Clipping and Intersection Algorithms:
Short Survey and References

Vaclav Skala
University of West Bohemia, Faculty of Applied Sciences
Dept. of Computer Science and Engineering
Pilsen, CZ 301 00, Czech Republic
skala@kiv.zcu.cz www.VaclavSkala.eu

Abstract. This contribution presents a brief survey of clipping and intersection algorithms in $E^2$ and $E^3$ with a nearly complete list of relevant references. Some algorithms use the projective extension of the Euclidean space and vector–vector operations, which supports GPU and SSE use. This survey is intended as help to researchers, students, and practitioners dealing with intersection and clipping algorithms. ¹

Keywords: Intersection algorithms · line clipping · line segment clipping · polygon clipping · triangle-triangle intersection · homogeneous coordinates · projective space · duality · computer graphics · geometry.

1 Introduction

Intersection algorithms are the key algorithms in many areas, e.g. in geometry intersection algorithms of two lines in $E^2$ or three planes in $E^3$. Many of those algorithms are part of standard courses and based on formulations in the Euclidean geometry, e.g. Schneider-Eberly[149]. However, there is a problem with results in an infinity or close to an infinity in some cases. Some cases can be solved using the projective extension of the Euclidean space extension of duality Skala[168]. The projective extension enables to represent points in an infinity and using the principle of duality to solve dual problems by the same algorithm Skala[167].

Also, as this approach leads to formulations using vector–vector operations, it is convenient for GPU and SSE use.

Algorithms for intersections of different geometric entities in $E^2$ and $E^3$ are studied for a long time from different aspects as their robustness and the precision of numerical computations is severely influenced by the limited numerical precision available at today’s computer system. It is well known, that $(1/3) * 3 \neq 1$ in "the computer world". Even a simple summation $S = \sum_{i=1}^{n} a_i$ is not easy Skala[171].

¹ The PDF drafts of the Skala’s papers can be found at the papers repository http://afrodita.zcu.cz/~skala/publications.htm
It should be noted that, not only in geometry oriented algorithms, a special care has to be devoted to the cases where differences between mathematics with infinite precision and mathematics with a limited precision might cause problems which could lead to the unexpected and incorrect results, sometimes also leads to disasters.

Unfortunately, programmers and computer scientists are mostly targeted to "the technology of implementation". They have a limited understanding of numerical aspects of today’s numerical data representation limited more or less to the IEEE floating-point representation IEEE-754[218]. Despite of the technological progress, the binary128 and binary256 precisions IEEE-754[218] are not supported in hardware.

It appears that there is no possibility to represent rational, irrational and transcendental numbers used in mathematics, where unlimited precision is expected, e.g. what is the difference of the value of $\pi$ and $(\text{longreal } \pi)(\text{longreal } \pi)$ if the IEEE-754 representation is used?

Line, half-line (ray), line segment and triangle-triangle intersection algorithms are considered as fundamental algorithms in nearly all algorithms dealing with geometrical aspects.

In computer graphics, some intersection algorithms are called clipping algorithms and serve to determine a part of one geometric entity inside of the second one.

2 Relevant books and journals

There are many books published related to intersection algorithms, clipping and computer graphics, which give more context, deeper understanding (*some books are available for free download via link.Springer.com), e.g.:

- Salomon,D.: The Computer Graphics Manual[148]*
  - highly recommended,
- Salomon,D.: Computer Graphics and Geometric Modeling[146],
- Agoston,M.K.: Computer Graphics and Geometric Modelling: Mathematics[2],
- Agoston,M.K.: Computer Graphics and Geometric Modelling: Implementation & Algorithms[1],
- Lengyel,E.: Mathematics for 3D Game Programming and Computer Graphics[95],
- Vince,J.: Introduction to the Mathematics for Computer Graphics[202]*
  - basic mathematical description of mathematics for undergraduates,
- Foley,J.D., van Dam,A., Feiner,S., Hughes,J.F.: Computer graphics - principles and practice[53],
- Hughes,J.F., van Dam, A., McGuire,M., Sklar,D.F., Foley,J.D., Feiner,S.K., Akeley, K.: Computer Graphics - Principles and Practice[72],
- Ferguson,R.S.: Practical Algorithms for 3D Computer Graphics[52],
- Shirley,P., Marschner,S.: Fundamentals of Computer Graphics[155]
There are also computer graphics books using OpenGL interface, e.g.:

- Hill, F.S., Kelley, S.M.: Computer Graphics Using OpenGL[68],
- Angel, E., Shreiner, D.: Interactive Computer Graphics[7],
- Hearn, D.D., Baker, M.P., Carithers, W.: Computer Graphics with OpenGL[64]
- Govil-Pai, S.: Principles of Computer Graphics: Theory and Practice Using OpenGL and Maya[56]

More advanced books using Geometric Algebra and Conformal Geometry Algebra approaches are recommended for a deeper study, e.g.:

- Vince, J.: Geometric Algebra: An Algebraic System for Computer Games and Animation[201],
- Vince, J.: Geometric Algebra for Computer Graphics[204],
- Dorst, L., Fontijne, D., Mann, S.: Geometric Algebra for Computer Science: An Object-Oriented Approach to Geometry[42],
- Hildenbrand, D.: Foundations of Geometric Algebra Computing[67],
- Kanatani, K.: Understanding Geometric Algebra: Hamilton, Grassmann, and Clifford for Computer Vision and Graphics[79],
- Calvet, R.G.: Treatise of Plane Geometry through Geometric Algebra[19]
- Guo, H.: Modern Mathematics and Applications in Computer Graphics and Vision[59].

A short description of barycentric coordinates using geometry algebra approach is available at Skala[166].

It is also recommended to study "the historical" books, e.g.:

- Newman, W.M., Sproull, R.F.: Principles of Interactive Computer Graphics[123],
- Harrington, S.: Computer Graphics: A Programming Approach[61],
- Mortenson, M.E.: Computer Graphics: An Introduction to the Mathematics and Geometry[121],
- Watt, A.: Fundamentals of Three-Dimensional Computer Graphics[211],
- Salomon, D.: Transformations and Projections in Computer Graphics[147],
- Akenine-Moller, T., Haines, E., Hoffman, N.: Real-Time Rendering[3],
- Eberly, D.H.: Game Physics[47],
- Pharr, M., Jakob, W., Humphreys, G.: Physically Based Rendering: From Theory to Implementation[131],
- Skala, V.: Clipping and Intersection Algorithms: Short Survey and References, ArXiv, https://doi.org/10.48550/arXiv.2206.13216, 2022
  DOI: 2206.13216
Many algorithms with codes are presented in GEMS books:

- Graphics Gems, Ed. Glassner, A. [55],
- Graphics Gems II, Ed. Arvo, J. [9],
- Graphics Gems III, Ed. Kirk, D. [80],
- Graphics Gems IV, Ed. Heckbert, P. S. [65].

Leading computer graphics journals:

- ACM Transactions on Graphics (TOG),
- Computer Graphics Forum (CGF),
- Computers & Graphics (C&G),
- IEEE Trans. on Visualization and Computer Graphics (TVCG),
- The Visual Computer (TVC),
- Computer Animation and Virtual Worlds (CAVW),
- Journal of Graphics Tools (JGT),
- Graphical Models

present a wide variety of intersection algorithm applications and theories.

In the following a brief classification of intersection algorithms in 2D and 3D will be made with short characteristics as Wiki [217]. The above-mentioned books present principles of the relevant methods and algorithms. Also, an overview of algorithms can be found in Skala [183] and the Bui’s PhD [16]. A deeper analysis, comparisons, classifications etc. can be found in the relevant papers.

There are so many fundamental algorithms variants that differ in some aspects; mainly, the timing factor is the primary motivation. However, claimed speed up mostly depends on the hardware properties (caching etc.), programmer’s skill and actual language and compiler used.

3 Intersection algorithms in 2D

Algorithms for intersections of different 2D geometric entities are studied for a long time from various aspects, primarily due to computation speed, robustness and limited numerical precision of the floating-point representation. The majority of 2D algorithms deals with an intersection of a line or a half-line (ray) or a line segment with 2D geometric entity, e.g. a rectangle, convex polygon, non-convex polygon, quadric and cubic curves, parametric curves and areas with quadratic arcs Skala [172] [181] [182], etc.

