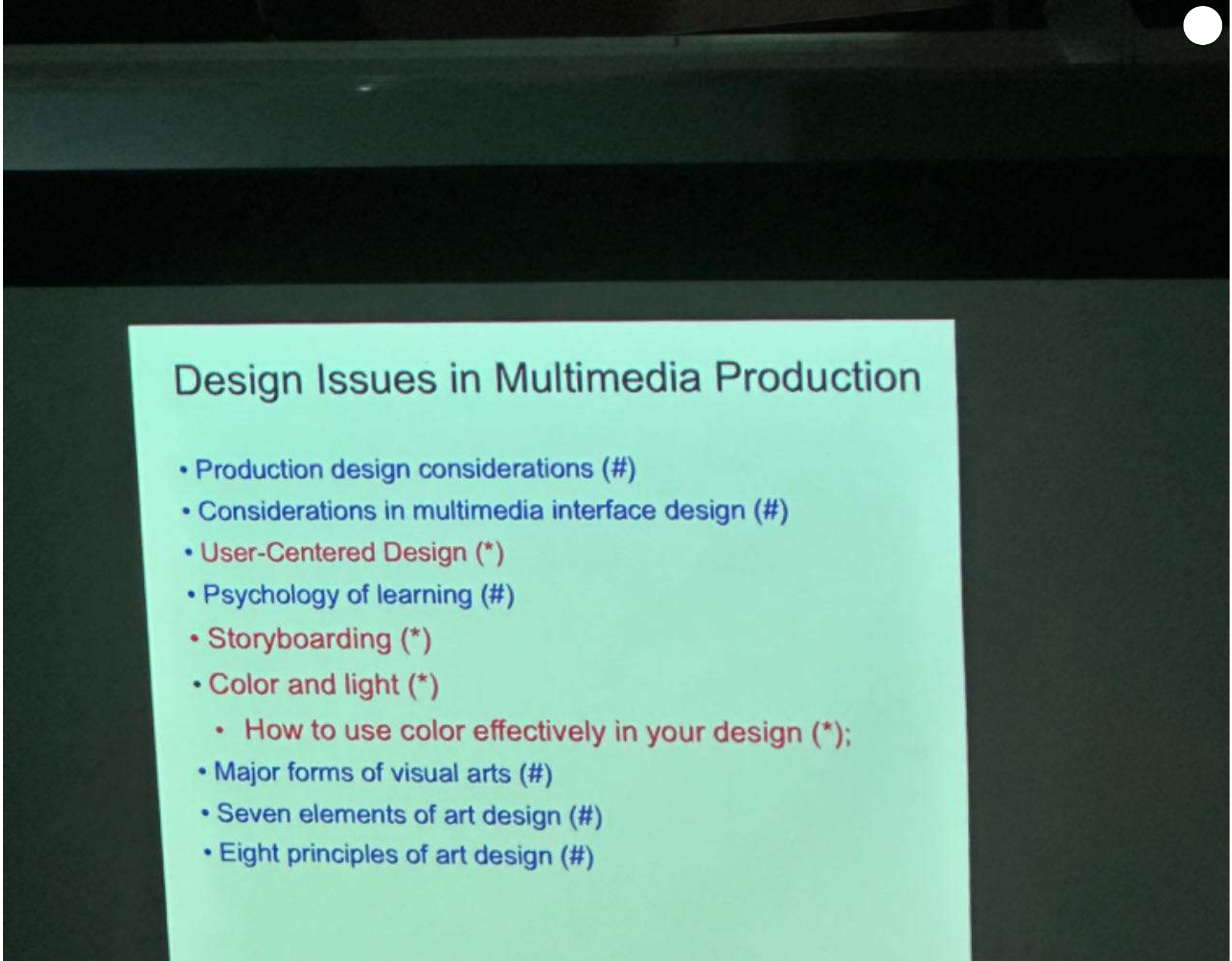
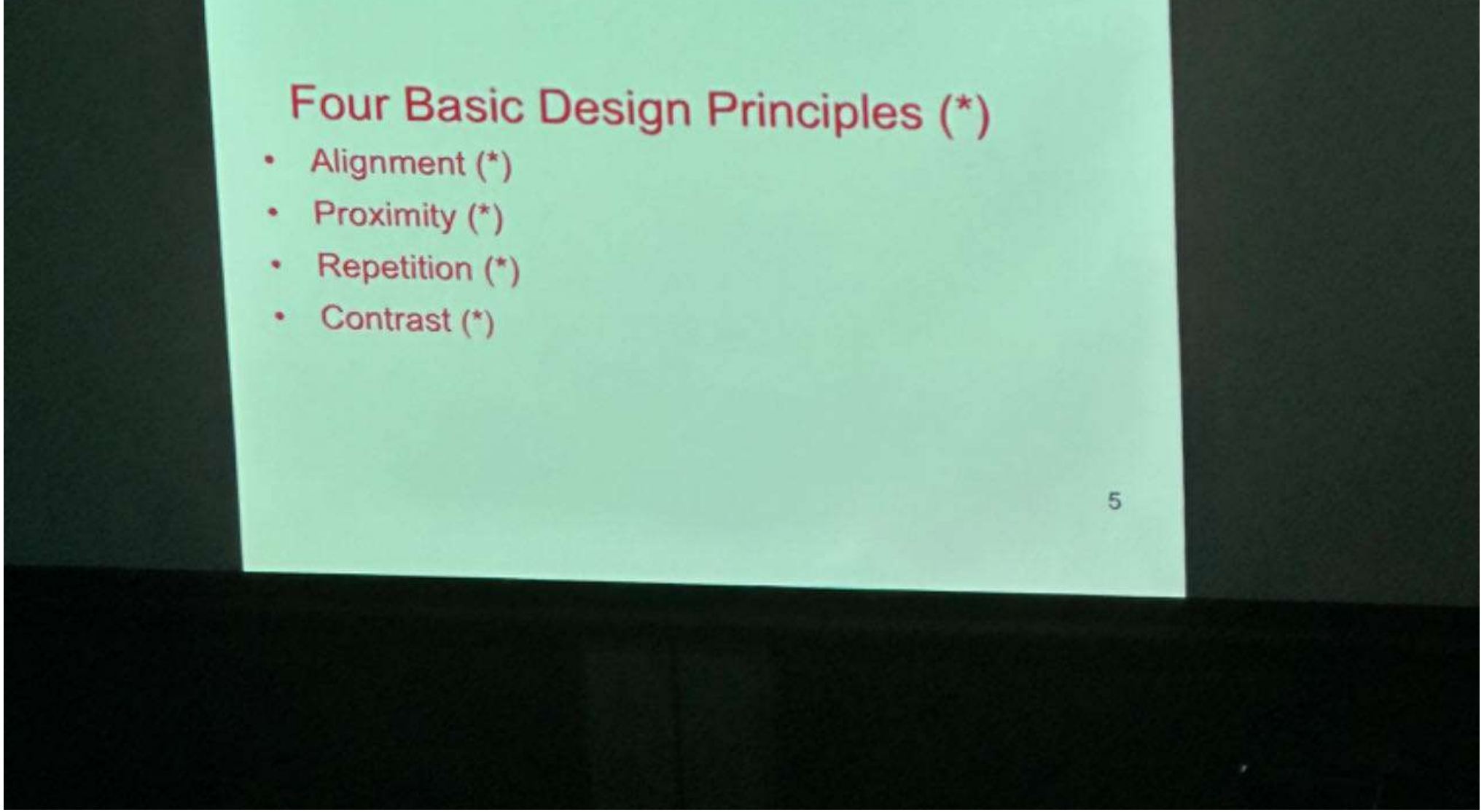
Comp5415 reviewing notes

Design issues


Design Issues in Multimedia Production
• Production design considerations (#)
• Considerations in multimedia interface design (#)
• User-Centered Design (*)
• Psychology of learning (#)
• Storyboarding (*)
• Color and light (*)
• How to use color effectively in your design (*);
• Major forms of visual arts (#)
• Seven elements of art design (#)
• Eight principles of art design (#)

