Raziskave v računalniški grafiki

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1 Izhodišča in predstavitev problema

1.1 Metoda žarčenja

V zadnjih desetih letih je računalniška grafika iz laboratorijev univerz pričela zahajati v vsakdanja področja uporabe. Srečamo jo pri vizualizaciji v medicini, kot orodja CAD v strojništvu, arhitekturi in drugod. Stalni cilj večine raziskav v razvoju je generiranje realističnih prikazov objektov z računalnikom. Metoda žarčenja (*radiosity*) je ena novejših pomembnih pristopov pri reševanju modela osvetlitve, ki je ključna naloga pri generiranju realistične slike.

V primerjavi z metodo sledenja žarka (*ray tracing*) ima metoda žarčenja, za uporabo v strojništvu nekaj prednosti. Posebno se izkaže pri upodabljanju statičnih objektov, saj je izračun osvetlitve, ki temelji na termofizičnih lastnostih površin, neodvisen od smeri pogleda. Tako je možno v realnem času ocenjevati in demonstrirati tridimenzionalne objekte.

Čeprav je razvoj zadnjih let pokazal, da je metoda uporabna za upodabljanje, obstaja potreba po temeljnih raziskavah, ki bi zagotovile točnost, predvidljive rezultate in ustrezne performanse. Področje raziskav zajema analizo napak, fizikalne modele žarčenja, mreženje in optimizacijo hierarhije.

1.2 Geometrijsko modeliranje

Pomembno področje raziskav je tudi razvoj geometrijskih modelirnikov za CAD. Področje zajema površinske, CSG in hibridne modelirnike z različnimi osnovnimi gradniki. Nekatere raziskave v našem laboratoriju so pokazale prednosti površin tipa NURBS primitivov superkvadrikov, ki pa jih ne srečamo v današnjih modelirnikih. Nadaljne raziskave bi bile potrebne za efektivno izračunavanje presekov takih površin in programsko implementacijo, ki bi nazorneje pokazale lastnosti primitivov.

2 Pregled relevantnih raziskav z referencami

Trenutne raziskave s poročja metode žarčenja obsegajo združevanje in hierarhične metode, ki zmanjšujejo potreben računski čas. Forsyth in ostali [4] uporabljajo hierarhičen model z združevanjem končnih elementov v okoljih z gibljivimi objekti. Drugačen pristop s hranjenjem vmesnih rezultatov je prikazan v [11].

Lokalno zgoščevanje mreže lahko zmanjša zahtevnost metode žarčenja, vendar je v hierarhičnih metodah omejeno v globino. Nekaj pristopov k reševanju tega problema je podano v [8, 16, 10]. Z nepravilnim mreženjem je mogoče doseči bistvene bistvene izboljšave v natančnosti, kot tudi v zmogljivosti. Predlagani so različni pristopi, kot so Dalaunay triangulacija in podobne apriori sheme za mreženje [2].

Pri analizi napak je pomembno razumevanje osvetlitve okolja in potrditev pravilnosti metod pri uvedbi natančnejših metod, ki upoštevajo tudi medij [13] ali pri uvedbi relaksacijskih metod pri reševanju metode žarčenja [12]. Podrobnejšo predstavitev metode žarčenja lahko najdemo v [17].

3 Hipoteza – pričakovani rezultati

Z uvedbo novih algoritmov so pričakovani boljši rezultati pri generiranju realističnih slik. Boljši algoritmi mreženja lahko pripomorejo k natančnim rezultatom ali zmanjšajo potreben čas za mreženje. Ustrezni algoritmi za oceno napake podajajo lokalno zgoščevanje mreže. Drugi problemi v računalniški grafiki, kot so nekateri podproblemi pri mreženju in koherenci v geometrijskem modeliranju, lahko prav tako izrabijo rezultate te raziskave.