3.1 Intersection with a rectangular area

Intersection algorithms with a rectangular area (window) are well known as line clipping or as line segment clipping algorithms were developed and used
for a flight simulator project led by Cohen[23] in 1967. An efficient coding of a line segment position coding leading to significant computational reduction was introduced in Sproull&Sutherland[189] and patented by Sutherland[192] in 1972. The Cohen&Sutherland algorithm is described in Newman[123], Conmynos[25], Matthes[113], Matthes[114], etc.

The Cohen-Sutherland algorithm can be extended to the 3D case, i.e. intersection of a line with a cube or right parallelepiped. The Cohen-Sutherland algorithm was improved by Nicholl–Lee–Nicholl[124] and Bui[17] by classification of some possible cases. Ultimate cases classification was made by Skala[175] in 2021. The algorithms Liang-Barsky[102] and Doerr[46] are based on direct intersection computation of a line with polygon edges in the parametric form. Simple and robust 3D Clipping algorithms based on projective representation and homogeneous coordinates using a separation of the convex polygon vertices by the given line was presented in Skala[164][165][169][173].

Other known proposed algorithms can be found in references Bui[16], Andreev[6], Bao[10], Devai[36][37][38], Duvalenko[43][44][45], Cai[18], Day[31][32], Evangeline[51], Kaijian[78], Kodituwakku[82], Kong[87], Maillot[110], Wei[213], Slater[187], Ray[136][137][138][139], Li[96], Singh[156], Dev[35], Tran[197], Wang[205].

Some additional modifications of algorithms were published in Brackenbury[15], Chen[21][22], Brackenbury[15], Dimri2015[40][41], Ellriki[49], Hattab[62], Iraji[73], Jiang[74], Jianrong[75], Kumar[90], Kuzmin[92], Li[98][100], Meriaux[119], Molla[120], Nisha[126], Nisha[127], Sobkow[188], Sharma[153], Skala[184], Wang[206][207][209][210], Yang[225], Pandey[129] and Bhuiyan[11]. Algorithms for clipping Bezier and Hermit parametric curve by a rectangular area was published in Skala[174]. Dawod[30] presented FPGA solution for a line clipping.

Analysis and comparisons of some clipping algorithms were published in Krammer[88], Skala[179][180], Nisha[126][127] and Ray[137]. Algorithms for triangle-triangle intersections were presented by Sabharwal[143][144][145].

### 3.2 Intersection with polygons

Generic solutions for polygon clipping was developed by Weiler&Atherton[215], Rappaport[135], Vatti[200], Wu[222], Xie[224], Zhang[227]. Boolean operations with polygons were introduced by Rivero[140] and Martinez[112].

Algorithms for line clipping by a polygon depend on the polygon property, i.e. if the polygon is convex or non-convex. In the case of convex polygons, the convexity property and ordering of vertices enable to decrease complexity to $O(\lg N)$. However, in the non-convex polygon cases, when the polygon can be self-intersecting, etc., problems with a robustness of computation can be expected, in some cases a three-value logic is to be used, e.g. Skala[181][182].

**Convex polygons** The Cyrus-Beck’s[28] algorithm is the famous algorithm for line-convex polygon clipping. It is based on computation of a parameter $t$ of a line in the parametric form and edges of the given convex polygon. The algorithm
is of $O(N)$ computational complexity. The algorithm can be extended for the $E^3$ case. Some improvements and modifications were described by Skala[157]. As the edges of the convex polygon are ordered, algorithm with the $O(lgN)$ was derived by Skala[158]. An algorithm based on space subdivision was described in Slater[187].

Another approach based on the implicit form of the given line and convex polygon vertices classification was developed in Skala[176] and modified by Konashkova[85][86]. Another algorithm based S-Clip was described in Skala[176]. Another algorithm for a line segment clipping based on the line segment endpoints evaluation with $O(N)$ complexity was described by Matthes&Drakopoulos[115].

The Liang-Barsky algorithm[101][102] is based on direct intersection computation of a line with the convex polygon edges in the parametric form and has $O(N)$ computational complexity, too.

The algorithm with a run-time $O(1)$ complexity using pre-computation was developed by Skala[160][162]. The algorithm was motivated by the scan-line raster conversion used recently for solving visibility in rendering. The memory requirements depend on the geometrical properties of the given convex polygon. A comparison of the $O(1)$ algorithm with the Cyrus-Beck algorithm is presented in Skala[185][186].

Other related algorithms or modification of existing ones were published in: Sun[191], Vatti[200], Wang[208], Li[97], Nishita[128], Gupta[60], Wijeweera[216], Raja[133] and Sharma[151][152] uses the affine transformation, Zheng[228] uses a linear programming method for ray-polyhedron intersection.

**Non-convex polygons** Probably, the first algorithm dealing with non-convex polygon clipping was published by Sutherland&Hodgman in the Reentrant polygon clipping algorithm paper[193] in 1974, followed by Weiler&Atherton algorithm for polygon-polygon clipping [214][215], Rappaport[135].

Intersections with arbitrary non-convex non-convex polygons were described in Greiner[57] and solutions of "the singular" (degenerated) cases were described in Skala[181] and Foster[54]. A robust solution of triangle-triangle intersection in $E^2$ is described in McCoid[116]. Other algorithms or modifications are described in Dimri[40], Evangeline[51], Tang[194], Lu[105][106] and the affine transformations are used in Huang[69][70][71].

An algorithm that handles also arcs and uses a three-value logic to handle singular cases properly, including self-intersecting non-convex triangles, was described in Skala[172][181][182]. Algorithm for circular arc was described in Van Wyk[199], for overlapping areas by Li[99] and for circular window in Lu[107], Kumar[91]. Wu[221] presented algorithm for intersection of parabola segments against circular windows. The paper Kui Liu[89] and Landier[94] present algorithms for union and intersection operations with polygons.
3.3 Clipping using homogeneous coordinates

Homogeneous coordinates are used in computer graphics not only for geometric transformations. Sproull[189] use them in the Clipping divider in 1968. Arokiasamy[8] use them with duality in 1989, Blinn[13][14] described the clipping pipeline using the projective extension of the Euclidean space. Nielsen[125] described use of semi-homogeneous coordinates for clipping, more general view was published by Stolfi[190].

New approach to 2D clipping based on separation of the convex polygon vertices by the given line was presented in Skala[164][165][169][173], Kolingerova[83]. The principle of duality Johnson[76] presents duality between line clipping and pint-in-polygon problem.

4 Intersection algorithms in 3D

Intersection algorithms in 3D are widely used in many applications. An overview of the clipping algorithms is given in the Bui’s PhD [16]. Intersection of a line segment with a polygon in 3D was studied in Segura[150], the intersection of polygonal models was analyzed by Melero[118].

Algorithms for 3D clipping were over-viewed in Skala[183] and Bui’s PhD[16]. A comparative study of selected algorithms was presented by Kolingerova[84]. Reliable intersection tests with geometrical objects were published by Held[66].

4.1 Line-viewing pyramid

Special attention was given recently to a line clipping by a pyramid in 3D due to the perspective pyramid clipping. The problem was analyzed very recently Cohen[23], Sproull[189], Blinn[13][14][12], Skala[177][178].

Convex polyhedron case The Cyrus-Beck’s[28] algorithm is probably the famous algorithm for line-convex polyhedron clipping in $E^3$. It is based on computation of a parameter $t$ of a line in the parametric form and plane of the given face of the convex polyhedron. The algorithm is of $O(N)$ computational complexity. Rogers[141] published a general clipping algorithm in 3D in 1995.

The algorithm with $O_{exp}(\sqrt{N})$ complexity was described in Skala[163]. The algorithm is based on two planes representing the given line in $E^3$ and the search of the neighbours in the triangular mesh of the given polygon. The algorithm was modified by Konashkova[86]. An interesting approach using the vertex connection table was published in Konashkova[85].

Using pre-computation, the algorithm in $E^3$ with a run-time $O(1)$ complexity was developed by Skala[161]; a comparison was presented in Skala[186].
Ray-convex polyhedron

Extensive list of relevant publications can be found via Wiki[219].

Intersection of a line or a ray with a triangle can be also found in algorithms presented by Havel[63] using the SSE4 instructions, Xiao[223] using GPUs and Skala[168] using the barycentric coordinates computation in the homogeneous coordinates, Rajan[134] uses dual-precision fixed-point arithmetic for low-power ray-triangle intersections. Platis&Theoharis[132] published algorithm for ray-tetrahedron intersection using the Plucker coordinates. The intersection with the AABBBox is described in Eisemann[48], Kodituwakkul[81], Maonica[111] and Mahovsky[108]. Other algorithms are available in Sharma[153], Skala[159], Williams[220], Llanas[103], Lagae[93] and Amanatides[4].