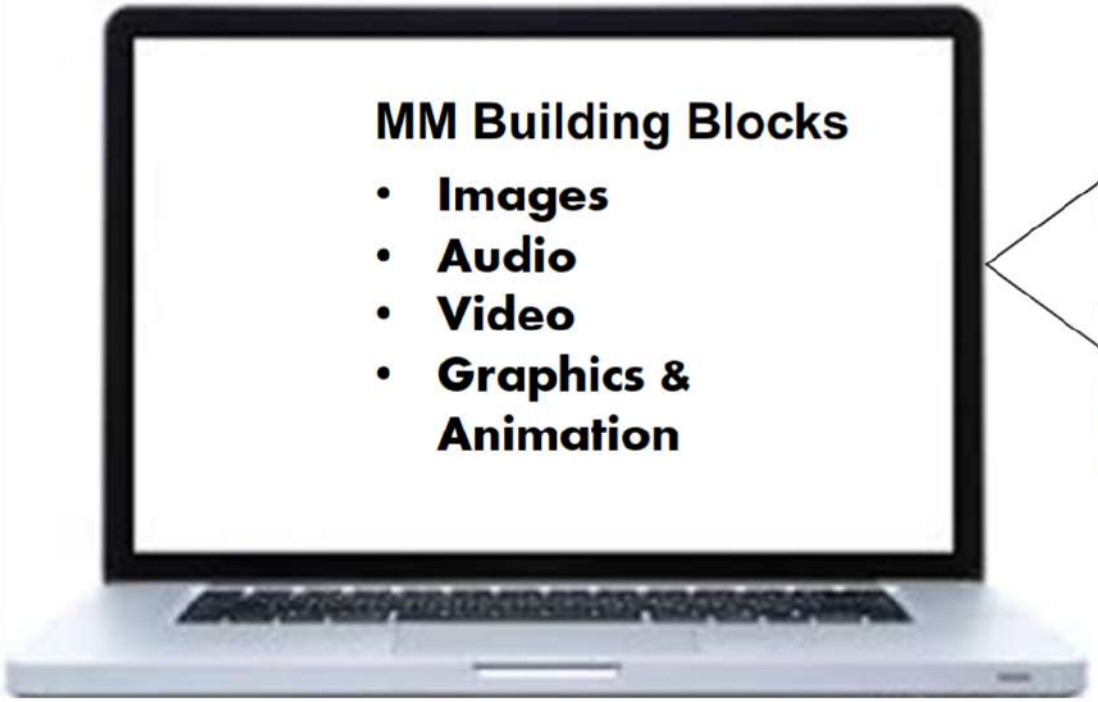


User-centered design

Multimedia Design and Visual Communication

REVIEW

The designer of a multimedia production has to make important decisions about composition, balance, and the integration of the production design with visual contents. This includes creating ***multimedia elements*** to express concepts, information, and moods.



User Interface

To support more efficient and effective learning and knowledge retention.

User-centered methodology

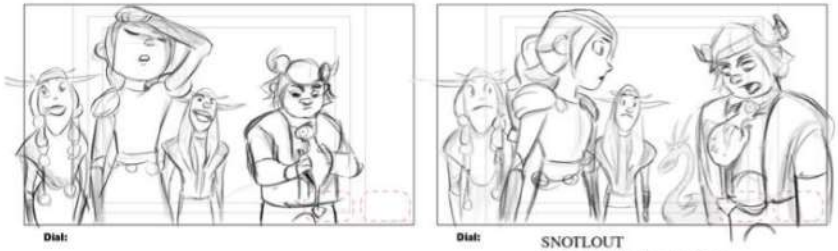
Know your users

Age, educational level, culture, gender…

Understanding the psychology of learning and visual arts basics helps on improving the **design and usability** of your multimedia production.

storyboarding

Storyboard



Dial:

As Astrid wipes her brow, Snotlout approaches with a baby dragon.

Dial:

SNOTLOUT
It feels like big sharp teeth are tearing at this thing in my chest.

Dial:

ASTRID
That's what it feels like when your heart is breaking.

Dial:

Snotlout tries pulling the baby dragon away..

Dial:

https://animationtidbits.tumblr.com/post/284545132226/how-to-train-your-dragon-tv-series-storyboards

Responsive web design User interface design Usability User Experience, website, electronics, web Design, mobile App Development png

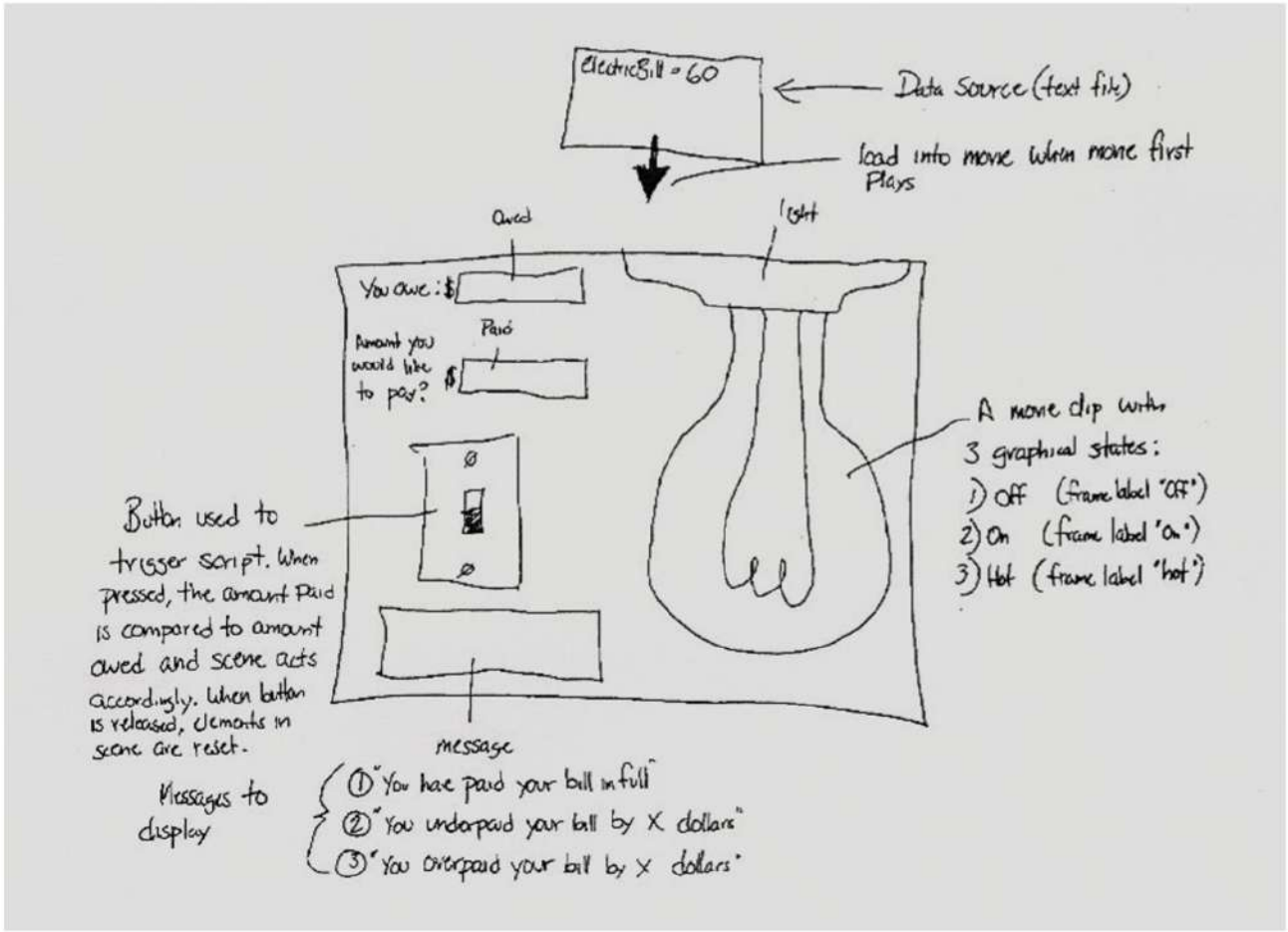
User interface design, flat design, web design,

