AMRF Part Model Extensions

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1 INTRODUCTION

1.1 Motivation

The AMRF part model format was created as a data specification language for the communication of product data between manufacturing application processes and the global database within the Automated Manufacturing Research Facility [Barkmeyer86]. The part model report format was intended to be a temporary solution to a subset of the complex problems in automating manufacturing that were not being addressed by the current standard Initial Graphics Exchange Specification (IGES). The experience gained through the implementation of the format was to be used as input for developing national standards [Hopp87a] such as ISO's Product Data Exchange Specification (PDES) [Smith88].

This document specifies the addition of coordinate system independent representations of ellipses, hyperbolas, parabolas and non-rational, uniform b-splines to the part model report. These changes were the recommendation of a Manufacturing Data Preparation project working group [Fowler88]. While the addition of these entities does not resolve all the shortcomings of the format, it was necessary to allow the use of more complex test parts within the AMRF. Further geometric extensions will result from the migration to PDES.

1.2 Audience

This document is a reference guide to the grammar of the extensions to the AMRF part model. This document is intended to be used by programmers implementing systems that will make use of AMRF part model data. It is expected that the user is familiar with the contents of the document "AMRF Database Report Format: Part Model" [Hopp87b] as this document contains only the additions to the part model format. The two documents must be used in conjunction with each other for completeness.

1.3 Overview

Section 2 of this document describes the structure and syntax of the part model report grammar and mentions tools that use the format. Appendix A provides a formal definition of the new grammar. Appendix B contains the revised dictionary definition. Appendix C provides a formal definition of the new data types. Appendix D contains sample part model files along with sketches of the parts being modeled.

2 PART MODEL EXTENSIONS

2.1 Structure of the Part Model Format

The AMRF part model format has five main sections; header, topology, geometry, features and functionality. At minimum, the report must contain the geometry and topology of a valid boundary representation solid model. Figure 1 illustrates the structure of the geometry and topology hierarchy. Ellipse, hyperbola, parabola and b-spline all fall under the curves subsection of the geometry section of the part model format.

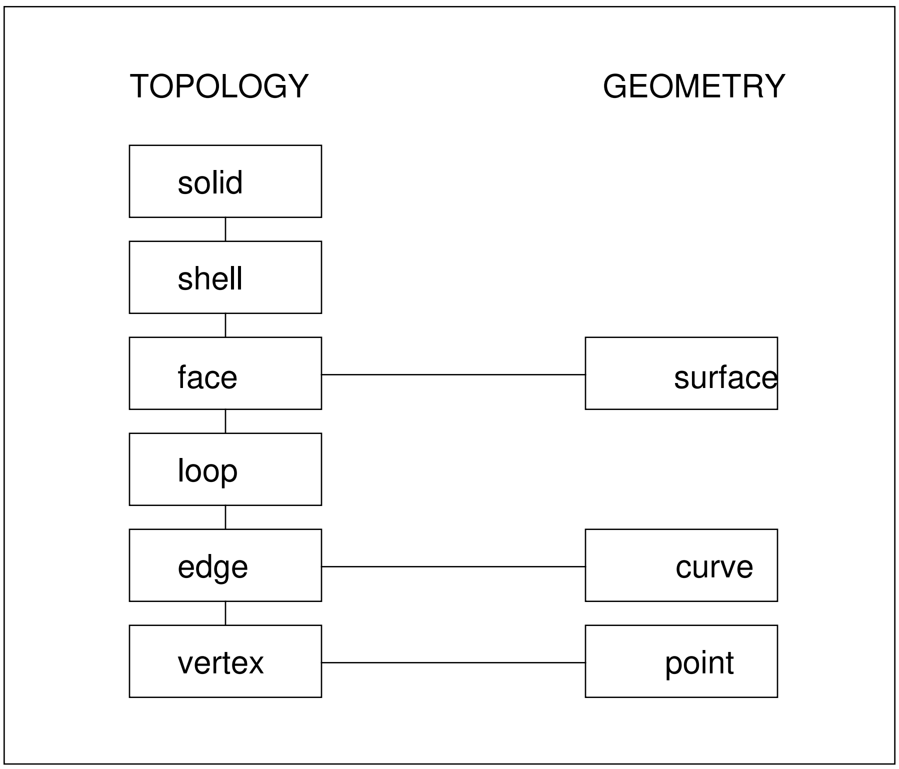

Figure 1. Topology and Geometry Hierarchy in a Boundary Model [Hopp87b]

2.2 Explanation of Formal Language Syntax

The additions, like the rest of the part model grammar, are expressed in Backus Naur Form (BNF); a context free syntax. This grammar has been annotated with semantic rules that define how the reports should be interpreted when parsed. The semantic rules express the standard AMRF interpretation for these reports. As such, these rules should be viewed as a guide, rather than a requirement as to how the parser should be implemented.

The syntax rules are of the form:

left-hand-side ::= right-hand-side

where the left-hand-side is a single non-terminal symbol in the grammar and the right-hand-side is a sequence of one or more grammar symbols. Grammar symbols in the right-hand side that are to appear verbatim in the report appear in boldface type. All other symbols are enclosed in angle brackets <like this>. Terminal symbols other than literals are underlined. Numbers are the only terminal symbols that appear in the extensions, they have a *val* attribute that represents the value of the number.

Semantic rules are associated with each reduction in the grammar. They define how attributes from the left-hand-side of a reduction should be computed from attributes of the right-hand-side syntactic elements. The semantic rules are divided into two parts: the first labeled **Semantics** defines the actions that should be taken when a particular reduction is applied during the parsing. The **Constraints** section defines consistency criteria that can be used at the time a reduction is applied to check for errors in the report.

The semantic rules make use of global dictionary data structures. Dictionaries may be any sort of convenient data structure, from a linked list to a hash table to a relational database. They function as symbol tables for objects named in the report. A dictionary should be considered an array of identical elements indexed by symbolic names. The extensions defined in this report specify new entity structures for curveDictionary. The semantic rules refer to entities in pointDictionary and unitVectorDictionary. Entities in all dictionaries are named entities; entities in different dictionaries in the same part may have the same name, while still being distinct entities. For further details see [Hopp87b].