Intersection with complex objects

Intersection computation with implicitly defined objects were published by Petrie[130] (Real Time Ray Tracing of Analytic and Implicit Surfaces), intersection with a torus was published by Cychosz[27] and alternative formulations were given in Skala[170]. Intersection with general quadrics using the homogeneous coordinates was described in Skala[172] and clipping by a spherical window was published by Deng[34].

However, as polygonal models are mostly formed by triangular surfaces a special attention is also targeted to triangle – triangle intersections.

Triangle-Triangle intersection in 3D

Computation of intersection of triangles is probably the most important as nearly all Computer Aided Design (CAD) systems depend on efficient, robust and reliable computation. In the CAD systems two different data sets are usually used:

- set of triangles - there is no connection between triangles; typical example is the STL format for 3D print
- triangular mesh - there is information on the neighbors of the given triangles and triangles sharing the given vertex; a typical example is the winged edge or the half-edge data structures

An efficient triangle-triangle intersection algorithm was developed by Moeller-Trumbore[122]. Other methods or approaches were described by Chang[20], Danaei[29], Devillers[39], Elsheikh[50], Guigue-Devillers[58], Jokanovi[77], McLaurin[117], Roy[142], Lo[104], Shen&Am[154], Tropp&Tai[198], Wei[212], Ye[226]. Clipping triangular strips using homogeneous coordinates was described by Mallot[109] in GEM II[9]. Parallel exact algorithm for the intersection of large 3D triangular meshes was described in de Magalhães[33]. Comparison of triangle-triangle tests on GPU was described in Xiao[223].

5 Conclusion

This contribution briefly summarizes known clipping algorithms with some extents to the intersection and ray-tracing algorithms. The list of published papers
related to clipping algorithms should be complete to the author’s knowledge and extensive search via Web of Science, Scopus, Research Gate and WEB search with the related topics. The relevant DOIs were included, if found. If other source was found, the relevant URL was included. Unfortunately, some papers are not publicly available.

There is a hope, that this summary will help researchers, students and software developers to find the relevant papers easily.

However, users are urged to consider a limited precision of the floating-point representation[218] and numerical robustness issues to proper handling near singular cases in the actual implementations.

Surprisingly, during the study and this summary preparation, there are still some problems to be explored more deeply, like a robust and efficient intersection of triangular meshes; application of triangle-triangle intersection algorithms leads to inconsistencies, inefficiency, and unreliability in general Those topics will be explored more in future work.

Acknowledgments

The author would like to thank colleagues and students at the University of West Bohemia in Plzen, VSB-Technical University and Ostrava University in Ostrava for their comments and recommendations.

Thanks also belong to several authors of recently published relevant papers for sharing their views and hints provided.
References