4 Podroben opis znanstvenih metod za dosego cilja

4.1 Metoda žarčenja *Radiosity Method*

Za dosego točnejših osvetlitev med površinami se lahko uporabi metoda žarčenja, ki temelji na fizikalnem modelu z uporabo končnih elementov površin, ki med seboj sproščajo energijo (svetlobo). Metoda je podobna v strojništvu spošno uveljavljenim metodam končnih elementov za izračun napetostnih ali termodinamičnih stanj v tridimenzionalnem modelu. Osnovna ideja metode žarčenja je v razdelitvi površin na končno velike površinice, ki med seboj sevajo svetlobo in tako vplivajo vsaka na vsako. Če napišeno enačbo za vsako površinico, dobimo sistem enačb za katerega je potrebno izračunati žarčenje posameznih ploskvic (*form factor determination*). Žarčenje ploskve je vsota vseh svetlobnih fluksov, ki izhaja kot difuzni odboj svetlobe ali sevana svetloba, če je površina uporabljena kot izvor (radiator) svetlobe.

Numeričen izračun sistema enačb je tudi generator napak, saj je za natančnejše izračunavanje potrebno večje število elementarnih ploskvic. Vsaka nova ploskev izboljša geometrijski model scene, poveča pa tudi numerične napake (konvergenca) in računsko zahtevnost celotnega sistema. Ocena globalnih in lokalnih napak je osnova za progresivno zgoščevanje mreže na kritičnih mestih.

Za kompleksne scene je potrebno veliko število ploskvic, kar prispeva k slabši konvergenci metode. Združevanje ploskvic lahko zmanjša zahtevnost metode, ne da bi bistveno zmanjšali natančnost. Z ustreznim hierarhičnim pristopom, lahko povečamo konvergenco in s tem zmanjšamo čas.

Drugi pristop k izboljševanju metode je inteligentno mreženje, z prilagajanjem mreže svetlobnim izvorom, ki pa je računsko zahtevno ter težko aplikativno. Inteligentno mreženje lahko predstavlja nslednjo fazo raziskav.

4.2 Geometrijsko modeliranje

Geometrijsko modeliranje trdnih teles je osnova večine aplikacij v strojništvu in drugih vejah industrije. Zaradi obsežnih izračunavanje je neizbežno povezano z računalniško tehnologijo s katero modeliramo abstraktne modele še pred fabrikacijo. Z uporabo abstrakcije CSG (*Constructive Solid Geometry*) lahko modeliramo poljubno zahtevna telesa s sestavljanjem osnovnih primitivov. Z uporabo zlepkov tipa NURBS (*Non-Uniform Rational B-Spline*) je mogoče sestaviti zaprte površine, ki jih lahko uporabimo kot osnovne gradnike za gradnjo drevesa CSG. S takim pristopom k abstrakciji modela, dobimo fleksibilen sistem z visoko stopnjo lokalne kontrole površine primitivov. Z uvedbo zlepkov NURBS v primitive se poveča računska zahtevnost izračunavanja presekov med primitivi. Ustrezni algoritmi in analitične rešitve lahko pripomorejo k efektivni implementaciji v tridimenzionalnih modelirnikih. Z bolj kompaktnimi primitivi, kot so *superkvadriki*, lahko podobno dosežemo množico osnovih primitivov le z variacijo parametrov osnovne enačbe površine. Superkvadriki so geometrijska telesa iz družine toroidov in elipsoidov. Ker splošne analitične rešitve niso znane, je z uporabo takih primitivov potrebno razviti učinkovite numerične metode za preseke površin.

5 Pomembnost pričakovanih rezultatov

5.1 Za razvoj znanosti

Seznam razvojnih možnosti za metodo žarčenja in geometrijskega modeliranja obsega veliko število naporov v znanosti. Obetajoča področija raziskav obsegajo:

- Implementacije v strojništvu

- Specializirani modelirniki
- Generiranje fotorealističnih slik
- Vizualizacija
- Animacija
- Mreženje in metode komčnih elementov
- Hiter pregled objektov v okolici

5.2 Za aplikacijo

6 Angleški prevod

6.1 Problem description

6.1.1 Radiosity method

Over the last decade, computer graphics has found their ways from the university research laboratories to everyday fields of usage. It can be found in medical visualization, as CAD tools in mechanical engineering, architecture and elsewhere. Persistent goal of vast number of research in computer graphics is realistic image synthesis with computer. Radiosity method is one of the novel methods for solving phisycaly-based illumination as key problem in photorealistic rendering.