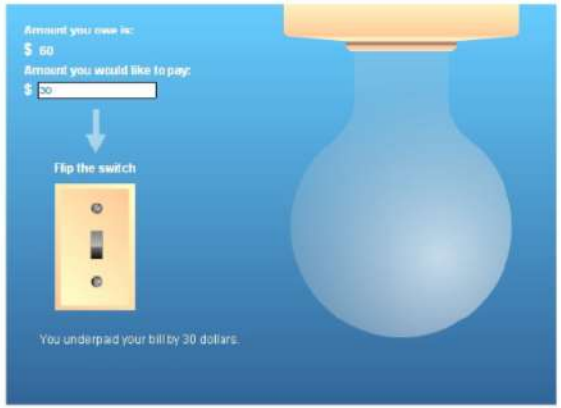
https://www.pngwing.com/en/free-png

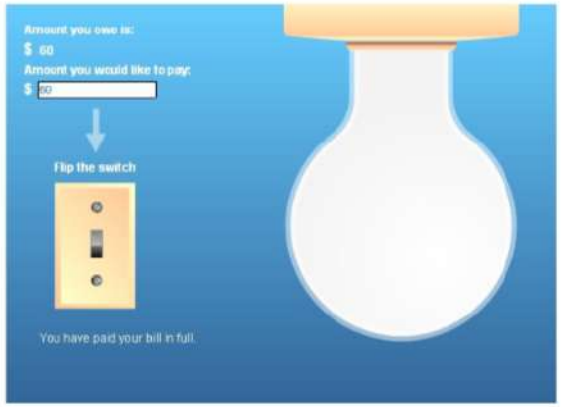
Storyboarding

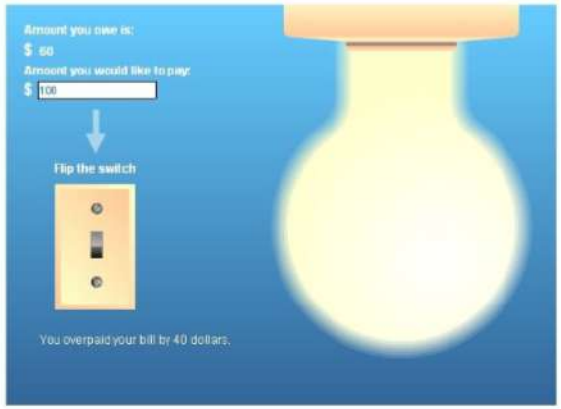
EXAMPLE [a very simple example for interactive electric bill payment]

Create a rough graphical representation of your scene (both its appearance and the action that will take place). Include all of the information you have gathered up to this point.









Color&light-how to use color effectively in your design

没找到在哪

Four Basic Principles

Alignment

我的理解是：alignment 的作用是使得页面里面的所有元素整齐有序，分组明确，让人的视觉更容易去注意到内容而不是被无序信息打扰。
所以我们要做的事情是降低页面中文字以及其他组成元素之间的无序度。

Basic Design Principle –

Alignment

Nothing should be placed on the page arbitrarily.
Every element should have some visual connection with another element on the page.

When items are aligned on the page, it creates a *strong cohesive unit*. Even when aligned elements are physically separated from each other, there would be an invisible line connecting them, both in your eye and in your mind.

Alignment helps to create a clean, sophisticated, fresh look.

Basic Design Principle – Alignment

For Beginners: Choose one alignment and use it on the entire page. Don't mix alignments!

This text is ***flush left***. Some people call it quad left, or we can say it is left aligned.

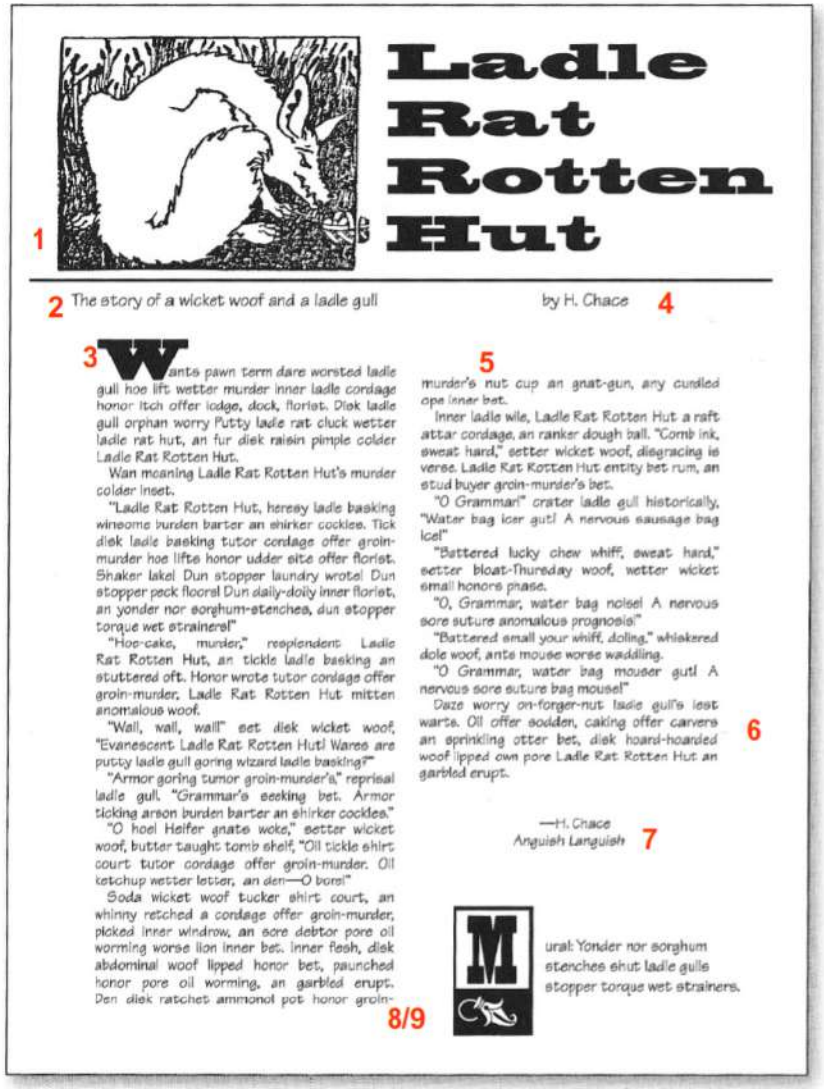
This text is ***centered***. If you are going to center text, make it obvious.

This text is ***flush right***. Some people call it quad right, or we can say it is right aligned.

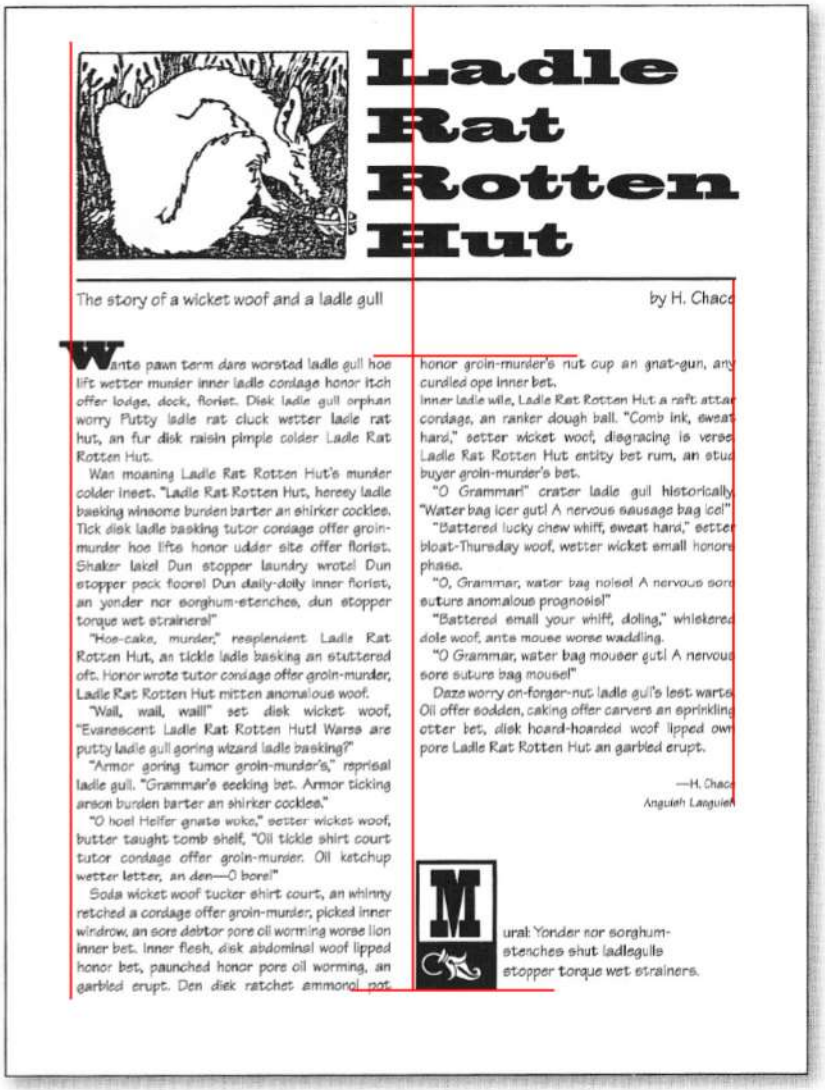
See, in this paragraph it is difficult to tell if this text was centered purposely or perhaps accidentally. The line lengths are not the same, but they can't instantly tell that the type is centered, why bother?