1. Agoston, M.K.: Computer Graphics and Geometric Modelling: Implementation & Algorithms. Springer-Verlag, Berlin, Heidelberg (2004)
2. Agoston, M.K.: Computer Graphics and Geometric Modelling: Mathematics. Springer-Verlag, Berlin, Heidelberg (2005)
3. Akenine-Moller, T., Haines, E., Hoffman, N.: Real-Time Rendering. A. K. Peters, Ltd., USA, 3rd edn. (2008)
4. Amanatides, J., Choi, K.Y.: Ray tracing triangular meshes. Western Computer Graphics Symposium p. 43–52 (1997)
5. Ammeraal, L., Zhang, K.: Computer graphics for java programmers. Computer Graphics for Java Programmers pp. 1–387 (2017). https://doi.org/10.1007/978-3-319-63357-2
6. Andreev, R., Sofianska, E.: New algorithm for two-dimensional line clipping. Computers and Graphics 15(4), 519–526 (1991). https://doi.org/10.1016/0097-8493(91)90051-I
7. Angel, E., Shreiner, D.: Interactive Computer Graphics: A Top-Down Approach with Shader-Based OpenGL. Addison-Wesley Publishing Company, USA, 6th edn. (2011)
8. Arockiasamy, A.: Homogeneous coordinates and the principle of duality in two dimensional clipping. Computers and Graphics 13(1), 99–100 (1989). https://doi.org/10.1016/0097-8493(89)90045-9
9. Arvo, J.: Graphics Gems II. Academic Press Professional, Inc., USA (1991)
10. Bao, H., Peng, Q.: Efficient polygon clipping algorithm. Zidonghua Xuebao/Acta Automatica Sinica 22(6), 741–744 (1996)
11. Bhuiyan, M.: Designing a line-clipping algorithm by categorizing line dynamically and using intersection point method. Proc. - Int. Conf. Electron. Comput. Technol., ICECT pp. 22–25 (2009). https://doi.org/10.1109/ICECT.2009.79
12. Blinn, J.F.: A homogeneous formulation for lines in 3 space. SIGGRAPH Comput. Graph. 11(2), 237–241 (jul 1977). https://doi.org/10.1145/965141.563900, https://doi.org/10.1145/965141.563900
13. Blinn, J.: A trip down the graphics pipeline: Line clipping. IEEE Comput Graphics Appl 11(1), 98–105 (1991). https://doi.org/10.1109/38.67707
14. Blinn, J., Newell, M.: Clipping using homogeneous coordinates. Proceedings of the 5th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH 1978 pp. 245–251 (1978). https://doi.org/10.1145/800248.807398
15. Brackenbury, I.: Line clipping in interactive computer graphics. IBM technical disclosure bulletin 27(1 B), 549–552 (1984)
16. Buc, D.H.: Algorithms for Line Clipping and Their Complexity. Ph.D. thesis, University of West Bohemia, University of West Bohemia, Pilsen (1999), http://graphics.zcu.cz/files/DIS_1999_Bui_Duc_Huy.pdf
17. Bui, D., Skala, V.: Fast algorithms for clipping lines and line segments in E2. Visual Computer 14(1), 31–37 (1998). https://doi.org/10.1007/s003710050121
18. Cai, M., Yuan, C.F., Song, J.Q., Cai, S.J.: A fast line clipping algorithm for circular windows. Journal of Computer-Aided Design and Computer Graphics 13(12), 1063–1067 (2001). https://doi.org/10.1012/jcda.2018.8201
19. Calvet, R.G.: Treatise of Plane Geometry through Geometric Algebra. Cerdanyola del Valles (2007), http://www.xtec.cat/~rgonzall/treatise-sample.pdf
20. Chang, J.W., Kim, M.S.: Technical section: Efficient triangle-triangle intersection test for OBB-based collision detection. Comput. Graph. 33(3), 235–240 (Jun 2009). https://doi.org/10.1016/j.cag.2009.03.009
21. Chen, C., Zhang, Z., Sun, C.: A midpoint segmentation clipping algorithm of circular window against line. IFCSTA-International Forum on Computer Science-Technology and Applications 1, 15–19 (2009). https://doi.org/10.1109/IFCSTA.2009.10
22. Cheng, F., kwo Yen, Y.: A parallel line clipping algorithm and its implementation. In: Dew, P., Heywood, T., Earnshaw, R. (eds.) Parallel Processing for Computer Vision and Display, pp. 338–350. Addison-Wesley (1989)
23. Cohen, D.: Incremental methods for computer graphics. Tech. rep., Harvard University, Cambridge, Massachusetts, USA (April 1969), https://apps.dtic.mil/sti/pdfs/AD0694550.pdf
24. Comninos, P.: Mathematical and Computer Programming Techniques for Computer Graphics. Springer-Verlag, Berlin, Heidelberg (2005). https://doi.org/10.1007/978-1-84628-292-8
25. Comninos, P.: Two-Dimensional Clipping, pp. 193–223. Springer London, London (2006). https://doi.org/10.1007/978-1-84628-292-8_6
26. Coxeter, H.S.M., Beck, G.: The Real Projective Plane. Springer-Verlag, Berlin, Heidelberg (1992)
27. Cychosz, J.M.: Intersecting a ray with an elliptical torus. Graphics Gems II (1991)
28. Cyrus, M., Beck, J.: Generalized two- and three-dimensional clipping. Computers and Graphics 3(1), 23–28 (1978). https://doi.org/10.1016/0097-8493(78)90021-3
29. Danaei, B., Karbasizadeh, N., Tale Masouleh, M.: A general approach on collision-free workspace determination via triangle-to-triangle intersection test. Robotics and Computer-Integrated Manufacturing 44, 230–241 (2017). https://doi.org/10.1016/j.rcim.2016.08.013
30. Dawod, A.I.: Hardware implementation of line clipping algorithm by using fpga. Tikrit Journal of Engineering Science 18, 89–105 (2011)
31. Day, J.: An algorithm for clipping lines in object and image space. Computers and Graphics 16(4), 421–426 (1992). https://doi.org/10.1016/0097-8493(92)90029-U
32. Day, J.: A new two dimensional line clipping algorithm for small windows. Computer Graphics Forum 11(4), 241–245 (1992). https://doi.org/10.1111/1467-8659.1140241
33. de Magalhães, S.V.G., Franklin, W.R., Andrade, M.V.A.: An efficient and exact parallel algorithm for intersecting large 3-d triangular meshes using arithmetic filters. Computer-Aided Design 120, 102801 (2020). https://doi.org/10.1016/j.cad.2019.102801, https://www.sciencedirect.com/science/article/pii/S0167-8090(20)305330
34. Deng, W., Lu, G., Chen, L.: New 3D line clipping algorithm against spherical surface window. In: International Technology and Innovation Conference 2006 (ITIC 2006). pp. 894–898. IET (2006). https://doi.org/10.1049/cp:20060886
35. Dev, D., Saharan, P.: Implementation of efficient line clipping algorithm. Int. J. of Innovative Technology and Exploring Engineering 8(7), 295–298 (2019)
36. Devai, F.: Analysis of the Nicholl-Lee-Nicholl algorithm. Lecture Notes in Computer Science 3480(1), 726–736 (2005). https://doi.org/10.1007/11424758_75
37. Devai, F.: A speculative approach to clipping line segments. Lecture Notes in Computer Science LNCS 3980, 131–140 (2006). https://doi.org/10.1007/11751540_15
38. Devai, F.: Analysis technique and an algorithm for line clipping. Proceedings of the IEEE Symposium on Information Visualization pp. 157–165 (1998). https://doi.org/10.1109/IV.1998.694214
39. Devillers, O., Guigue, P.: Faster Triangle-Triangle Intersection Tests. Tech. Rep. RR-4488, INRIA (June 2002), https://hal.inria.fr/inria-00072100
40. Dimri, S.C.: Article: A simple and efficient algorithm for line and polygon clipping in 2-d computer graphics. Int. Journal of Computer Applications 127(3), 31–34 (October 2015). https://doi.org/10.5120/ijca2015906352
41. Dimri, S.C., Tiwari, U.K., Ram, M.: An efficient algorithm to clip a 2d-polygon against a rectangular clip window. Applied Mathematics-A Journal of Chinese Universities 37, 147–158 (2022). https://doi.org/10.1007/s11766-022-4556-0
42. Dorst, L., Fontijne, D., Mann, S.: Geometric Algebra for Computer Science: An Object-Oriented Approach to Geometry. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA (2009). https://doi.org/10.1016/B978-0-12-374942-0.X0000-0
43. Duvalenko, V.J., Robbins, W.E., Gyurcsik, R.S.: Improving line segment clipping. Dr Dobbs Journal 15(7), 36–& (July 1990)
44. Duvanenko, V.J., Gyurcsik, R.S., Robbins, W.: Simple and efficient 2D and 3D span clipping algorithms. Computers and Graphics 17(1), 39–54 (1993). https://doi.org/10.1016/0097-8493(93)90050-J
45. Duvanenko, V.J., Robbins, W.E., Gyurcsik, R.S.: Line-segment clipping revisited. DR DOBBS JOURNAL 21(1), 107–& (JAN 1996)
46. Dörr, M.: A new approach to parametric line clipping. Comput Graphics (Pergamon) 14(3-4), 449–464 (1990). https://doi.org/10.1016/0097-8493(90)90067-8
47. Eberly, D.H.: Game Physics. Elsevier Science Inc., USA (2003)
48. Eisemann, M., Magnor, M., Grosch, T., Müller, S.: Fast ray/axis-aligned bounding box overlap tests using ray slopes. Journal of Graphics Tools 12(4), 35–46 (2007). https://doi.org/10.1080/2151237X.2007.10129248
49. Elliriki, M., Reddy, C., Anand, K.: An efficient line clipping algorithm in 2D space. Int. Arab J. of Info. Tech. 16(5), 798–807 (2019), https://iajit.org/PDF/September%202019,%20No.%205/11103.pdf
50. Elsheikh, A., Elsheikh, M.: A reliable triangular mesh intersection algorithm and its application in geological modelling. Engineering with Computers 30(1), 143–157 (2014). https://doi.org/10.1007/s00366-012-0297-3
51. Evangeline, D., Anitha, S.: 2D polygon clipping using shear transformation: An extension of shear based 2D line clipping. 2014 IEEE Int.Conf.on Advanced Communications, Control and Computing Technologies pp. 1379–1383 (2014). https://doi.org/10.1109/ICACCCCT.2014.7019326
52. Ferguson, R.S.: Practical Algorithms for 3D Computer Graphics. A. K. Peters, Ltd., USA, 2nd edn. (2013)
53. Foley, J.D., van Dam, A., Feiner, S., Hughes, J.F.: Computer graphics - principles and practice, 2nd Edition. Addison-Wesley (1990)
54. Foster, E.L., Hormann, K., Popa, R.T.: Clipping simple polygons with degenerate intersections. Computers & Graphics: X 2, Article 100007, 10 pages (Dec 2019). https://doi.org/10.1016/j.cagxx.2019.100007
55. Glassner, A.S. (ed.): Graphics Gems. Academic Press Professional, Inc., USA (1990)
56. Govil-Pai, S.: Principles of Computer Graphics: Theory and Practice Using OpenGL and Maya. Springer-Verlag, Berlin, Heidelberg (2005)
57. Greiner, G., Hormann, K.: Efficient clipping of arbitrary polygons. ACM Trans. Graph. 17(2), 71–83 (April 1998). https://doi.org/10.1145/274363.274364
58. Guique, P., Devillers, O.: Fast and robust triangle-triangle overlap test using orientation predicates. Journal of Graphics Tools 8(1), 25–32 (2003). https://doi.org/10.1080/10867651.2003.10487580
59. Guo, H.: Modern Mathematics and Applications in Computer Graphics and Vision. World Scientific Publ., Singapore (2014). https://doi.org/10.1142/8703.

60. Gupta, R., Tripathi, V., Singh, K., Pathak, N., Rastogi, R.: An innovative and easy approach for clipping curves along a circular window. Proceedings - 2016 2nd International Conference on Computational Intelligence and Communication Technology, CICT 2016 pp. 638–643 (2016). https://doi.org/10.1109/CICT.2016.132

61. Harrington, S.: Computer Graphics: A Programming Approach, 2nd Ed. McGraw-Hill, Inc., USA (1987)

62. Hattab, A., Yusof, Y.: Line clipping based on parallelism approach and midpoint intersection. AIP Conference Proceedings 1602, 371–374 (2014). https://doi.org/10.1063/1.4882513

63. Havel, J., Herout, A.: Yet faster ray-triangle intersection (using SSE4). IEEE Transactions on Visualization and Computer Graphics 16(3), 434–438 (2010). https://doi.org/10.1109/TVCG.2009.73

64. Hearn, D.D., Baker, M.P., Carithers, W.: Computer Graphics with OpenGL. Prentice Hall Press, USA, 4th edn. (2010)

65. Heckbert, P.S. (ed.): Graphics Gems IV. Academic Press Professional, Inc., USA (1994)

66. Held, M.: Erit: A collection of efficient and reliable intersection tests. J. Graph. Tools 2(4), 25–44 (Jan 1998). https://doi.org/10.1080/10867651.1997.10487482

67. Hildenbrand, D.: Foundations of Geometric Algebra Computing. Springer Publishing Company, Incorporated (2012). https://doi.org/10.1007/978-1-84628-997-2

68. Hill, F.S., Kelley, S.M.: Computer Graphics Using OpenGL (3rd Edition). Prentice-Hall, Inc., USA (2006)

69. Huang, W.: Line clipping algorithm of affine transformation for polygon. Lecture Notes in Computer Science 7995 LNCS, 55–60 (2013). https://doi.org/10.1007/978-3-642-39479-9_7

70. Huang, W., Wangyong: A novel algorithm for line clipping. Proceedings - 2009 International Conference on Computational Intelligence and Software Engineering, CiSE 2009 pp. 1–5 (2009). https://doi.org/10.1109/CISE.2009.5366550