2.3 Use of the Part Model Extensions

Several tools exist which support the AMRF part model format. Manufacturing applications within the AMRF receive information from the part model through a parser which treats the report as a source of data and creates a set of initialized data structures in memory. An updated version of the part model parser exists and can be invoked by following the directions found in "Using the AMRF Part Model Format" [Ressler87]. Prototype part model report generation software has been implemented on several publicly available CAD systems at NIST. Solid model representations of parts created on these systems may be extracted from the proprietary database and converted to the AMRF part model format. The part model report may then be translated into a subset of PDES/STEP by another translator. For details on PDES conversion, see "Converting the AMRF Part Model Report to a PDES/STEP Subset" [Lee88].

APPENDIX A: GRAMMAR

1. <curve-description> ::= **ELLIPSE**; <point-id>; <unit-vector-id>$_1$; <unit-vector-id>$_2$; <number>$_1$; <number>$_2$.

   Semantics:

   curve(<curve-description>)<--
   ELLIPTICAL_CURVE(
   center: pointDictionary [name(<point-id>)],
   major_axis: unitVectorDictionary [name(<unit-vector-id>$_1$)],
   normal: unitVectorDictionary [name(<unit-vector-id>$_2$)],
   major_radius: val(<number>$_1$),
   minor_radius: val(<number>$_2$))

   Constraints:

   If d_1 = dir(unitVectorDictionary [name(<unit-vector-id>$_1$)])
   d_2 = dir(unitVectorDictionary [name(<unit-vector-id>$_2$)])

   Then $d_1 \cdot d_2 = 0$
   <number>$_1$, <number>$_2$ > 0

2. <curve-description> ::= **HYPERBOLA**; <point-id>; <unit-vector-id>$_1$; <unit-vector-id>$_2$; <number>$_1$; <number>$_2$.

   Semantics:

   curve(<curve-description>)<--
   HYPERBOLIC_CURVE(
   center: pointDictionary [name(<point-id>)],
   major_axis: unitVectorDictionary [name(<unit-vector-id>$_1$)],
   normal: unitVectorDictionary [name(<unit-vector-id>$_2$)],
   major_radius: val(<number>$_1$),
   minor_radius: val(<number>$_2$))

   Constraints:

   If d_1 = dir(unitVectorDictionary [name(<unit-vector-id>$_1$)])
   d_2 = dir(unitVectorDictionary [name(<unit-vector-id>$_2$)])

   Then $d_1 \cdot d_2 = 0$
   <number>$_1$, <number>$_2$ > 0
   The branch of the hyperbola represented is that pointed to by the major_axis.

3. <curve-description> ::= **PARABOLA**; <point-id>; <unit-vector-id>$_1$; <unit-vector-id>$_2$; <number>.

   Semantics:

   curve(<curve-description>)<--

PARABOLIC_CURVE(
center: pointDictionary [name(<point-id>)],
focal_dir: unitVectorDictionary [name(<unit-vector-id>$_1$)],
normal: unitVectorDictionary [name(<unit-vector-id>$_2$)],
focal_dist: val(<number>))

Constraints:

If d_1 = dir(unitVectorDictionary [name(<unit-vector-id>$_1$)])
d_2 = dir(unitVectorDictionary [name(<unit-vector-id>$_2$)])

Then $d_1 \cdot d_2 = 0$
<number> <> 0

4. <curve-description> ::= **B-SPLINE**; <number>$_1$; <number>$_2$; <point-id-list>.

Semantics:

curve(<curve-description>)<--
B-SPLINE_CURVE(
degree: val(<number>$_1$),
number_control_points: val(<number>$_2$),
control_points: points(<point-id-list>))

Constraints:

val(<number>$_1$) is an integer >= 0
val(<number>$_2$) is an integer >= (val(<number>$_1$) + 1)
<point-id-list> is an array [1..val(<number>$_2$)] of points

5. <point-id-list> ::= <point-id>

Semantics:

points(<point-id-list>)<--
LIST(
head: pointDictionary[name(<point-id>)],
tail: nil)

Constraints: NONE

6. <point-id-list>$_1$ ::= <point-id>, <point-id-list>$_2$

Semantics:

points(<point-id-list>$_1$)<--
LIST(
head: pointDictionary[name(<point-id>)],
tail: points(<point-id-list>$_2$))

Constraints: NONE

APPENDIX B: DICTIONARY STRUCTURES

curveDictionary

index: curve id string
contents:
name: curve id string
curve: a curve description

A curve description can now be one of ELLIPTICAL_CURVE, HYPERBOLIC_CURVE, PARABOLIC_CURVE, B-SPLINE_CURVE data structures in addition to the LINEAR_CURVE and CIRCULAR_CURVE data structures previously allowed.

The following dictionary structures are unchanged but are included for completeness:

pointDictionary

index: point id string
contents:
name: point id string
vec: a vector

A vector is a VECTOR data structure.

unitVectorDictionary

index: unit vector id string
contents:
name: unit vector id string
dir: a direction

A direction is a UNIT_VECTOR data structure.

APPENDIX C: TYPE DEFINITIONS

ELLIPTICAL_CURVE

A structure with five fields:

center: a point
major_axis: a direction
normal: a direction
major_radius: a number
minor_radius: a number

A point data structure is an entry in pointDictionary. A direction data structure is an entry in the unitVectorDictionary.

HYPERBOLIC_CURVE

A structure with five fields:

center: a point
major_axis: a direction
normal: a direction
major_radius: a number
minor_radius: a number

A point data structure is an entry in pointDictionary. A direction data structure is an entry in the unitVectorDictionary.

PARABOLIC_CURVE

A structure with four fields:

center: a point
focal_dir: a direction
normal: a direction
focal_dist: a number

A point data structure is an entry in pointDictionary. A direction data structure is an entry in the unitVectorDictionary.

B-SPLINE_CURVE

A structure with three fields:

degree: a number
number_control_points: a number
control_points: a list of points

A point data structure is an entry in pointDictionary.