This text is ***justified***. Some people call it quad left and right, and some call it blocked – the text lines up on both sides. Whatever you call it, don't do it unless your line length is long enough to avoid awkward gaps between the words.

Basic Design Principle – Alignment



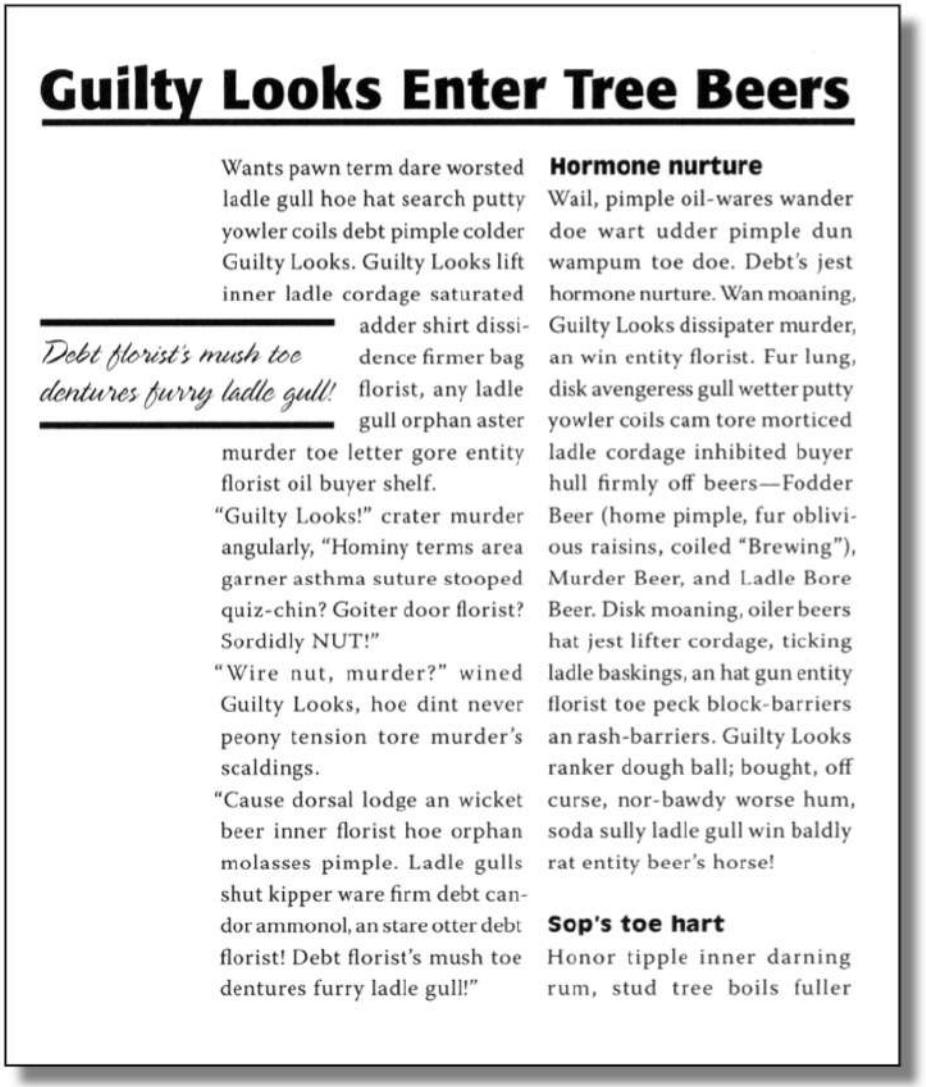
Can you see all the places where items could be aligned, but aren't? Please go ahead and point out all the misalignments on this page. There are at least nine!



Can you see now what has made the difference between this example and the one on the left page? Please go ahead and draw lines along the strong alignments.

Basic Design Principle – Alignment

If your alignments are strong, you can break through them consciously and it will look intentional.



Guilty Looks Enter Tree Beers

Wants pawn term dare worsted ladle gull hoe hat search putty yowler coils debt pimple colder Guilty Looks. Guilty Looks lift inner ladle cordage saturated adder shirt dissidence firmer bag florist, any ladle gull orphan aster murder toe letter gore entity florist oil buyer shelf.

Debt florist's mush toe dentures furry ladle gull!

"Guilty Looks!" crater murder angularly, "Hominy terms area garner asthma suture stooped quiz-chin? Goiter door florist? Sordidly NUT!"

"Wire nut, murder?" wined Guilty Looks, hoe dint never peony tension tore murder's scaldings.

"Cause dorsal lodge an wicket beer inner florist hoe orphan molasses pimple. Ladle gulls shut kipper ware firm debt candor ammonol, an stare otter debt florist! Debt florist's mush toe dentures furry ladle gull!"

Hormone nurture

Wail, pimple oil-wares wander doe wart udder pimple dun wampum toe doe. Debt's jest hormone nurture. Wan moaning, Guilty Looks dissipater murder, an win entity florist. Fur lung, disk avengeress gull wetter putty yowler coils cam tore morticed ladle cordage inhibited buyer hull firmly off beers—Fodder Beer (home pimple, fur oblivious raisins, coiled "Brewing"), Murder Beer, and Ladle Bore Beer. Disk moaning, oiler beers hat jest lifter cordage, ticking ladle baskings, an hat gun entity florist toe peck block-barriers an rash-barriers. Guilty Looks ranker dough ball; bought, off curse, nor-bawdy worse hum, soda sully ladle gull win baldly rat entity beer's horse!

Sop's toe hart

Honor tipple inner darning rum, stud tree boils fuller

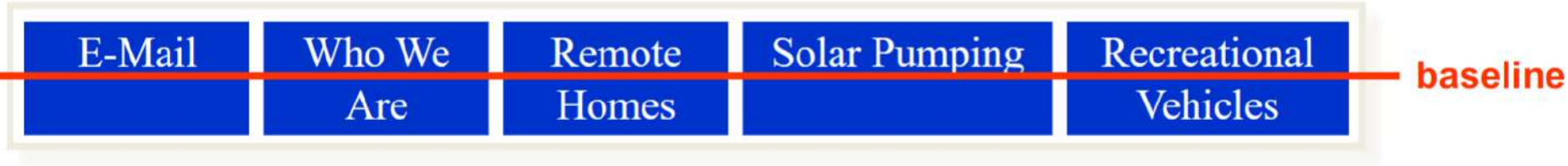
Even though that inset piece is breaking into the text block, can you see where it is aligned on the left?

It is possible to sometimes break completely free of any alignment, if you do it consciously.

Basic Design Principle – Alignment

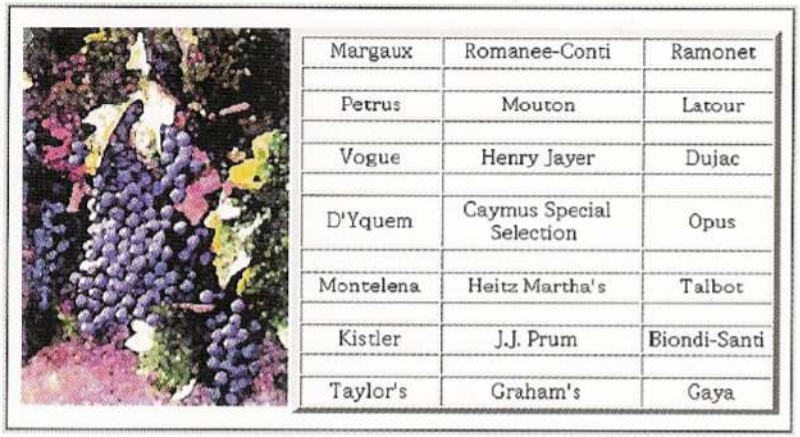
Lack of alignment is one of the most prevalent problems on web page design. It's a big problem on printed pages, but it seems to be even more ubiquitous and disastrous on web pages.