71. Huang, Y., Liu, Y.: An algorithm for line clipping against a polygon based on shearing transformation. Computer Graphics Forum 21(4), 683–688 (2002). https://doi.org/10.1111/1467-8659.00626

72. Hughes, J.F., van Dam, A., McGuire, M., Sklar, D.F., Foley, J.D., Feiner, S.K., Akeley, K.: Computer Graphics - Principles and Practice, 3rd Edition. Addison-Wesley (2014)

73. Iraji, M.S., Mazandarani, A., Motameni, H.: An efficient line clipping algorithm based on Cohen-Sutherland line clipping algorithm. American Journal of Scientific Research 14(1), 65–71 (2011). https://www.researchgate.net/publication/275964580_An_Efficient_Line_Clipping_Algorithm_based_on_Cohen-Sutherland_Line_Clipping_Algorithm

74. Jiang, B., Han, J.: Improvement in the Cohen-Sutherland line segment clipping algorithm. IEEE Int. Conf. on Granular Computing, GrC 2013 pp. 157–161 (2013). https://doi.org/10.1109/GrC.2013.6740399

75. Jianrong, T.: A new algorithm of polygon clipping against rectangular window based on the endpoint and intersection-point encoding. Journal of Engineering Graphics (2006)
76. Johnson, M.: Proof by duality: or the discovery of “new” theorems. Mathematics Today December, 138–153 (1996)
77. Jokanovic, S.: Two-dimensional line segment–triangle intersection test: revision and enhancement. Visual Computer 35(10), 1347–1359 (2019). https://doi.org/10.1007/s00371-018-01614-1
78. Kajijian, S., Edwards, J., Cooper, D.: An efficient line clipping algorithm. Computers and Graphics 14(2), 297–301 (1990). https://doi.org/10.1016/0097-8493(90)90041-U
79. Kanatani, K.: Understanding Geometric Algebra: Hamilton, Grassmann, and Clifford for Computer Vision and Graphics. A. K. Peters, Ltd., USA (2015). https://doi.org/10.1201/b18273
80. Kirk, D. (ed.): Graphics Gems III. Academic Press Professional, Inc., USA (1992)
81. Kodituwakku, R., Wijeweera, K.R.: An efficient line clipping algorithm for 3D space. Int. journal of Advanced Research in Computer Science and Software Engineering 2(5) (2012)
82. Kodituwakku, S.R., Wijeweera, K.R., Chamikara, M.A.P.: An efficient algorithm for line clipping in computer graphics programming. Ceylon Journal of Science 17(1), 1–7 (2013), https://www.researchgate.net/publication/261288113_An_Efficient_Algorithm_for_Line_Clipping_in_Computer_Graphics_Programming
83. Kolingerova, I.: Convex polyhedron-line intersection detection using dual representation. Visual Computer 13(1), 42–49 (1997). https://doi.org/10.1007/s003710050088
84. Kolingerová, I.: 3d-line clipping algorithms - a comparative study. The Visual Computer 11(2), 96–104 (1994). https://doi.org/10.1007/BF01889980
85. Konashkova, A.: Line - convex polyhedron intersection using vertex connections table. Applied Mathematical Sciences 8(21-24), 1177–1186 (2014). https://doi.org/10.12988/ams.2014.1334
86. Konashkova, A.: Modified Skala’s plane tested algorithm for line-polyhedron intersection. Applied Mathematical Sciences 9(61-64), 3097–3103 (2015). https://doi.org/10.12988/ams.2015.52169
87. Kong, D.H., Yin, B.C.: The improvement on the algorithm of Cohen-Sutherland line clipping. CAD/GRAPHICS 2001 pp. 807–810 (2001)
88. Krammer, G.: A line clipping algorithm and its analysis. Computer Graphics Forum 11(3), 253–266 (1992). https://doi.org/10.1111/1467-8659.1130253
89. Kui Liu, Y., Qiang Wang, X., Zhe Bao, S., Gomboši, M., Žalik, B.: An algorithm for polygon clipping, and for determining polygon intersections and unions. Computers and Geosciences 33(5), 589–598 (2007). https://doi.org/10.1016/j.cageo.2006.08.008
90. Kumar, J., Awasthi, A.: Modified trivial rejection criteria in Cohen-Sutherland line clipping algorithm. Commun. Comput. Info. Sci. 125 CCIS, 1–10 (2011). https://doi.org/10.1007/978-3-642-18440-6_1
91. Kumar, P., Patel, F., Kanna, R.: An efficient line clipping algorithm for circular windows using vector calculus and parallelization. International Journal of Computational Geometry and Applications 8, 01–08 (2018). https://doi.org/10.5121/ijcga.2018.8201
92. Kuzmin, Y.: Bresenham’s line generation algorithm with built-in clipping. Computer Graphics Forum 14(5), 275–280 (1995). https://doi.org/10.1111/1467-8659.1450275
93. Lagae, A., Dutré, P.: An efficient ray-quadrilateral intersection test. Journal of Graphics Tools 10(4), 23–32 (2005). https://doi.org/10.1080/2151237X.2005.10129208
94. Landier, S.: Boolean operations on arbitrary polygonal and polyhedral meshes. CAD Computer Aided Design 85, 138–153 (2017). https://doi.org/10.1016/j.cad.2016.07.013
95. Lengyel, E.: Mathematics for 3D Game Programming and Computer Graphics, Third Edition. Course Technology Press, Boston, MA, USA, 3rd edn. (2011)
96. Li, H.: Analysis and implementation of Cohen-Sutherland line clipping algorithm. In: Proc. of the 2016 Int. Conf. on Sensor Network and Computer Engineering. pp. 482–485. Atlantis Press (2016/07). https://doi.org/https://doi.org/10.2991/icsnce-16.2016.94
97. Li, W.: Bisearch-based line clipping algorithm against a convex polygonal window. Journal of Computer-Aided Design and Computer Graphics 17(5), 962–965 (2005)
98. Li, Z., He, D., Wang, J., Wang, M.: An improved algorithm of Cohen-Sutherland line clipping. WIT Transactions on Information and Communication Technologies 49, 575–582 (2014)
99. Li, Z.Q., He, Y., Tian, Z.J.: Overlapping area computation between irregular polygons for its evolutionary layout based on convex decomposition. Journal of Software 7(2), 482–492 (2012). https://doi.org/10.4304/jsw.7.2.485-492
100. Li, Z., Lei, G.: Modified Sutherland-Cohen line clipping algorithm (in Chinese). Computer Engineering and Applications 48(34), 175 (2012), https://caod.oriprobe.com/articles/31582699/Modified_Sutherland_Cohen_line_clipping_algorithm.htm
101. Liang, Y.D., Barsky, B.A.: A new concept and method for line clipping. ACM Transactions on Graphics (TOG) 3(1), 1–22 (1984). https://doi.org/10.1145/357332.357333
102. Liang, Y.D., Barsky, B.A.: An analysis and algorithm for polygon clipping. Commun. ACM 26(11), 868–877 (November 1983). https://doi.org/10.1145/182.358439
103. Llanas, B., Sainz, F.: A local search algorithm for ray-convex polyhedron intersection. Computational Optimization and Applications 51(2), 533–550 (2012). https://doi.org/10.1007/s10589-010-9354-2
104. Lo, S., Wang, W.: A fast robust algorithm for the intersection of triangulated surfaces. Engineering with Computers 20, 11–21 (2004). https://doi.org/10.1007/s00366-004-0277-3
105. Lu, G., Wu, X.: Midpoint-subdivision line clipping algorithm based on filtering technique. Journal of Computer-Aided Design and Computer Graphics 14(6), 513–517 (2002)
106. Lu, G., Wu, X., Peng, Q.: An efficient line clipping algorithm based on adaptive line rejection. Computers and Graphics (Pergamon) 26(3), 409–415 (2002). https://doi.org/10.1016/S0097-8493(02)00084-5
107. Lu, G., Xing, J., Tan, J.: New clipping algorithm of line against circular window with multi-encoding approach. Journal of Computer-Aided Design and Computer Graphics 14(12), 1133–1137 (2002)
108. Mahovsky, J., Wyvill, B.: Fast ray-axis aligned bounding box overlap tests with plucker coordinates. Journal of Graphics Tools 9(1), 35–46 (2004). https://doi.org/10.1080/10867651.2004.10487597
109. Maillot, P.G.: Three-dimensional homogeneous clipping of triangle strips. Elsevier Inc. (1991). https://doi.org/10.1016/B978-0-08-050754-5.50050-5
10. Maillot, P.G.: A new, fast method for 2D polygon clipping: Analysis and software implementation. ACM Transactions on Graphics (TOG) 11(3), 276–290 (1992). https://doi.org/10.1145/130881.130894