The type LIST was used in "AMRF Database Report Format: Part Model" but was omitted from the type definitions. It is included here for the sake of completeness.

LIST

A LIST is either the constant nil or a structure with two fields:

head: an element from a dictionary
tail: a LIST

The data structure of the head is determined by the dictionary in which the element occurs.

The types VECTOR and UNIT_VECTOR are unchanged but are included here for the completeness.

VECTOR

A structure with three fields:

x: a number
y: a number
z: a number

UNIT_VECTOR

A structure with three fields:

x: a number
y: a number
z: a number

APPENDIX D: SAMPLE PART MODEL FILES

The following examples are included to illustrate the use of the extensions. To test the implementation of these extensions, solid models containing the curves were created on the Computervision CAD system. A prototype extraction tool developed in-house was then used to convert between Computervision's proprietary database and the AMRF part model report format. In the text, the curve representations have been emboldened.

Ellipse

The part ELLIPSE_TEST was created by subtracting a block from a cylinder such that the block intersected the curved surface at an angle. There are four distinct ellipses represented in this model. The part model file follows Figure 2.

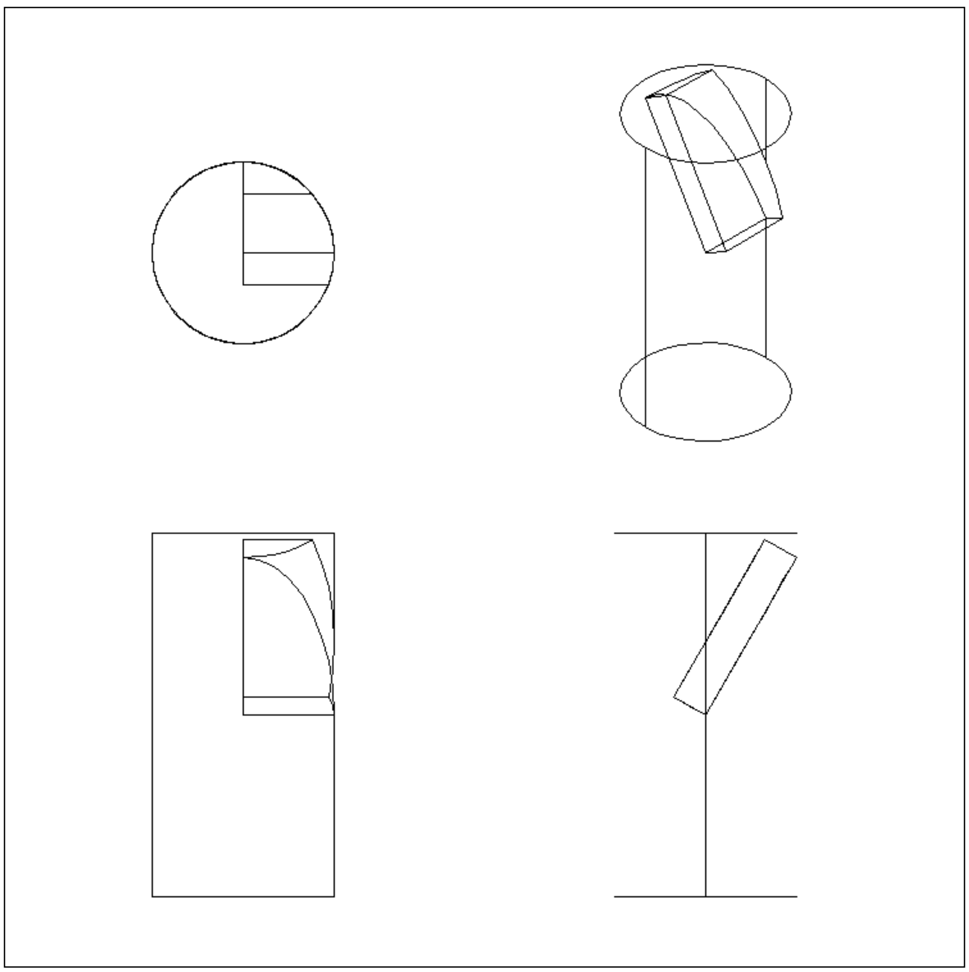

Figure 2. Sketch of Solid Model Containing Ellipses

```
/PART_MODEL
/HEADER
        PART_NAME = 'ELLIPSE_TEST'.
/END_HEADER
/TOPOLOGY
/SHELLS
        SHL1;FAC280,FAC281,FAC282,FAC284,FAC283,FAC285,FAC286,FAC295,FAC297.
/END_SHELLS
/FACES
        FAC280;LOP28001; SRF288 + .
        FAC281;LOP28101; SRF289 + .
        FAC282;LOP28201; SRF290 + .
        FAC284;LOP28401; SRF291 + .
        FAC283;LOP28301; SRF292 + .
        FAC285;LOP28501; SRF293 + .
        FAC286;LOP28601; SRF294 + .
        FAC295;LOP29501; SRF296 + .
        FAC297;LOP29701; SRF298 + .
/END_FACES
/LOOPS
        LOP28001;EDG301-,EDG264+,EDG270-,EDG299+.
        LOP28101;EDG266+,EDG299-,EDG268+,EDG276+.
        LOP28201;EDG268-,EDG270+,EDG279+.
        LOP28401;EDG264-,EDG262+,EDG278-.
        LOP28301;EDG277-,EDG262-,EDG301+,EDG266-,EDG275-.
        LOP28501;EDG276-,EDG272-,EDG307+,EDG305+,EDG303-,EDG274-,EDG275+.
        LOP28601;EDG274+,EDG311-,EDG305-,EDG309+,EDG272+,EDG279-,EDG278+,
        EDG277+.
        LOP29501;EDG303+,EDG311+.
        LOP29701;EDG309-,EDG307-.
/END_LOOPS
/EDGES
        EDG299;VTX316,VTX315; CRV300 +.
        EDG270;VTX316,VTX260; CRV269 +.
        EDG264;VTX317,VTX260; CRV263 +.
        EDG301;VTX317,VTX315; CRV302 +.
        EDG276;VTX258,VTX257; CRV252 +.
        EDG268;VTX316,VTX258; CRV267 +.
        EDG266;VTX257,VTX315; CRV265 +.
        EDG279;VTX260,VTX258; CRV255 +.
```

```
	EDG278;VTX260,VTX256; CRV254 +.
	EDG262;VTX317,VTX256; CRV261 +.
	EDG275;VTX259,VTX257; CRV251 +.
	EDG277;VTX256,VTX259; CRV253 +.
	EDG274;VTX259,VTX319; CRV273 +.
	EDG303;VTX319,VTX318; CRV304 +.
	EDG305;VTX314,VTX318; CRV306 +.
	EDG307;VTX313,VTX314; CRV308 +.
	EDG272;VTX313,VTX258; CRV271 +.
	EDG309;VTX314,VTX313; CRV310 +.
	EDG311;VTX318,VTX319; CRV312 +.
/END_EDGES
/VERTICES
	VTX316;PNT3160.
	VTX315;PNT3150.
	VTX260;PNT2600.
	VTX317;PNT3170.
