitive that makes smooth-surfaced images,*

Here are the papers I know about. I'm sure this isn't a complete bibliography, however. I'll point out some of the differences in terminology as I summarize the papers below.

A BRIEF HISTORY OF BLOBBY MODELING

People have known for a long time that if you have two implicit surfaces f(x,y,z)=0 and g(x,y,z)=0 that are fairly continuous, with a common sign convention (f and g positive on the inside, negative on the outside, say) then the implicit surface defined by f+g=0 is a blend of the shapes. See [Ricci 1983] for a variant of this.

The van der Waals surfaces of molecules (roughly speaking, iso-potentials of the electron density) are described in Chemistry and Physics books and [Max 1983]. To create animation of DNA for Carl Sagan's COSMOS TV Series, Jim Blinn proposed approximating each atom by a Gaussian potential, and using superposition of these potentials to define a surface. He ray traced these [Blinn 1982], and called them "blobby models".

Shortly thereafter, people at Osaka University and at Toyo Links in Japan began using blobby models also. They called theirs "metaballs" (or, when misspelled, "meatballs"). Yoichiro Kawaguchi became a big user of their software and their Links parallel processor machine to create his "Growth" animations which have appeared in the SIGGRAPH film show over the years. The graduate students implementing the metaball software under Koichi Omura at Osaka used a piecewise quadratic approximation to the Gaussian, however, for faster ray-surface intersection testing (no need for iterative root finders; you just solve a quadratic). I don't know of any papers by the Japanese on their blobby modeling work, which is too bad, because they have probably pushed the technique further than anyone.

Bloomenthal has discussed techniques for modeling organic forms (trees, leaves, arms) using blobby techniques [Bloomenthal 1991] (though he prefers the term "implicit modeling") and for polygonizing these using adaptive, surface- tracking octrees [Bloomenthal 1988]. The latter algorithm is not limited to blobby models, but works for any implicit model, not just blobs. Polygonization allows fast z-buffer renderers to be used instead of ray tracers, for interactive previewing of shapes. A less general variant of this algorithm was described in the "marching cubes" paper by [Lorensen 87] and some bugs in this paper have been discussed in the scientific visualization community in the years since. In the sci-vis community, people call them "iso-surfaces" not "implicit surfaces".

Meanwhile, in Canada and New Zealand, the Wyvill brothers, and grad students, were doing investigating many of the same ideas: approximations of Gaussians, animation, and other ideas. See their papers listed below. Rather than "blobbies" or "metaballs", they called their creations "soft objects". But it's really the same idea.

Bloomenthal and Wyvill collected many good papers on blobby and implicit modeling for a recent

SIGGRAPH tutorial (1991?).

%A A. Ricci
%T A Constructive Geometry for Computer Graphics
%J Computer Journal
%V 16
%N 2
%D May 1973
%P 157–160
%K blob, CSG

%A Nelson L. Max
%T Computer Representation of Molecular Surfaces
%J IEEE Computer Graphics and Applications
%V 3
%N 7
%D Aug. 1983
%P 21–29
%O reprinted in Nicograph '83 Proceedings, 1983, pp. 323–331.

%A James F. Blinn
%T A Generalization of Algebraic Surface Drawing
%J ACM Trans. on Graphics
%V 1
%N 3
%D July 1982
%P 235–256
%Z ray tracing "blobby" models: finding roots of sums of gaussians
%K ray tracing, blob, root finding

%A Paul S. Heckbert
%T Fun With Gaussians
%R (3DTM 12, NYIT Computer Graphics Lab, Mar. 1985)
%B SIGGRAPH '86 Advanced Image Processing seminar notes
%D Aug. 1986
%K filter, image processing, interpolation, spline, blob
%Z includes very brief discussion of approximating a Gaussian with
piecewise quadratic for faster ray tracing of blobby models

%A Jules Bloomenthal
%T Polygonization of Implicit Surfaces
%J Computer Aided Geometric Design
%V 5
%D 1988
%P 341–355
%K implicit, parametric, surface, blob

%A Jules Bloomenthal
%A Ken Shoemake
%T Convolution Surfaces
%J Computer Graphics
(SIGGRAPH '91 Proceedings)
%V 25
%N 4
%D July 1991
%P 251–256
%K blob, implicit model

%A William E. Lorensen

%A Harvey E. Cline
%T Marching Cubes: A High Resolution 3D Surface Reconstruction Algorithm
%J Computer Graphics
(SIGGRAPH '87 Proceedings)
%V 21
%N 4
%D July 1987
%P 163-170
%I implicit surface, isosurface

%A Brian Wyvill
%A Craig McPheeters
%A Geoff Wyvill
%T Data Structure for Soft Objects
%J The Visual Computer
%V 2
%N 4
%D 1986
%P 227-234
%K blob

%A Brian Wyvill
%A Craig McPheeters
%A Geoff Wyvill
%T Animating Soft Objects
%J The Visual Computer
%V 2
%N 4
%D 1986
%P 235-242
%K blob
%Z animating blobs