11. Maonica, B., Das, P., Ramteke, P.B., Koolagudi, S.G.: Selective cropper for geometrical objects in openflipper. In: Satapathy, S.C., Bhateja, V., Joshi, A. (eds.) Proceedings of the International Conference on Data Engineering and Communication Technology. pp. 391–399. Springer Singapore, Singapore (2017). https://doi.org/10.1007/978-981-10-1675-2_39

12. Martinez, F., Rueda, A., Feito, F.: A new algorithm for computing boolean operations on polygons. Computers and Geosciences 35(6), 1177–1185 (2009). https://doi.org/10.1016/j.cageo.2008.08.009

13. Matthes, D., Drakopoulos, V.: Another simple but faster method for 2D line clipping. International Journal of Computer Graphics & Animation (IJCGA) 9(1/2/3) (July 2019). https://doi.org/10.5121/ijcga.2019.9301, https://aircconline.com/ijcga/V9N3/9319ijcga01.pdf

14. Matthes, D., Drakopoulos, V.: A simple and fast line-clipping method as a scratch extension for computer graphics education. Computer Science and Information Technology 7, 40–47 (2019). https://doi.org/10.13189/csit.2019.070202

15. Matthes, D., Drakopoulos, V.: A very simple algorithm for line segment clipping against a convex polygon, private communication

16. Mccoid, C., Gander, M.J.: A provably robust algorithm for triangle-triangle intersections in floating-point arithmetic. ACM Trans. Math. Softw. 48(2) (May 2022). https://doi.org/10.1145/3513264, https://doi.org/10.1145/3513264

17. McLaurin, D., Marcum, D., Remotigue, M., Blades, E.: Repairing unstructured triangular mesh intersections. International Journal for Numerical Methods in Engineering 93(3), 266–275 (2013). https://doi.org/10.1002/nme.4385

18. Melero, F., Aguilera, A., Feito, F.: Fast collision detection between high resolution polygonal models. Computers and Graphics (Pergamon) 83, 97–106 (2019). https://doi.org/10.1016/j.cag.2019.07.006

19. Meriaux, M.: A two-dimensional clipping divider. Eurographics Conference Proceedings (1984). https://doi.org/10.2312/eg.19841031

20. Molla, R., Jorquera, P., Vivo, R.: Fixed-point arithmetic line clipping. WSCG’2003 Proc. pp. 93–96 (2003)

21. Mortenson, M.E.: Computer Graphics: An Introduction to the Mathematics and Geometry. Industrial Press, Inc., USA (1988)

22. Möller, T., Trumbore, B.: Fast, minimum storage ray-triangle intersection. Journal of Graphics Tools 2(1), 21–28 (1997). https://doi.org/10.1080/10867651.1997.10487468

23. Newman, W.M., Sproull, R.F.: Principles of Interactive Computer Graphics (2nd Ed.). McGraw-Hill, Inc., USA (1979)

24. Nicholl, T., Lee, D., Nicholl, R.: An efficient new algorithm for 2-d line clipping: Its development and analysis. Proceedings of the 14th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH 1987 pp. 253–262 (1987). https://doi.org/10.1145/37401.37432

25. Nielsen, H.: Line clipping using semi-homogeneous coordinates. Computer Graphics Forum 14(1), 3–16 (1995). https://doi.org/10.1111/1467-8659.1410003

26. Nisha, A.: Comparison of various line clipping algorithms: Review. International Journal of Advanced Research in Computer Science and Software Engineering 7(1) (2017). https://doi.org/10.23956/ijarcse/V7I1/0149
A Survey of Line Clipping Algorithms

127. Nisha, A.: A review: Comparison of line clipping algorithms in 3D space. International Journal of Advanced Research (IJAR) 5(1) (2017). https://doi.org/10.21474/IJAR01/3022

128. Nishita, T., Johan, H.: A scan line algorithm for rendering curved tubular objects. Proc. - Pac. Conf. Comput. Graph. Appl., Pac. Graphics pp. 104–105 (1999). https://doi.org/10.1109/PCCGA.1999.803352

129. Pandey, A., Jain, S.: Article: Comparison of various line clipping algorithm for improvement. International Journal of Modern Engineering Research 3(1), 69–74 (January-February 2013)

130. Petrie, F., Mills, S.: Real time ray tracing of analytic and implicit surfaces. International Conference Image and Vision Computing New Zealand 2020-November (2020). https://doi.org/10.1109/IVCNZ51579.2020.9290653

131. Pharr, M., Jakob, W., Humphreys, G.: Physically Based Rendering; From Theory to Implementation. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 3rd edn. (2016)

132. Platis, N., Theoharis, T.: Fast ray-tetrahedron intersection using plucker coordinates. Journal of Graphics Tools 8(4), 37–48 (2003). https://doi.org/10.1080/10667651.2003.10487593

133. Raja, S.: Line and polygon clipping techniques on natural images - a mathematical solution and performance evaluation. Int. Journal of Image and Graphics 19(2) (2019). https://doi.org/10.1142/S0219467819500128

134. Rajan, K., Hashemi, S., Karpuzcu, U., Doggett, M., Reda, S.: Dual-precision fixed-point arithmetic for low-power ray-triangle intersections. Computers and Graphics (Pergamon) 87, 72–79 (2020). https://doi.org/10.1016/j.cag.2020.01.006

135. Rappoport, A.: An efficient algorithm for line and polygon clipping. The Visual Computer 7(1), 19–28 (1991). https://doi.org/10.1007/BF01994114

136. Ray, B.K.: An alternative algorithm for line clipping. Journal of Graphics Tools 16(1), 12–24 (2012). https://doi.org/10.1080/2151237X.2012.641824

137. Ray, B.K.: A line segment clipping algorithm in 2D. Int.J.of Computer Graphics 3(2), 51–76 (2012)

138. Ray, B.K.: A procedure to clip line segment. Int.J.of Computer Graphics 5(1), 9–19 (2014). https://doi.org/10.14257/ijgc.2014.5.1.02

139. Ray, B.K.: Line clipping against arbitrary polygonal window. Int.J.of Computer Graphics 6(1), 12–24 (2015). https://doi.org/10.14257/ijgc.2015.6.1.01

140. Rivero, M., Feito, F.: Boolean operations on general planar polygons. Computers and Graphics (Pergamon) 24(6), 881–896 (2000). https://doi.org/10.1016/S0097-8493(00)00090-X

141. Rogers, D., Rybak, L.: On an efficient general line-clipping algorithm. IEEE Comput Graphics Appl 5(1), 82–86 (1985). https://doi.org/10.1109/MCG.1985.276298

142. Roy, U., Dasari, V.: Implementation of a polygonal algorithm for surface-surface intersections. Computers & Industrial Engineering 34(2), 399–412 (1998). https://doi.org/10.1016/S0360-8352(97)00276-3

143. Sabharwal, C., Leopold, J., McGeehan, D.: Triangle-triangle intersection determination and classification to support qualitative spatial reasoning. Polibits 48, 13–22 (12 2013). https://doi.org/10.17562/PB-48-2