	VTX258;PNT2580.
	VTX257;PNT2570.
	VTX256;PNT2560.
	VTX259;PNT2590.
	VTX319;PNT3190.
	VTX318;PNT3180.
	VTX314;PNT3140.
	VTX313;PNT3130.
/END_VERTICES
/END_TOPOLOGY
/GEOMETRY
/SURFACES
	SRF288; PLANE; UNV2650; 0.00000000 .
	SRF289; PLANE; UNV2510; 0.00000000 .
	SRF290; PLANE; UNV2540; 0.00000000 .
	SRF291; PLANE; UNV2521; 10.00000000 .
	SRF292; PLANE; UNV3000; 2.00000000 .
	SRF293; CYLINDER; PNT3080; UNV2730; 5.00000000 .
	SRF294; CYLINDER; PNT3080; UNV2730; 5.00000000 .
	SRF296; PLANE; UNV2730; 10.00000000 .
	SRF298; PLANE; UNV2730; -10.00000000 .
/END_SURFACES
/CURVES
```

CRV300; LINE; PNT3160; UNV3000.
CRV269; LINE; PNT3160; UNV2690.
CRV263; LINE; PNT3170; UNV2630.
CRV302; LINE; PNT3170; UNV3020.
CRV252; ELLIPSE; PNT3160; UNV3000; UNV2521; 5.77350283; 5.00000000 .
CRV267; LINE; PNT3160; UNV2670.
CRV265; LINE; PNT2570; UNV2650.
CRV255; ELLIPSE; PNT2550; UNV2521; UNV3000; 10.00000000; 5.00000000 .
CRV254; ELLIPSE; PNT2540; UNV2540; UNV2521; 5.77350283; 5.00000000 .
CRV261; LINE; PNT3170; UNV2670.
CRV251; ELLIPSE; PNT2510; UNV2510; UNV3000; 10.00000000; 5.00000000 .
CRV253; ELLIPSE; PNT2510; UNV2510; UNV3000; 10.00000000; 5.00000000 .
CRV273; LINE; PNT2590; UNV2730.
CRV304; CIRCLE; PNT3040; UNV2730; PNT3190.
CRV306; LINE; PNT3140; UNV2730.
CRV308; CIRCLE; PNT3080; UNV2730; PNT3130.
CRV271; LINE; PNT3130; UNV2730.
CRV310; CIRCLE; PNT3080; UNV2730; PNT3101.
CRV312; CIRCLE; PNT3040; UNV2730; PNT3121.

/END_CURVES
/POINTS

PNT3160; 0.00000000, 0.00000000, 0.00000000 .
PNT3150; 0.00000000, -1.00000000, 1.73205078 .
PNT2600; 0.00000000, -8.66025448, -5.00000000 .
PNT3170; 0.00000000, -9.66025448, -3.26794910 .
PNT2580; 5.00000000, 0.00000046, 0.00000000 .
PNT2570; 4.69041586, -1.00000000, 1.73205078 .
PNT2560; 3.78424478, -9.66025448, -3.26794910 .
PNT2590; 5.00000000, -3.99999952, 0.00000000 .
PNT3190; 5.00000000, -10.00000000, 0.00000000 .
PNT3180; -5.00000000, -10.00000000, 0.00000000 .
PNT3140; -5.00000000, 10.00000000, 0.00000000 .
PNT3130; 5.00000000, 10.00000000, 0.00000000 .
PNT2550; 0.00000000, -0.00000030, 0.00000000 .
PNT2540; 0.00000000, -11.54700565, 0.00000000 .
PNT2510; 0.00000000, -4.00000048, 0.00000000 .
PNT3040; 0.00000000, -10.00000000, 0.00000000 .
PNT3080; 0.00000000, 10.00000000, 0.00000000 .
PNT3101; -5.00000000, 10.00000000, -0.00000044 .
PNT3121; -5.00000000, -10.00000000, -0.00000044 .

```
/END_POINTS
/UNIT_VECTORS
    UNV3000; 0.00000000, -0.50000000, 0.86602539 .
    UNV2690; 0.00000000, -0.86602539, -0.49999997 .
    UNV2630; 0.00000000, 0.49999997, -0.86602539 .
    UNV3020; 0.00000000, 0.86602539, 0.49999997 .
    UNV2521; 0.00000000, -0.86602539, -0.50000000 .
    UNV2670; 1.00000000, 0.00000000, 0.00000000 .
    UNV2650; -1.00000000, 0.00000000, 0.00000000 .
    UNV2540; 0.00000000, 0.50000000, -0.86602539 .
    UNV2510; 0.00000000, 0.86602539, 0.50000000 .
    UNV2730; 0.00000000, -1.00000000, 0.00000000 .
/END_UNIT_VECTORS
/END_GEOMETRY
/END_PART_MODEL
```

Hyperbola

The part HYPERBOLA_TEST was modeled by subtracting a block from a cone where the sides of the block were parallel to and as long as the axis of the cone. There are four distinct hyperbolas in the model. The complete part model file follows the illustration in Figure 3.