Radiosity has several advantages over *ray tracing* method which are important for use in mechanical engineering CAD applications. Especialy is good in rendering of the still images. Method has been derived from the field of Heat Transfer. The lightning calculations are performed only once for a given environment. To render a view of the environment is relatively simple from any position. *View independence* is cruical for object demonstration and evaluation.

Although developements over last years showed that radiosity is useful for a range of applications there is still need for basic research to achieve better accuracy, predictable results and better performance. Research of the radiosity is driven in the areas of error analysis, physical-based lightning, meshing and hierarchy optimization.

6.1.2 Geometric modeling

Geometric modeling is one of the research area in the development of CAD (*Computer Aided Design*) modelers. Areas include development of the surface, solid and hybrid modelers. Some research at our lab has shown advatnages of NURBS (Non Uniform Rational B-Spline) patches and superquadrics primitives which are rarely found in modelers. Further research is neaded to develop algorithms for effective intersection calculus and program implementation showing properties of such primitives.

6.2 Expected results

Better results in synthesis of the realistic pictures will be obtained with implementation of the novel algorithms. Novel meshing algorithms can significally improve image quality, accuracy and cuts down total meshing time. Quantitative error measures for quality of meshing ad suggestions for discontinuity meshing will be introduced. Other problems, such as some subproblems in meshing and coherence in geometric modeling, can benefit from results of this research.

6.3 Research program and scientific background

6.3.1 Radiosity Method

For achievment of better results in image synthesis, radiositity methods can be applied. They provide more accurate treatment of interobject reflections based on physicallightning model and finite elementh method. Finite element method is similar to the well known methods used in mechanical engineering for stress analysis, with difference that radiosity is based on thermal engineering methods and surface finite elements. The basic idea of radiosity is to generate finite number of patches and take into account secondary illumination reflected from surfaces. If we write down equation for every element describing outcoming light flux, we get system of equations which describes interacion of light in the environment. The radiosity of a surface is light energy that leaves surface. Outgoing energy or *radiant exitance* is sum of the reflected energy and the emmited light if the surface is self-luminous.

Numerical calculaction and iterative aproach to the radiosity method is generator of errors. For accurate evaluation of the global ilumination, more finite elements is needed, introducing slower convergence of the method and longer processing time. Better treatment of errors introduced with discretizations and propagated numerical errors is key to progresive refinement and spatial subdivision of the environment.

Huge number of elements in complex scenes contributes to slower convergence of the method. Hierarhical aproach to form lagrer cluster of elements or polygons can be used to reduce the cost of the radiosity solution.

Other aproaches to the radiosity improvement include discontinuity meshing with adapting the mesh to light sources or other apriori approaches. Inteligent meshing can be next stage of the research.

6.3.2 Geometric modeling

Geometry modeling of the solids is basis for major number of mechanical engineering applications as well as other industry branches. With CSG (*Constructive Solid Geometry*) computer abstraction complex objects can be modeled. Incorporation of the NURBS patches (*Non-Uniform Rational B-Splines)* can form closed surfaces useful as primitives for CSG tree construction. Such primitives shows higher local control in modification of primitives and thus higher level of flexibility. Introduction of NURBS in 3D modeler demands accurate and fast calculation of the intersections. Novel algorithms and analythic results can contribute to efective implementation in the geometric modelers. More compact primitives as superquadrics are also apropriate for primitives in modelers. Superquadrics are solids from the family of the elipsoids and toroids with several parameters which controls shape and covers basic primitives found in modelers. Eficient algorithms for numerical intersection of such solid is necessity for implementation in the modelers.

6.4 Importance of espected results

6.4.1 Science

The list of research opportunities for Radiosity method and geometric modeling spans a lot of contemporary scientific endeavour. The most promising areas for research include:

- Modelers for special purposes
- Mechanical design
- Protorealistic image synthesis
- Visualization
- Animation
- Meshing and finite element methods
- Fast previewing

6.4.2 Application

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