144. Sabharwal, C.L., Leopold, J.L.: A triangle-triangle intersection algorithm. Computers and Graphics –(May), 27–35 (2015). https://doi.org/10.5121/csit.2015.51003
145. Sabharwal, C.L., Leopold, J.L.: A generic design for implementing intersection between triangles in computer vision and spatial reasoning. In: Pal, R. (ed.) Innovative Research in Attention Modeling and Computer Vision Applications, p. 41. IGI Global (2016). https://doi.org/10.4018/978-1-4666-8723-3.ch008
146. Salomon, D.: Computer Graphics and Geometric Modeling. Springer-Verlag, Berlin, Heidelberg, 1st edn. (1999)
147. Salomon, D.: Transformations and Projections in Computer Graphics. Springer-Verlag, Berlin, Heidelberg (2006)
148. Salomon, D.: The Computer Graphics Manual. Springer (2011). https://doi.org/10.1007/978-1-4666-8723-3.ch008
149. Schneider, P.J., Eberly, D.H.: Geometric Tools for Computer Graphics. The Morgan Kaufmann Series in Computer Graphics, Morgan Kaufmann, San Francisco (2003). https://doi.org/10.1016/B978-1-55860-594-7.50025-4
150. Segura, R., Feito, F.: An algorithm for determining intersection segment-polygon in 3D. Computers and Graphics (Pergamon) 22, 587–592 (1998). https://doi.org/10.1016/S0097-8493(98)00064-8
151. Sharma, M., Kaur, J.: An improved polygon clipping algorithm based on affine transformation. Advances in Intelligent Systems and Computing 379, 783–792 (2016). https://doi.org/10.1007/978-81-322-2517-1_75
152. Sharma, N., Manohar, S.: Line clipping revisited: Two efficient algorithms based on simple geometric observations. Computers and Graphics 16, 51–54 (1992). https://doi.org/10.1016/0097-8493(92)90071-3
153. Sharma, N., Manohar, S.: Three dimensional line-clipping by systematic enumeration. IFIP Trans B Comput Appl Technol 1, 225–232 (1993)
154. Shen, H., Heng, P.A., Tang, Z.: A fast triangle-triangle overlap test using signed distances. Journal of Graphics Tools 8(1), 17–23 (2003). https://doi.org/10.1080/10867651.2003.10487579
155. Shirley, P., Marschner, S.: Fundamentals of Computer Graphics. A. K. Peters, Ltd., USA, 3rd edn. (2009)
156. Singh, R., Lumar, A.: RJ-ASHI algorithm: A new polygon/line clipping algorithm for 2D space. Int. Journal of Advanced Research in Computer Science and Software Engineering 6, 215–219 (2016)
157. Skala, V.: An efficient algorithm for line clipping by convex polygon. Computers and Graphics 17(4), 417–421 (1993). https://doi.org/10.1016/0097-8493(93)90030-D
158. Skala, V.: O(lg N) line clipping algorithm in E2. Computers and Graphics 18(4), 517–524 (1994). https://doi.org/10.1016/0097-8493(94)90064-7
159. Skala, V.: An efficient algorithm for line clipping by convex and non-convex polyhedra in E3. Computer Graphics Forum 15(1), 61–68 (1996). https://doi.org/10.1111/1467-8659.15.10061
160. Skala, V.: Line clipping in E2 with O(1) processing complexity. Comput Graphics (Pergamon) 20(4), 523–530 (1996). https://doi.org/10.1016/0097-8493(96)00024-6
161. Skala, V.: Line clipping in E3 with expected complexity O(1). Machine Graphics and Vision 5(4), 551–562 (1996)
162. Skala, V.: Trading time for space: An O(1) average time algorithm for point-in-polygon location problem: Theoretical fiction or practical usage? Machine Graphics and Vision 5(3), 483–494 (1996)
163. Skala, V.: A fast algorithm for line clipping by convex polyhedron in E3. Computers and Graphics (Pergamon) 21(2), 209–214 (1997). https://doi.org/10.1016/0097-8493(96)00084-2
164. Skala, V.: A new line clipping algorithm with hardware acceleration. Proceedings of Computer Graphics International Conference, CGI pp. 270–273 (2004). https://doi.org/10.1109/CGI.2004.1309220

165. Skala, V.: A new approach to line and line segment clipping in homogeneous coordinates. Visual Computer 21(11), 905–914 (2005). https://doi.org/10.1007/s00371-005-0305-3

166. Skala, V.: Barycentric coordinates computation in homogeneous coordinates. Computers and Graphics (Pergamon) 32(1), 120–127 (2008). https://doi.org/10.1016/j.cag.2007.09.007

167. Skala, V.: Intersection computation in projective space using homogeneous coordinates. Int. J. Image Graphics 8(4), 615–628 (2008). https://doi.org/10.1142/S021946780800326X

168. Skala, V.: Duality, barycentric coordinates and intersection computation in projective space with GPU support. WSEAS Transactions on Mathematics 9(6), 407–416 (2010), http://afrodita.zcu.cz/~skala/PUBL/PUBL_2010/2010_NAUN-journal.pdf

169. Skala, V.: S-clip E2: A new concept of clipping algorithms. SIGGRAPH Asia Posters, SA pp. 1–2 (2012). https://doi.org/10.1145/2407156.2407200

170. Skala, V.: Line-torus intersection for ray tracing: Alternative formulations. WSEAS Trans. Comput. 12(7), 288–297 (2013)

171. Skala, V.: Summation problem revisited - more robust computation. In: Recent Advances in Computer Science. pp. 56–64 (2013)

172. Skala, V.: A new approach to line - sphere and line - quadrics intersection detection and computation. AIP Conference Proceedings 1648, 1–4 (2015). https://doi.org/10.1063/1.4913058

173. Skala, V.: Optimized line and line segment clipping in E2 and geometric algebra. Ann. Math. Inf. 52, 199–215 (2020). https://doi.org/10.33039/amipc.2020.05.001

174. Skala, V.: Efficient intersection computation of the Bezier and Hermite curves with axis aligned bounding box. WSEAS Transactions on Systems 20, 320–323 (2021). https://doi.org/10.37394/23202.2021.20.36

175. Skala, V.: A new coding scheme for line segment clipping in E2. Lecture Notes in Computer Science LNCS 12953, 16–29 (2021). https://doi.org/10.1007/978-3-030-86976-2_2

176. Skala, V.: A novel line convex polygon clipping algorithm in E2 with parallel processing modification. Lecture Notes in Computer Science LNCS Vol.12953, 3–15 (2021). https://doi.org/10.1007/978-3-030-86976-2_1

177. Skala, V., Bui, D.: Faster algorithm for line clipping against a pyramid in E3. Machine Graphics and Vision 9(4), 841–850 (2000)

178. Skala, V., Bui, D.: Extension of the Nicholls-Lee-Nichols algorithm to three dimensions. Visual Comput 17(4), 236–242 (2001). https://doi.org/10.1007/s003710000094

179. Skala, V., Huy, B.: Two new algorithms for line clipping in E2 and their comparison. Machine Graphics and Vision 9(1/2), 297–306 (2000)

180. Skala, V., Kolingerova, I., Blaha, P.: A comparison of 2D line clipping algorithms. Machine Graphics and Vision 3(4), 625–633 (1995)

181. Skala, V.: Algorithms for 2D Line Clipping. In: Hansmann, W., Hopgood, F.R.A., Strafer, W. (eds.) EG 1989 proceedings. Eurographics Association (1989). https://doi.org/10.2312/egtp.19891026

182. Skala, V.: Algorithms for Clipping Quadratic Arcs. In: Chua, T., Kunii, T. (eds.) CGI proceedings. pp. 255–268. Springer (1990). https://doi.org/10.1007/978-4-431-68123-6_16
183. Skala, V.: Clipping Algorithm - Habilitation thesis. University of West Bohemia (1990), http://afrodita.zcu.cz/~skala/EDU-PUB/Habilitace-komplet.pdf, (partially in Czech)

184. Skala, V.: Algorithms for line and plane intersection with a convex polyhedron with $O(\sqrt{N})$ expected complexity in E3. In: SIGGRAPH Asia 2014 Posters. SA ’14, Association for Computing Machinery, New York, NY, USA (2014). https://doi.org/10.1145/2668975.2668976

185. Skala, V., Lederbuch, P.: A Comparison of a New O(1) and the Cyrus-Beck Line Clipping Algorithms in E2. In: Compugraphics’96: Fifth International Conference on Computational Graphics and Visualization Techniques, pp. 281–287. Comenius University, Slovakia (1996), https://dspace5.zcu.cz/handle/11025/11808

186. Skala, V., Lederbuch, P., Sup, B.: A Comparison of O(1) and Cyrus-Beck Line Clipping Algorithm in E2 and E3. In: SCCG96 Conference proceedings, pp. 17–44. Comenius University, Slovakia (1996), https://dspace5.zcu.cz/handle/11025/11806

187. Slater, M., Barsky, B.: 2D line and polygon clipping based on space subdivision. The Visual Computer 10(7), 407–422 (1994). https://doi.org/10.1007/BF01900665

188. Sobkow, M., Pospisil, P., Yang, Y.H.: A fast two-dimensional line clipping algorithm via line encoding. Computers and Graphics 11(4), 459–467 (1987). https://doi.org/10.1016/0097-8493(87)90061-6

189. Sproull, R.F., Sutherland, I.E.: A clipping divider. In: Fall Joint Computer Conference Proc., Dec. 9-11, 1968, Part I. p. 765–775. AFIPS’68 (Fall, part I), Association for Computing Machinery, New York, NY, USA (1968). https://doi.org/10.1145/1476389.147687