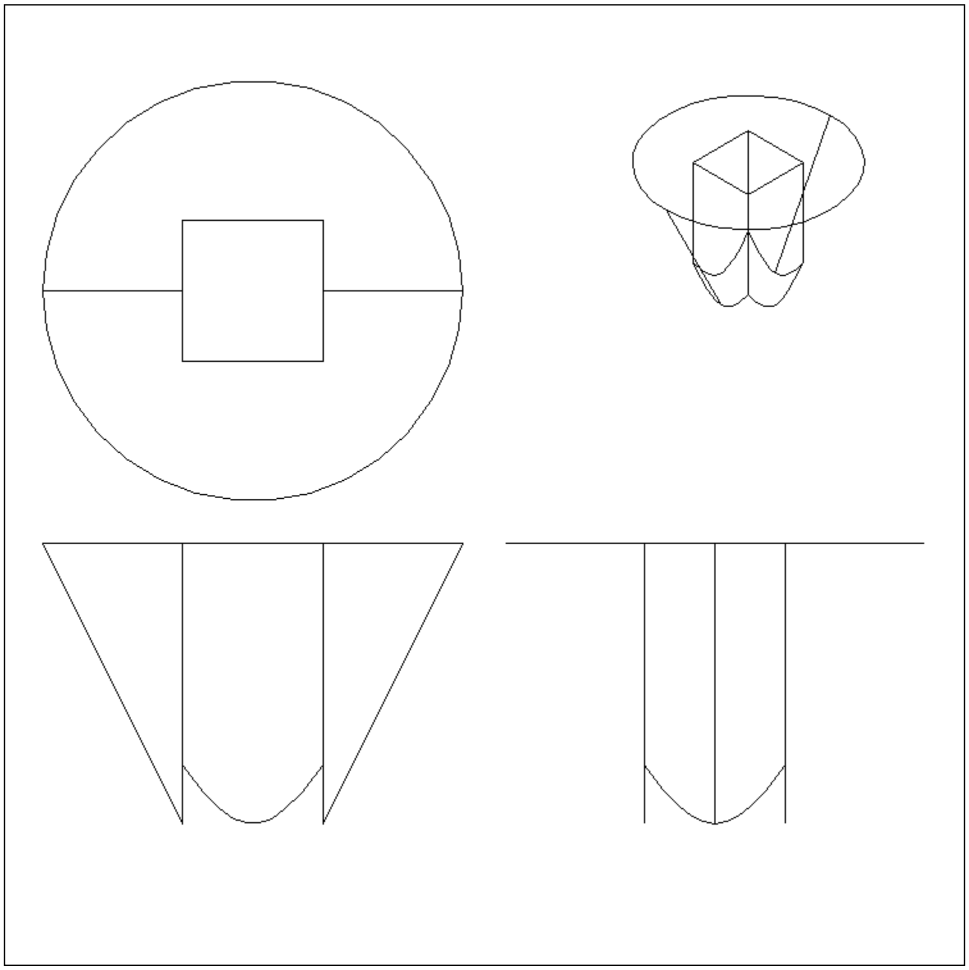

Figure 3. Sketch of Solid Model Containing Hyperbolas

```
/PART_MODEL
/HEADER
	PART_NAME = 'HYPERBOLA_TEST'.
/END_HEADER
/TOPOLOGY
/SHELLS
	SHL1;FAC2075,FAC2081,FAC2076,FAC2077,FAC2078,FAC2079,FAC2080.
/END_SHELLS
/FACES
	FAC2075;LOP207501; SRF2083 + .
```

FAC2081;LOP208101; SRF2084 + .
FAC2076;LOP207601; SRF2085 + .
FAC2077;LOP207701,LOP207702; SRF2086 + .
FAC2078;LOP207801; SRF2087 + .
FAC2079;LOP207901; SRF2088 + .
FAC2080;LOP208001; SRF2089 + .
/END_FACES
/LOOPS
LOP207501;EDG2074-,EDG2073-,EDG2054-,EDG2090+,EDG2056+,EDG2072-.
LOP208101;EDG2062-,EDG2072+,EDG2069+,EDG2064-,EDG2065+.
LOP207601;EDG2056-,EDG2092+,EDG2054+,EDG2071-,EDG2070-,EDG2069-.
LOP207701;EDG2090-,EDG2092-.
LOP207702;EDG2066+,EDG2067-,EDG2068-,EDG2065-.
LOP207801;EDG2060-,EDG2071+,EDG2073+,EDG2058-,EDG2067+.
LOP207901;EDG2058+,EDG2074+,EDG2062+,EDG2068+.
LOP208001;EDG2064+,EDG2070+,EDG2060+,EDG2066-.
/END_LOOPS
/EDGES
EDG2072;VTX2049,VTX2044; CRV2040 +.
EDG2056;VTX2095,VTX2044; CRV2055 +.
EDG2090;VTX2094,VTX2095; CRV2091 +.
EDG2054;VTX2094,VTX2043; CRV2053 +.
EDG2073;VTX2043,VTX2046; CRV2041 +.
EDG2074;VTX2046,VTX2049; CRV2042 +.
EDG2065;VTX2051,VTX2050; CRV2033 +.
EDG2064;VTX2051,VTX2052; CRV2063 +.
EDG2069;VTX2044,VTX2052; CRV2037 +.
EDG2062;VTX2049,VTX2050; CRV2061 +.
EDG2070;VTX2052,VTX2047; CRV2038 +.
EDG2071;VTX2047,VTX2043; CRV2039 +.
EDG2092;VTX2095,VTX2094; CRV2093 +.
EDG2068;VTX2050,VTX2045; CRV2036 +.
EDG2067;VTX2045,VTX2048; CRV2035 +.
EDG2066;VTX2051,VTX2048; CRV2034 +.
EDG2058;VTX2045,VTX2046; CRV2057 +.
EDG2060;VTX2047,VTX2048; CRV2059 +.
/END_EDGES
/VERTICES
VTX2049;PNT20490.
VTX2044;PNT20440.