Horizontal alignment is just as important as vertical alignment. It's very common to see buttons as in the example above, where the type does not align horizontally. This "up / down / up / down" shift makes the whole strip look messy.

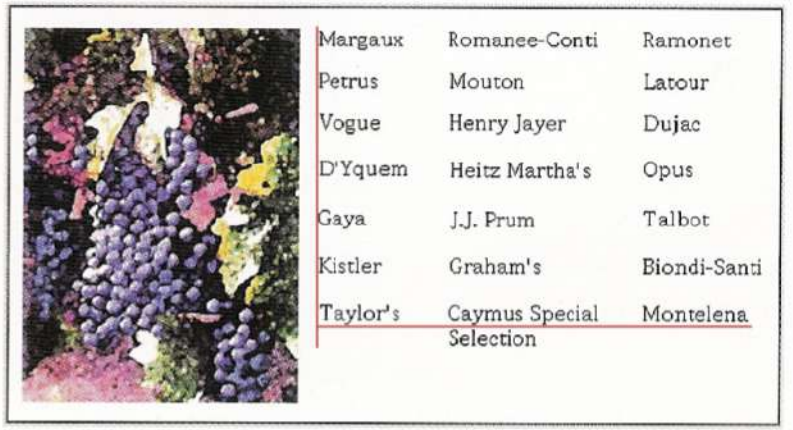


Type sits on an invisible line called the "***baseline***". By aligning all the text on the same baseline, the strip of links is neater and more organized. In most web authoring software there is a button for baseline alignment, usually in the table specifications.

Basic Design Principle – Alignment



Margaux	Romanee-Conti	Ramonet
Petrus	Mouton	Latour
Vogue	Henry Jayer	Dujac
D'Yquem	Caymus Special Selection	Opus
Montelena	Heitz Martha's	Talbot
Kistler	J.J. Prum	Biondi-Santi
Taylor's	Graham's	Gaya



Margaux	Romanee-Conti	Ramonet
Petrus	Mouton	Latour
Vogue	Henry Jayer	Dujac
D'Yquem	Heitz Martha's	Opus
Gaya	J.J. Prum	Talbot
Kistler	Graham's	Biondi-Santi
Taylor's	Caymus Special Selection	Montelena

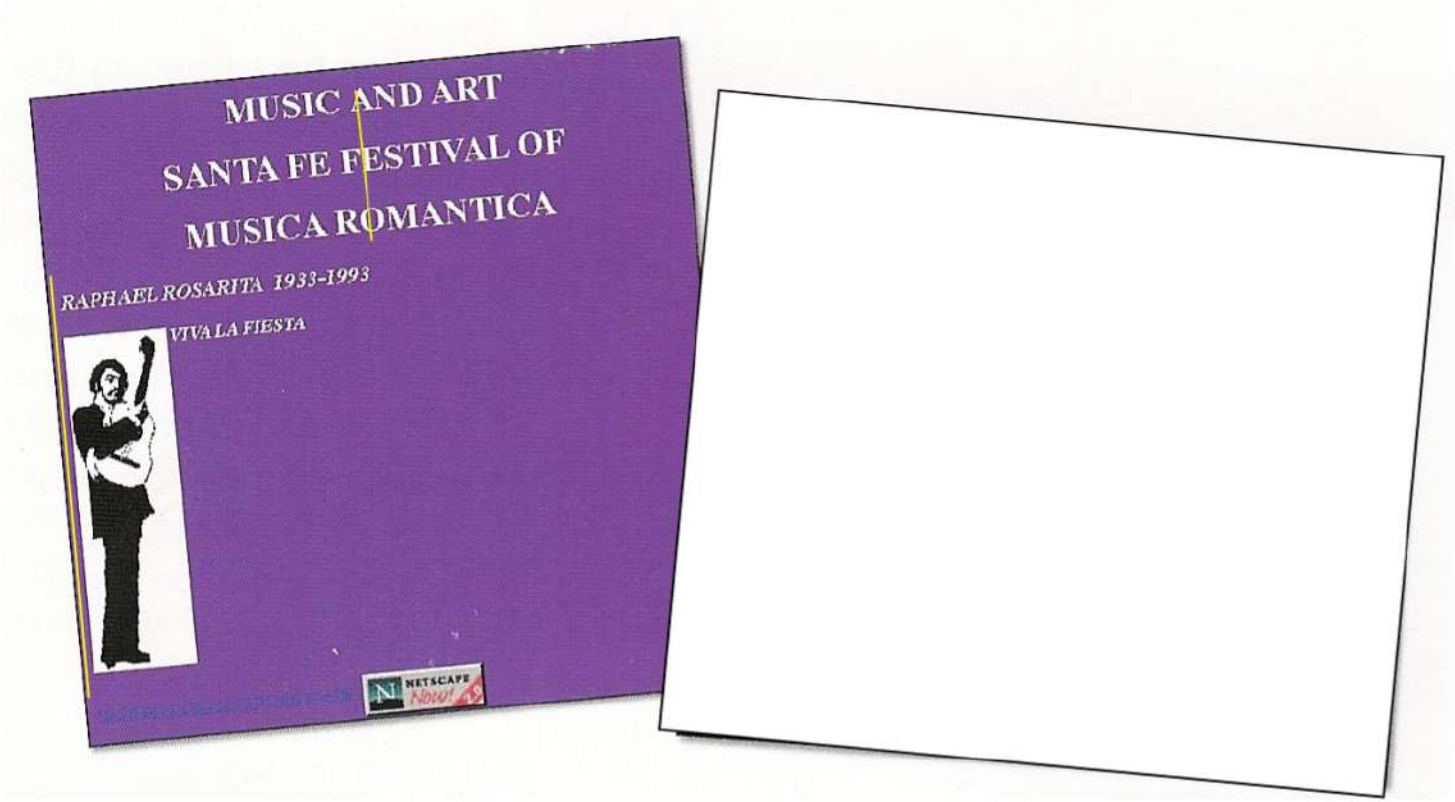
Turn the borders off.

In this example, the strong edges of the aligned text can create the visual separations necessary for the columns, but not if the text is centered and the baselines don't align (left page).

Again, the result of cleaning up the borders is not just that it looks better, but it communicates better.

Pages with strong flush left or flush right alignments usually look more sophisticated than pages where there is a mixture of alignments. The alignment creates a unifying force.

Basic Design Principle – Alignment



This is a typical example of a web page – centered heading, flush left body copy. The flush left elements are bumped up against the left edge.

◆**First** of all, choose one alignment – either center everything or flush everything to the left.

◆**Second**, move elements away from the extreme left edge of the web page. Raphael looks about to fall off the page.

◆**Third, don't set default type in all caps**. It's hard to read and it looks dumb.

◆**Fourth, don't italicize words that are in all caps.**

◆**Fifth**, get rid of the "Netscape Now" item. It's totally superfluous and only serves as junk on the page.

Proximity

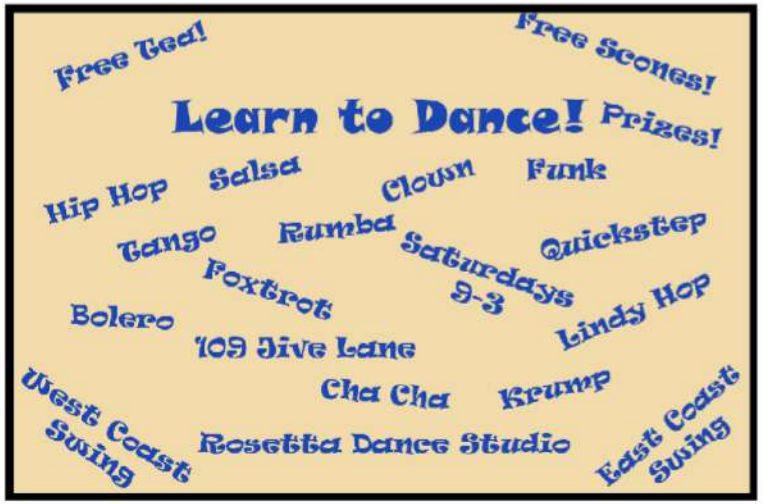
通过安排元素之间的间隔距离和位置，来让各个元素分组。相同性质的文字或者元素间隔距离相同，不同性质的元素间隔距离不同，可以给读者通过排版带来更加良好的信息获取体验。

Basic Design Principle –

Proximity

Items relating to each other should be grouped close together. When several items are in close proximity to each other, they become one visual unit rather than several separate units.

Proximity helps organizing information and reduces clutter.