190. Stolli, J.: Oriented Projective Geometry. Academic Press Professional, Inc., USA (1991)

191. Sun, C., Wang, W., Li, J., Wu, E.: Line clipping against a polygon through convex segments. Journal of Computer-Aided Design and Computer Graphics 18(12), 1799–1805 (2006)

192. Sutherland, I.E.: Display windowing by clipping (May 2 1972). https://patents.google.com/patent/US3639736A/en

193. Sutherland, I.E., Hodgman, G.W.: Reentrant polygon clipping. Commun. ACM 17(1), 32–42 (Jan 1974). https://doi.org/10.1145/360767.360820

194. Tang, L.L., He, Y.J.: A linear time algorithm for the line clipping against concave polygon. Proceedings - 2009 International Conference on Information Engineering and Computer Science, ICIECS 2009 pp. 1–4 (2009). https://doi.org/10.1109/ICIECS.2009.5364626

195. Theoharis, T., Platis, N., Papaioannou, G., Patrikalakis, N.: Graphics and Visualization: Principles & Algorithms (1st ed.). A K Peters/CRC Press (2008). https://doi.org/10.1201/b10676

196. Thomas, A.: Integrated Graphic and Computer Modelling. Springer Publishing Company, Incorporated, 1 edn. (2008)

197. Tran, C.H.: Fast clipping algorithms for computer graphics. Ph.D. thesis, University of British Columbia (1986). https://doi.org/http://dx.doi.org/10.14288/1.0096928, https://open.library.ubc.ca/collections/ubetheses/831/items/1.0096928

198. Tropp, O., Tal, A., Shimshoni, I.: A fast triangle to triangle intersection test for collision detection. Computer Animation and Virtual Worlds 17(5), 527–535 (2006). https://doi.org/10.1002/cav.115
199. Van Wyk, C.J.: Clipping to the boundary of a circular-arc polygon. Computer Vision, Graphics, and Image Processing 25(3), 383–392 (1984). https://doi.org/10.1016/0734-189X(84)90202-0

200. Vatti, B.R.: A generic solution to polygon clipping. Commun. ACM 35(7), 56–63 (Jul 1992). https://doi.org/10.1145/129902.129906

201. Vince, J.: Geometric Algebra: An Algebraic System for Computer Games and Animation. Springer Publishing Company, Incorporated, 1st edn. (2009)

202. Vince, J.: Introduction to the Mathematics for Computer Graphics. Springer-Verlag, Berlin, Heidelberg, 3rd edn. (2010), https://link.springer.com/book/10.1007/978-1-4471-6290-2#toc

203. Vince, J.: Matrix Transforms for Computer Games and Animation. Springer Publishing Company, Incorporated (2012)

204. Vince, J.A.: Geometric Algebra for Computer Graphics. Springer-Verlag TELOS, Santa Clara, CA, USA, 1 edn. (2008). https://doi.org/10.1007/978-1-84628-997-2

205. Wang, H., Chong, S.: A high efficient polygon clipping algorithm for dealing with intersection degradation. Dongnan Daxue Xuebao (Ziran Kexue Ban)/Journal of Southeast University (Natural Science Edition) 46(4), 702–707 (2016). https://doi.org/10.3969/j.issn.1001-0505.2016.04.005

206. Wang, H., Wu, R., Cai, S.: A new algorithm for two-dimensional line clipping via geometric transformation. Journal of Computer Science and Technology 13(5), 410–416 (1998). https://doi.org/10.1007/bf02948499

207. Wang, H., Wu, R., Cai, S.: New efficient line clipping algorithm based on geometric transformation. Ruan Jian Xue Bao/Journal of Software 9(10), 728–733 (1998)

208. Wang, J., Lu, G.D., Peng, Q.S., Wu, X.H.: Line clipping against polygonal window algorithm based on the multiple virtual boxes rejecting. Journal of Zhejiang University: Science 6 A(SUPPL.), 100–107 (2005). https://doi.org/10.1631/jzus.2005.AS0100

209. Wang, J., Cui, C., Gao, J.: An efficient algorithm for clipping operation based on trapezoidal meshes and sweep-line technique. Advances in Engineering Software 47(1), 72–79 (2012). https://doi.org/10.1016/j.advengsoft.2011.12.003

210. Wang, X., Xue, Y., Fang, F., Chen, G.: From probability model to a fast line clipping algorithm. CAD/GRAPHICS 2001 pp. 802–806 (2001)

211. Watt, A.: Fundamentals of Three-Dimensional Computer Graphics. Addison-Wesley Longman Publishing Co., Inc., USA (1990)

212. Wei, L.Y.: A faster triangle-to-triangle intersection test algorithm. Computer Animation and Virtual Worlds 25(5-6), 553–559 (2014). https://doi.org/10.1002/cav.1558

213. Wei, W., Ma, P., Lin, W.: An improved Cohen-Sutherland region encoding algorithm. Applied Mechanics and Materials 239-240, 1313–1317 (2013). https://doi.org/10.4028/www.scientific.net/AMM.239-240.1313

214. Weiler, K.: Polygon comparison using a graph representation. Proc. Annu. Conf. Comput. Graph. Interact. Tech., SIGGRAPH pp. 10–18 (1980). https://doi.org/10.1145/800250.807462

215. Weiler, K., Atherton, P.: Hidden surface removal using polygon area sorting. Proc. Annu. Conf. Comput. Graph. Interact. Tech., SIGGRAPH pp. 214–222 (1977). https://doi.org/10.1145/563858.563896

216. Wijeweera, K., Kodituwakk, S.R., Pathum Chamikara, M.A.: A novel and efficient approach for line segment clipping against a convex polygon. Ruhuna Journal of Science 10(2), 161–173 (2019). https://doi.org/10.4038/rjs.v10i2.81, https://rjs.sljol.info/articles/abstract/10.4038/rjs.v10i2.81/
217. Wikipedia: Clipping (computer graphics) - Wikipedia, the free encyclopedia (2021), https://en.wikipedia.org/wiki/Clipping_(computer_graphics), [Online; accessed 28-July-2021]

218. Wikipedia: IEEE 754 - Wikipedia, the free encyclopedia (2021), https://en.wikipedia.org/wiki/IEEE_754, [Online; accessed 11-July-2021]

219. Wikipedia: Ray tracing (graphics) - Wikipedia, the free encyclopedia (2021), https://en.wikipedia.org/wiki/Ray_tracing_(graphics), [Online; accessed 3-August-2021]

220. Williams, A., Barrus, S., Morley, R.K., Shirley, P.: An efficient and robust ray-box intersection algorithm. In: ACM SIGGRAPH 2005 Courses. p. 9–es. ACM, New York, NY, USA (2005). https://doi.org/10.1145/1198555.1198748

221. Wu, Q., Huang, X., Han, Y.: A clipping algorithm for parabola segments against circular windows. Computers & Graphics 30(4), 540–560 (2006). https://doi.org/https://doi.org/10.1016/j.cag.2006.03.001, https://www.sciencedirect.com/science/article/pii/S0097849306000732

222. Wu, Z., Gou, C., Yang, D., Luo, Z.: Line clipping algorithm against arbitrary polygons. Journal of Computer-Aided Design and Computer Graphics 16(2), 228–233 (2004)

223. Xiao, L., Mei, G., Cuomo, S., Xu, N.: Comparative investigation of GPU-accelerated triangle-triangle intersection algorithms for collision detection. Multimedia Tools and Applications (2020). https://doi.org/10.1007/s11042-020-09066-3

224. Xie, L., Li, P., Zhou, M., Wang, X.: An clipping general polygons in regular grids algorithm base on successive encoding. ICCASM - Int. Conf. Comput. Appl. Syst. Model., Proc. 4, V4709–V4713 (2010). https://doi.org/10.1109/ICCASM.2010.5619427

225. Yang, W.: New approach to line clipping in computer graphics display. Zhongnan Kuangyue Xueyuan Xuebao 18(1), 73–78 (1988)

226. Ye, X., Huang, L., Wang, L., Xing, H.: An improved algorithm for triangle to triangle intersection test. ICIA 2015 proceedings pp. 2689–2694 (2015). https://doi.org/10.1109/ICInfA.2015.7279740

227. Zhang, M., Sabharwal, C.: An efficient implementation of parametric line and polygon clipping algorithm. Proceedings of the ACM Symposium on Applied Computing pp. 796–800 (2002). https://doi.org/10.1145/508791.508945

228. Zheng, J., Millham, C.: A linear programming method for ray-convex polyhedron intersection. Computers and Graphics 15(2), 195–204 (1991). https://doi.org/10.1016/0097-8493(91)90073-Q