VTX2095;PNT20950.
VTX2094;PNT20940.
VTX2043;PNT20430.
VTX2046;PNT20460.
VTX2051;PNT20510.
VTX2050;PNT20500.
VTX2052;PNT20520.
VTX2047;PNT20470.
VTX2045;PNT20450.
VTX2048;PNT20480.
/END_VERTICES
/END_TOPOLOGY
/GEOMETRY
/SURFACES
SRF2083; CONE; PNT20831; UNV20910; 0.89442718 .
SRF2084; PLANE; UNV20401; 1.00000000 .
SRF2085; CONE; PNT20831; UNV20910; 0.89442718 .
SRF2086; PLANE; UNV20910; -6.00000000 .
SRF2087; PLANE; UNV20411; 1.00000000 .
SRF2088; PLANE; UNV20421; 1.00000000 .
SRF2089; PLANE; UNV20381; 1.00000000 .
/END_SURFACES
/CURVES
CRV2040; HYPERBOLA; PNT20400; UNV20400; UNV20401; 2.00000000; 1.00000000 .
CRV2055; LINE; PNT20950; UNV20550.
CRV2091; CIRCLE; PNT20910; UNV20910; PNT20940.
CRV2053; LINE; PNT20940; UNV20530.
CRV2041; HYPERBOLA; PNT20410; UNV20400; UNV20411; 2.00000000; 1.00000000 .
CRV2042; HYPERBOLA; PNT20420; UNV20400; UNV20421; 2.00000000; 1.00000000 .
CRV2033; LINE; PNT20330; UNV20421.
CRV2063; LINE; PNT20510; UNV20910.
CRV2037; HYPERBOLA; PNT20400; UNV20400; UNV20401; 2.00000000; 1.00000000 .
CRV2061; LINE; PNT20490; UNV20400.
CRV2038; HYPERBOLA; PNT20380; UNV20400; UNV20381; 2.00000000; 1.00000000 .
CRV2039; HYPERBOLA; PNT20410; UNV20400; UNV20411;

2.00000000; 1.00000000 .

CRV2093; CIRCLE; PNT20910; UNV20910; PNT20950.

CRV2036; LINE; PNT20360; UNV20411.

CRV2035; LINE; PNT20350; UNV20381.

CRV2034; LINE; PNT20340; UNV20411.

CRV2057; LINE; PNT20450; UNV20910.

CRV2059; LINE; PNT20470; UNV20400.

/END_CURVES

/POINTS

PNT20490; -1.00000000, -2.82842708, -1.00000000 .

PNT20440; -1.00000000, -2.00000000, 0.00000000 .

PNT20950; -3.00000000, -6.00000000, 0.00000000 .

PNT20940; 3.00000000, -6.00000000, 0.00000000 .

PNT20430; 1.00000000, -2.00000000, 0.00000000 .

PNT20460; 1.00000000, -2.82842708, -1.00000000 .

PNT20510; -1.00000000, -6.00000000, 1.00000000 .

PNT20500; -1.00000000, -6.00000000, -1.00000000 .

PNT20520; -1.00000000, -2.82842708, 1.00000000 .

PNT20470; 1.00000000, -2.82842708, 1.00000000 .

PNT20450; 1.00000000, -6.00000000, -1.00000000 .

PNT20480; 1.00000000, -6.00000000, 1.00000000 .

PNT20400; -1.00000000, 0.00000000, 0.00000000 .

PNT20910; 0.00000000, -6.00000000, 0.00000000 .

PNT20410; 1.00000000, 0.00000000, 0.00000000 .

PNT20420; 0.00000000, 0.00000000, -1.00000000 .

PNT20330; -1.00000000, -6.00000000, 1.00000012 .

PNT20380; 0.00000000, 0.00000000, 1.00000000 .

PNT20360; -1.00000012, -6.00000000, -1.00000000 .

PNT20350; 1.00000000, -6.00000000, -1.00000012 .

PNT20340; -1.00000012, -6.00000000, 1.00000000 .

PNT20831; 0.00000000, 0.00000000, 0.00000000 .

/END_POINTS

/UNIT_VECTORS

UNV20400; 0.00000000, -1.00000000, 0.00000000 .

UNV20401; -1.00000000, 0.00000000, 0.00000000 .

UNV20550; 0.44721359, 0.89442718, 0.00000000 .

UNV20910; 0.00000000, 1.00000000, 0.00000000 .

UNV20530; -0.44721359, 0.89442718, 0.00000000 .

UNV20411; 1.00000000, 0.00000000, 0.00000000 .

UNV20421; 0.00000000, 0.00000000, -1.00000000 .

```
    UNV20381; 0.00000000, 0.00000000, 1.00000000 .
/END_UNIT_VECTORS
/END_GEOMETRY
/END_PART_MODEL
```

Parabola

A parabolic intersection curve occurs when a plane is oriented such that the angle of the plane and the angle of the cone surface to the cone axis is the same. However, no Computervision solid models created in this manner contain parabolas. An example of the representation of a parabola is included in the place of a part model file:

CRV13300; PARABOLA; PNT132920; UNV117340; UNV121220; PNT132897.

B-Spline

The part TORPEDO_MOTOR was also modeled on the Computervision system and is an example of an AMRF test part. The part model file for the torpedo motor is too long to be included in its entirety. This part is an example of the complexity of the parts that can now be handled with the AMRF part model format.