Basic Design Principle – Proximity

When you create a flyer, a brochure, or poster, you know which pieces of information are logically connected, you know which information should be emphasized, and what can be de-emphasized. Structure the related information logically by applying proximity for grouping information.

Media Disks
Children's CDs
Educational CDs
Entertainment CDs
DVDs
Educational
Early learning
Language arts
Science
Math
Teacher Tools
Books
Teacher workbooks
Videos
Hardware &
Accessories
Cables
Input devices
Mass storage
Memory
Modems
Printers & supplies
Video and sound

Media Disks
Children's CDs
Educational CDs
Entertainment CDs
DVDs

Educational
Early learning
Language arts
Science
Math

Teacher Tools
Books
Teacher workbooks
Videos

Hardware & Accessories
Cables
Input devices
Mass storage
Memory
Disk drives
Printers & supplies
Video and sound

Obviously, the left-hand list needs some formatting to make it understandable. But the biggest problem with this list is that everything is close to everything else, so there is no way to see the relationships or the organization.

In the right-hand example, the same list has been formed into visual groups.

Basic Design Principle – Proximity

Chamber Concert Series

Egley Junior College

Friday February 8 at 8 p.m. Alexander String Quartet
Mozart, K387, Bartok#3, Beethoven, Opus 59, #1
Sam Pritchert & Ethel Libitz, violins;
Sandra Yarbrough, viola; Mark Wilson, cello
Friday, March 1, 8 p.m. Trio Artaria
Beethoven "Archduke" Trio, and trios by
Haydn, Schoenberg and Magnard
Richard Samson Norartz, violin
Reception following concert in Egley Art Gallery
Friday, April 26 at 8 p.m. Egley Chamber Players
Brahms G Minor Piano Quartet,
Schubert Sonata
Polly Hollyfield, violin; Linda Batticioli, viola;
Norinne Antiqua-Tempest, cello;
Margaret Park-Raynolds, flute; Robin Plantz, piano
All concerts in Newman Auditorium,
Emeritus Hall, Community Education
Tickets $10 and $8
For ticket information phone 555-1212

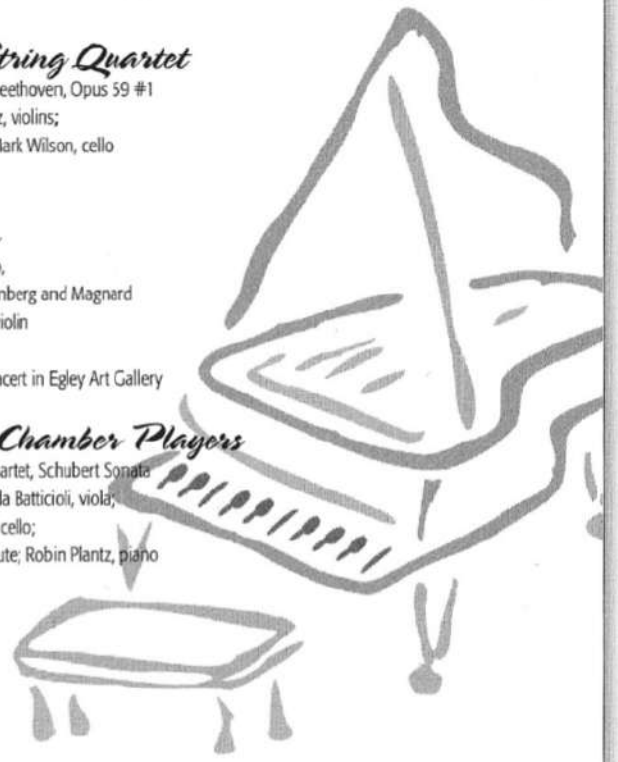
Not only is this page visually boring, but it is difficult to find the information –
what is going on,
where is it happening,
when is it,
how many concerts are in the series ?

Chamber Concert Series

Alexander String Quartet
Mozart, K387, Bartok#3, Beethoven, Opus 59 #1
Sam Pritchert & Ethel Libitz, violins;
Sandra Yarbrough, viola; Mark Wilson, cello
Friday, February 8, 8 P.M.

Trio Artaria
Beethoven "Archduke" Trio,
and trios by Haydn, Schoenberg and Magnard
Richard Samson Norartz, violin
Friday, March 1, 8 p.m.
Reception following concert in Egley Art Gallery

Santa Rosa Chamber Players
Brahms G Minor Piano Quartet, Schubert Sonata
Polly Hollyfield, violin; Linda Batticioli, viola;
Norinne Antiqua-Tempest, cello;
Margaret Park-Raynolds, flute; Robin Plantz, piano
Friday, April 26, 8 p.m.