%A Brian Wyvill
%A Geoff Wyvill
%T Using Soft Objects in Computer Generated Animation
%B ?
%I Springer Verlag
%D 1986

%A Geoff Wyvill
%A Brian Wyvill
%A Craig McPheeters
%T Soft Objects
%B Advanced Computer Graphics (Proc. CG Tokyo 1986)
%D 1986
%P 113-128
%K blob

%A Geoff Wyvill
%A Brian Wyvill
%A Craig McPheeters
%T Solid Texturing of Soft Objects
%B CG International '87
%C Tokyo
%D May 1987

%A Brian Wyvill
%A Geoff Wyvill
%T Field Functions for Implicit Surfaces

From: Jules Bloomenthal, 11 Jun 93

Modeling

- *A Generalization of Algebraic Surface Drawing,* by James Blinn, Transactions on Graphics, July 1982

- *The Algebraic Properties of Homogeneous Second Order Surfaces,* by James Blinn, in Mathematics of Computer Graphics course notes, SIGGRAPH 1984, (and in Modeling and Animating with Implicit Surfaces notes, SIGGRAPH 1990)

- *Exact and Least Squares Approximate Gk Fitting of Implicit Algebraic Surfaces,* by C. Bajaj, I. Ihm, and J. Warren, Transactions on Graphics, to appear (1993)

- *C1 Smoothing of Polyhedra with Implicit Algebraic Splines,* by C. Bajaj and I. Ihm, SIGGRAPH 1992

- *Surface Fitting with Implicit Algebraic Surface Patches* by Chanderjit Bajaj, in Topics in Surface Modeling, ed. by H. Hagen, SIAM Publications, 1992

- *Implicit Surfaces in CSG Systems by Geoff Wyvill,* unpublished

Polygonization

- *Data Structure for Soft Objects* by G. Wyvill, C. McPheeters, and B. Wyvill, The Visual Computer, August 1986

- *Polygonization of Implicit Surfaces* by Jules Bloomenthal, Computer Aided Geometric Design, November 1988

- *Evaluation of Implicit Surface Tilers* by P. Ning and J. Bloomenthal, Computer Graphics and Applications, to appear (1993)

- *Table Driven Polygonization* by B. Wyvill and D. Jevans, unpublished

Blending

- *Using Implicit Surfaces to Blend Arbitrary Solid Models* by Alyn Rockwood, Transactions on Graphics, October 1989

- *Convolution Surfaces* by J. Bloomenthal and K. Shoemake, SIGGRAPH '91

- *Hand Crafted* by Jules Bloomenthal, Proc. of 4th Annual Western Computer Graphics Symposium, Banff, April 1992

- *Techniques for Implicit Modeling* by Jules Bloomenthal, Xerox PARC Technical Report P89-00106, (and in Modeling and Animating with Implicit Surfaces notes, SIGGRAPH 1990)

Rendering

- *Ray Tracing Implicit Surfaces* by John Hart, unpublished

- *Sphere Tracing* by John Hart, unpublished

- *Ray Tracing Soft Objects* by G. Wyvill and A. Trotman, unpublished

- *Texturing Implicit Surfaces* by Geoff Wyvill, unpublished

- *Solid Texturing of Soft Objects* by G. Wyvill, B. Wyvill, and C. McPheeters, Computer Graphics and Applications, December 1987

Interaction and Animation

- *Interactive Techniques for Implicit Modeling* by J. Bloomenthal and B. Wyvill, Computer Graphics, March 1990

- *Animating Soft Objects* by B. Wyvill, C. McPheeters, and G. Wyvill, The Visual Computer, August 1986

- *Metamorphosis of Implicit Surfaces* by Brian Wyvill, unpublished

- *Practical Uses for Implicit Surfaces in Animation* by Thad Beier, unpublished

Recommended Reading

- *Free-Form Deformation of Solid Geometric Models* by Thomas Sederberg and Scott Parry, SIGGRAPH 1986

- *Smooth Piecewise Quadratic Surfaces* by W. Dahmen in Mathematical Methods in Computer Aided Geometric Design, ed. by T. Lyche and L. Schumaker Academic Press, Boston, 1989

- *Electronic Models of the Human Anatomy* by Bajaj, C. in Curves and Surfaces in Computer Vision and Graphics II, Proc. Symposium on Electronic Imaging Science & Technology, vol. 1610, Boston, 1991, p. 230-237

- *Interactions between Flexible Solids: an Implicit Formulation for a Precise Contact Modeling*, by Marie-Paule Gascuel SIGGRAPH 1993

From: [A Opalach](#), comp.graphics, 8 Feb 1994

I remember a few messages asking for references on metaballs etc. Since my research is in this area I thought I could post the list of references I managed to look up.

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Vol. 25, No 4, July 1991, pp 227-235

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- Nishimura, H., Hirai, M., Kawai, T., Kawata, T., Shirakawa, I. and Omura, K., "*Object Modelling by Distribution Function and a Method of Image Generation*", The Transactions of the Institute of Electronics and Communication Engineers of Japan, 1985, Vol. J68-D, Part 4, pp. 718-725, in Japanese, translated into English by Takao Fujuwara

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