Figure 4. Torpedo Motor Containing B-Splines

```
PART_MODEL
/HEADER
        PART_NAME = 'TORPEDO_MOTOR'.
/END_HEADER
/TOPOLOGY
/SHELLS
        SHL1;FAC11846,FAC11859,FAC11864,FAC11861,FAC11858,FAC11851,
            FAC11872,FAC11874,FAC11876,FAC11878,FAC11880,FAC11882,FAC11884,
            FAC11886,FAC11888,FAC11890,FAC11892,FAC11894,FAC11850,FAC11847,
```

FAC11862,FAC11855,FAC11854,FAC11863,FAC11852,FAC11848,FAC11849,
FAC11853,FAC11860,FAC11857,FAC11856,FAC11909,FAC11911,FAC11913,
FAC11915,FAC11917,FAC11919,FAC11921,FAC11923,FAC11925,FAC11927,
FAC12293,FAC12295,FAC12297,FAC12299,FAC12301,FAC12303,FAC12305,
FAC12307,FAC12309,FAC12311,FAC12313,FAC12315,FAC12317,FAC12319,
FAC12321,FAC12323,FAC12325,FAC12327,FAC12329,FAC12331,FAC12333,
FAC12335,FAC12337,FAC12339,FAC12341,FAC12343,FAC12345,FAC12347,
FAC12349,FAC12351,FAC12353,FAC12355,FAC12357,FAC12359,FAC12361,
FAC12363,FAC12365,FAC12367,FAC12369,FAC12371,FAC12373,FAC12375.
. . .
/END_SHELLS
/FACES
FAC11846;LOP1184601; SRF11866 + .
FAC11859;LOP1185901; SRF11867 + .
FAC11864;LOP1186401; SRF11868 + .
FAC11861;LOP1186101; SRF11869 + .
FAC11858;LOP1185801,LOP1185802; SRF11870 + .
FAC11851;LOP1185101; SRF11871 + .
FAC11872;LOP1187201,LOP1187202,LOP1187203,LOP1187204; SRF11873 + .
FAC11874;LOP1187401; SRF11875 + .
FAC11876;LOP1187601,LOP1187602; SRF11877 + .
FAC11878;LOP1187801; SRF11879 + .
FAC11880;LOP1188001; SRF11881 + .
. . .
/END_FACES
/LOOPS
LOP1211901;EDG12937+,EDG12895+,EDG12935-,EDG13199-.
LOP1212101;EDG13167+,EDG12959+,EDG12897+,EDG13201-.
LOP1212301;EDG13203+,EDG13205+,EDG12907+,EDG13131-.
LOP1212501;EDG12909+,EDG13207-,EDG13209-,EDG13001+.
LOP1212701;EDG13169+,EDG13201+,EDG12917+,EDG12991+.
LOP1212901;EDG13213-,EDG13211-.
LOP1212902;EDG12921-,EDG12925-.
LOP1213101;EDG13217-,EDG13215-.
LOP1213102;EDG12929-,EDG12933-.
LOP1213301;EDG13219+,EDG12939+,EDG13221-,EDG13223-.
LOP1213501;EDG13227-,EDG12955-,EDG12967-,EDG13225-,EDG12945-,
EDG12943-.
LOP1213502;EDG13231-,EDG13229-.
LOP1213701;EDG12951+,EDG13233-,EDG13235+,EDG13237+.

```
        LOP1213901;EDG12953+,EDG13237-,EDG13239+,EDG13233+.
        LOP1214101;EDG12983+,EDG13241+,EDG12965-,EDG13149-.
        LOP1214301;EDG12969+,EDG13243-,EDG13245+,EDG13247+.
        . . .
/END_LOOPS
/EDGES
        EDG12441;VTX13739,VTX13727; CRV12442 +.
        EDG12443;VTX13727,VTX13734; CRV12444 +.
        EDG12445;VTX13734,VTX13740; CRV12446 +.
        EDG12447;VTX13740,VTX13736; CRV12448 +.
        EDG12449;VTX13736,VTX13716; CRV12450 +.
        EDG12451;VTX13738,VTX13737; CRV12452 +.
        EDG12453;VTX13737,VTX13738; CRV12454 +.
        EDG12455;VTX13725,VTX13736; CRV12456 +.
        EDG12457;VTX13725,VTX13726; CRV12458 +.
        EDG12459;VTX13724,VTX13725; CRV12460 +.
        EDG12461;VTX13723,VTX13724; CRV12462 +.
        EDG12463;VTX13730,VTX13732; CRV12464 +.
        EDG12465;VTX13730,VTX13720; CRV12466 +.
        EDG12467;VTX13720,VTX13719; CRV12468 +.
        EDG12469;VTX13719,VTX13733; CRV12470 +.
        . . .
/END_EDGES
/VERTICES
        VTX14074;PNT140740.
        VTX14077;PNT140770.
        VTX14091;PNT140910.
        VTX14090;PNT140900.
        VTX14095;PNT140950.
        VTX14094;PNT140940.
        VTX14112;PNT141120.
        VTX14115;PNT141150.
        VTX13755;PNT137550.
        VTX13748;PNT137480.
        VTX13783;PNT137830.
        VTX13770;PNT137700.
        VTX13778;PNT137780.
        VTX13767;PNT137670.
        VTX13784;PNT137840.
        VTX14075;PNT140750.
```

```
    . . .
/END_VERTICES
/END_TOPOLOGY
/GEOMETRY
/SURFACES
    SRF11907; CYLINDER; PNT119071; UNV117340; 0.12850013 .
    SRF11908; CYLINDER; PNT119071; UNV117340; 0.12850013 .
    SRF11910; PLANE; UNV117340; 1.18700004 .
    SRF11912; CONE; PNT119121; UNV117440; -0.94405442 .
    SRF11914; CYLINDER; PNT118661; UNV117340; 0.93750000 .
    SRF11916; CYLINDER; PNT118661; UNV117340; 0.87500000 .
    SRF12348; PLANE; UNV117440; -0.12200000 .
    SRF12350; CYLINDER; PNT134680; UNV117440; 0.65649998 .
    SRF12352; CYLINDER; PNT134680; UNV117440; 0.65649998 .
    SRF12354; PLANE; UNV117440; -0.06200000 .
    SRF12356; PLANE; UNV117340; 0.59299999 .
    SRF12358; PLANE; UNV117340; 0.59299999 .
    SRF12360; CONE; PNT138920; UNV117340; 0.51795375 .
    SRF12362; CONE; PNT138920; UNV117340; 0.51795375 .
    SRF12364; CONE; PNT138930; UNV117340; 0.51795363 .
    SRF12366; CONE; PNT138930; UNV117340; 0.51795363 .
    SRF12368; CYLINDER; PNT124080; UNV117340; 1.83700001 .
    SRF12370; CYLINDER; PNT124080; UNV117340; 2.77699995 .
    SRF12372; PLANE; UNV117440; -0.12200000 .
    SRF12374; PLANE; UNV117340; 0.43700001 .
    SRF12376; CYLINDER; PNT124080; UNV117340; 1.83700001 .
    . . .
/END_SURFACES
/CURVES
    CRV11734; CIRCLE; PNT117340; UNV117340; PNT117341.
    CRV11736; BSPLINE; 3; 24;PNT11736001,PNT11736002,PNT11736003,
      PNT11736004,PNT11736005,PNT11736006,PNT11736007,PNT11736008,
      PNT11736009,PNT11736010,PNT11736011,PNT11736012,PNT11736013,
      PNT11736014,PNT11736015,PNT11736016,PNT11736017,PNT11736018,
      PNT11736019,PNT11736020,PNT11736021,PNT11736022,PNT11736023,
      PNT11736024.
    CRV13296; LINE; PNT139360; UNV117340.
    CRV13302; CIRCLE; PNT133020; UNV117340; PNT139230.
    CRV13304; LINE; PNT139230; UNV117340.
    CRV13306; LINE; PNT139240; UNV117340.
```