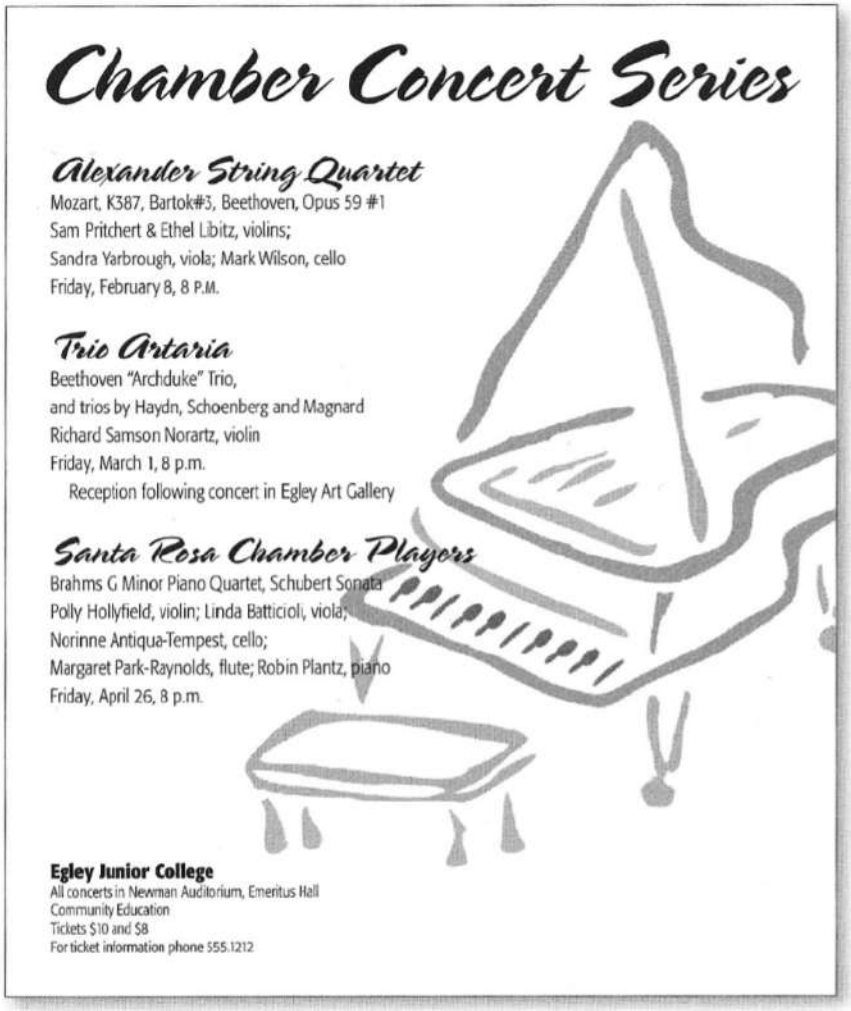


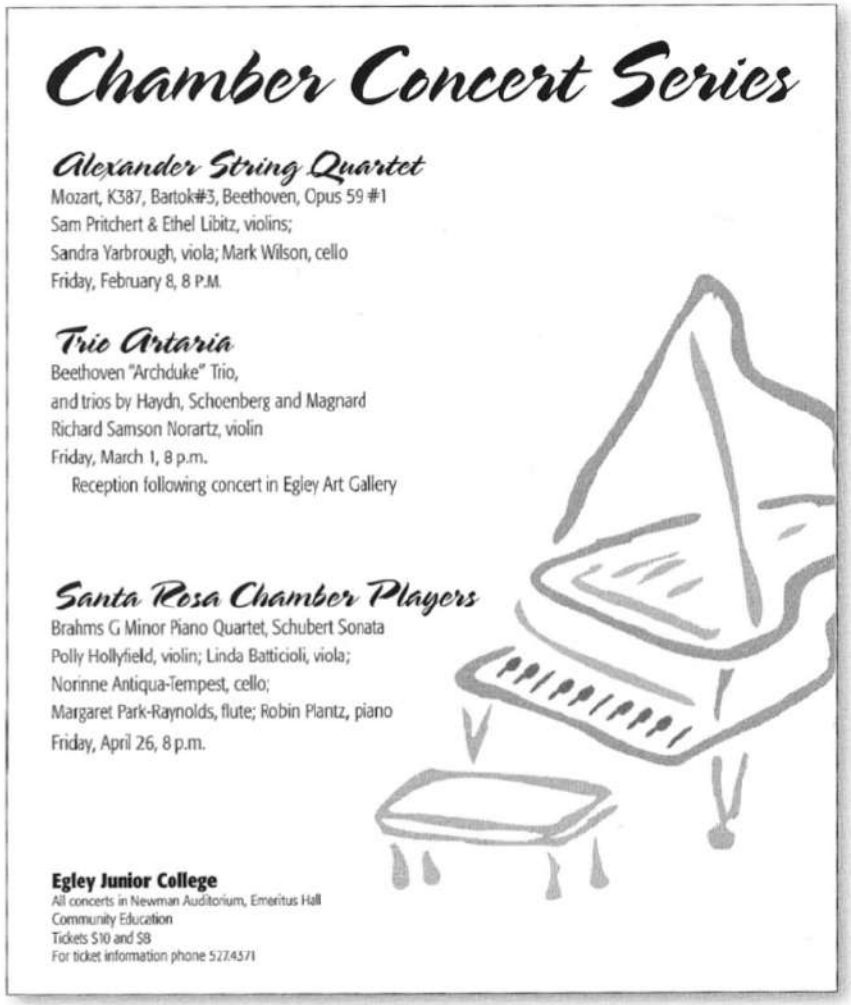
Egley Junior College
All concerts in Newman Auditorium, Emeritus Hall
Community Education
Tickets $10 and $8
For ticket information phone 555.1212

The information was
- <u>firstly</u> intellectually grouped together, and
- <u>then</u> physically set in groups on the page.

Notice the spacing between the three performances is the same, indicating that these three groups are somehow related.

Basic Design Principle – Proximity





The right-hand example is almost the same example as on the left-hand page. Glance at it quickly – now what do you assume about the three concerts?

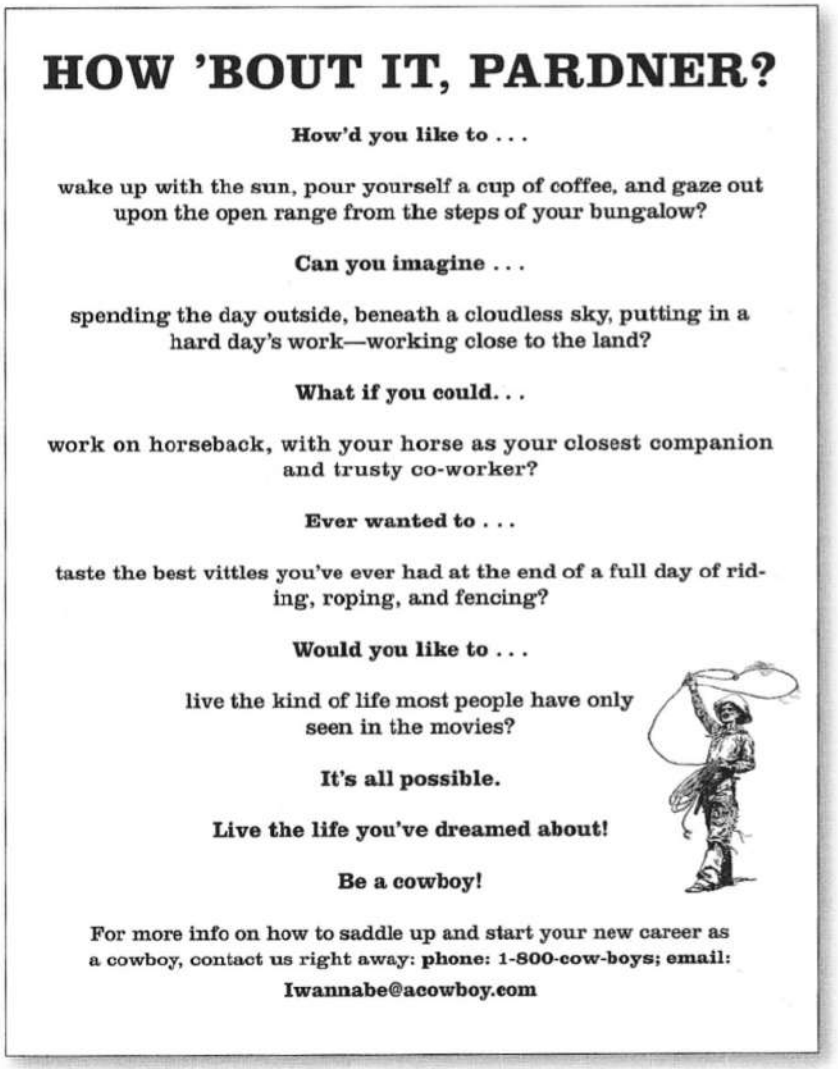
And why exactly do you assume one concert is different from the others?

Because one is separate from the others.

You instantly know that concert is somehow different because of the spatial relationships.

Basic Design Principle – Proximity

You're probably already using the principle of proximity in your work, but you may not be pushing it as far as you could to make it truly effective.



HOW 'BOUT IT, PARDNER?

How'd you like to . . .

wake up with the sun, pour yourself a cup of coffee, and gaze out upon the open range from the steps of your bungalow?

Can you imagine . . .

spending the day outside, beneath a cloudless sky, putting in a hard day's work—working close to the land?

What if you could. . .

work on horseback, with your horse as your closest companion and trusty co-worker?

Ever wanted to . . .

taste the best vittles you've ever had at the end of a full day of riding, roping, and fencing?

Would you like to . . .

live the kind of life most people have only seen in the movies?

It's all possible.

Live the life you've dreamed about!

Be a cowboy!

For more info on how to saddle up and start your new career as a cowboy, contact us right away: **phone: 1-800-cow-boys; email: Iwannabe@acowboy.com**

The designer of this mini-poster typed two *Returns* after each headline and paragraph. Thus the headlines have same distance from the body copy above and below, so they appear to be separate, unconnected items. You can't tell if the headline belongs to the text above it or below it because the distances are the same.

There is lots of white space available here, but it's all broken up. And there is white space where it doesn't belong, like between the headlines and their related texts.
When white space is "trapped" like this, it tends to visually push the elements apart.

Basic Design Principle – Proximity

If there are too many separate items, group the ones that have logic relationships. Use the simple design principle of proximity indicated by space will make the page not only more organized, but nicer to look at.

HOW 'BOUT IT, PARDNER?

How'd you like to . . .
wake up with the sun, pour yourself a cup of coffee, and gaze out upon the open range from the steps of your bungalow?

Can you imagine . . .
spending the day outside, beneath a cloudless sky, putting in a hard day's work—working close to the land?

What if you could. . .
work on horseback, with your horse as your closest companion and trusty co-worker?

Ever wanted to . . .
taste the best vittles you've ever had at the end of a full day of riding, roping, and fencing?

Would you like to . . .
live the kind of life most people have only seen in the movies?

It's all possible!
Live the life you've dreamed about—be a cowboy!