CRV13308; CIRCLE; PNT133020; UNV117340; PNT133081.
**CRV13310; BSPLINE; 3; 42;PNT13310001,PNT13310002,PNT13310003,
PNT13310004,PNT13310005,PNT13310006,PNT13310007,PNT13310008,
PNT13310009,PNT13310010,PNT13310011,PNT13310012,PNT13310013,
PNT13310014,PNT13310015,PNT13310016,PNT13310017,PNT13310018,
PNT13310019,PNT13310020,PNT13310021,PNT13310022,PNT13310023,
PNT13310024,PNT13310025,PNT13310026,PNT13310027,PNT13310028,
PNT13310029,PNT13310030,PNT13310031,PNT13310032,PNT13310033,
PNT13310034,PNT13310035,PNT13310036,PNT13310037,PNT13310038,
PNT13310039,PNT13310040,PNT13310041,PNT13310042.**
CRV13312; CIRCLE; PNT133020; UNV117340; PNT139240.
**CRV13314; BSPLINE; 3; 16;PNT13314001,PNT13314002,PNT13314003,
PNT13314004,PNT13314005,PNT13314006,PNT13314007,PNT13314008,
PNT13314009,PNT13314010,PNT13314011,PNT13314012,PNT13314013,
PNT13314014,PNT13314015,PNT13314016.**
CRV13316; CIRCLE; PNT133160; UNV117340; PNT139200.
CRV13324; CIRCLE; PNT133160; UNV117340; PNT133241.
CRV13412; CIRCLE; PNT134020; UNV117340; PNT134121.
**CRV13414; BSPLINE; 3; 16;PNT13414001,PNT13414002,PNT13414003,
PNT13414004,PNT13414005,PNT13414006,PNT13414007,PNT13414008,
PNT13414009,PNT13414010,PNT13414011,PNT13414012,PNT13414013,
PNT13414014,PNT13414015,PNT13414016.**
CRV13416; CIRCLE; PNT134160; UNV117340; PNT139330.
CRV13418; LINE; PNT139330; UNV117340.
CRV13420; LINE; PNT139990; UNV117340.
**CRV13422; BSPLINE; 3; 29;PNT13422001,PNT13422002,PNT13422003,
PNT13422004,PNT13422005,PNT13422006,PNT13422007,PNT13422008,
PNT13422009,PNT13422010,PNT13422011,PNT13422012,PNT13422013,
PNT13422014,PNT13422015,PNT13422016,PNT13422017,PNT13422018,
PNT13422019,PNT13422020,PNT13422021,PNT13422022,PNT13422023,
PNT13422024,PNT13422025,PNT13422026,PNT13422027,PNT13422028,
PNT13422029.**
CRV13424; CIRCLE; PNT134160; UNV117340; PNT134241,
. . .
/END_CURVES
/POINTS
PNT12694007; 1.03147268, -1.88477874, 2.65294743 .
PNT12694008; 1.02363145, -1.88648355, 2.64048505 .
PNT12694009; 1.01508069, -1.88823354, 2.62891936 .
PNT12694010; 1.00586081, -1.88999414, 2.61816525 .

```
        PNT12694011; 0.99601489, -1.89173067, 2.60823250 .
        PNT12694020; 0.88674426, -1.90130079, 2.55522299 .
        PNT12694021; 0.87319481, -1.90126789, 2.55334210 .
        PNT12694022; 0.85955244, -1.90096474, 2.55223274 .
        PNT12694023; 0.85042524, -1.90058005, 2.55199599 .
        PNT12694024; 0.84586364, -1.90034223, 2.55200005 .
        PNT12720001; 0.84609222, -1.90035415, 2.95799994 .
        PNT12720002; 0.85065025, -1.90059030, 2.95799994 .
        PNT12720003; 0.85976994, -1.90097165, 2.95775509 .
        PNT12720004; 0.87340039, -1.90127027, 2.95663476 .
        PNT12720014; 0.99608731, -1.89171839, 2.90169883 .
        . . .
/END_POINTS
/UNIT_VECTORS
        UNV120460; 0.99452192, 0.10452847, 0.00000000 .
        UNV120500; 0.74314481, -0.66913062, 0.00000000 .
        UNV120540; -0.30901700, -0.95105654, 0.00000000 .
        UNV120940; -0.20791164, 0.97814763, 0.00000000 .
        UNV120980; 0.80901700, 0.58778524, 0.00000000 .
        UNV121220; 0.20791170, 0.97814763, 0.00000000 .
        UNV121260; -0.80901700, 0.58778524, 0.00000000 .
        . . .
/END_UNIT_VECTORS
/END_GEOMETRY
/END_PART_MODEL
```

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