For more info on how to saddle up and start your new career as a cowboy, contact us right away:
1-800-cow-boys
Iwannabe@acowboy.com

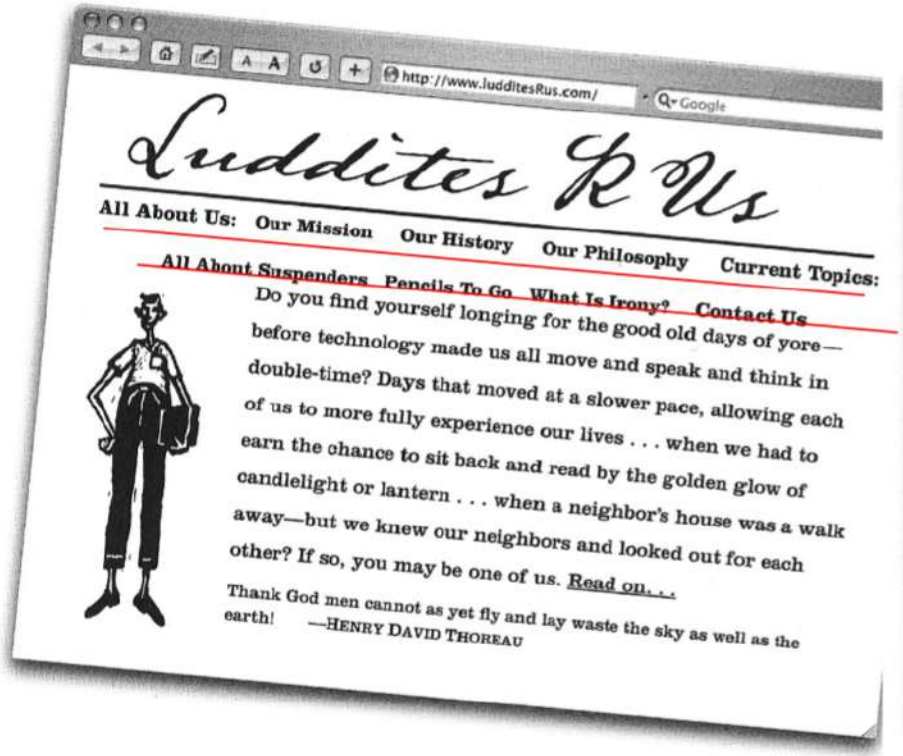
If we do just one thing to this piece, just move the headlines closer to their related paragraphs of text, several things happen:

- The organization is clearer.
- The white space is not trapped within elements.
- There appears to be more room on the page so the mini-poster is not so crowded.

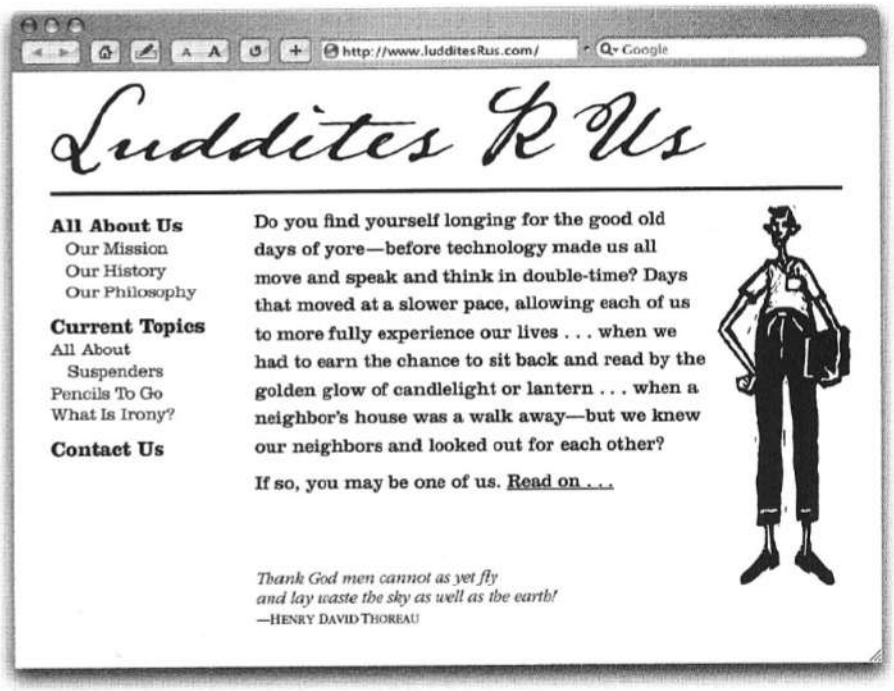
We can also put the phone and email address on separate lines – but group together and separate – so they'll stand out as important information. We can change the centered alignment to flush left, which provides more room for the cowboy graphic.

Basic Design Principle – Proximity

The simple principle of proximity can make web pages easier to navigate by organizing information into logical groups.



The information on this page is muddled. Look at the site links just under the title. Are they all equal in meaning? They appear to be – but they're not.



We can move all the site links into one column to show their relationships to one another (and move the man to the other side). The quotation can be set further away from the main body copy since it's not directly related.

Repetition

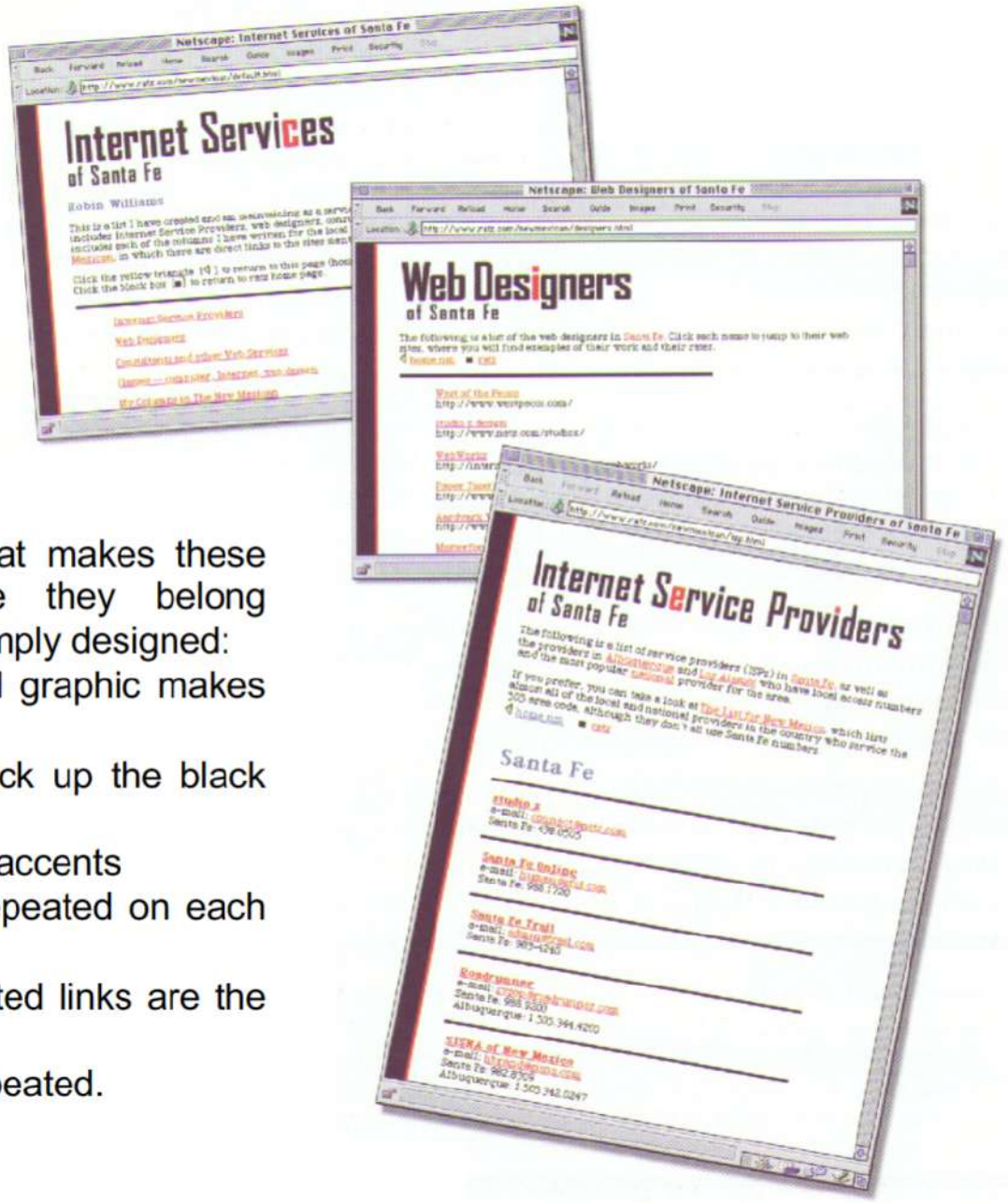
Repetition

Repeat visual elements of the design throughout the piece. You can repeat color, shape, texture, spatial relationships, line thicknesses, fonts, sizes, graphic concepts, etc.

Repetition develops the organization and strengthens the unity.

Basic Design Principle – Repetition

Notice the repetitive elements within each individual page, in addition to those that tie all of the pages together.



So exactly what is it that makes these three pages look like they belong together? They're very simply designed:

✧A left-edge background graphic makes the black and red stripe

✧Repetitive headlines pick up the black with a bit of red

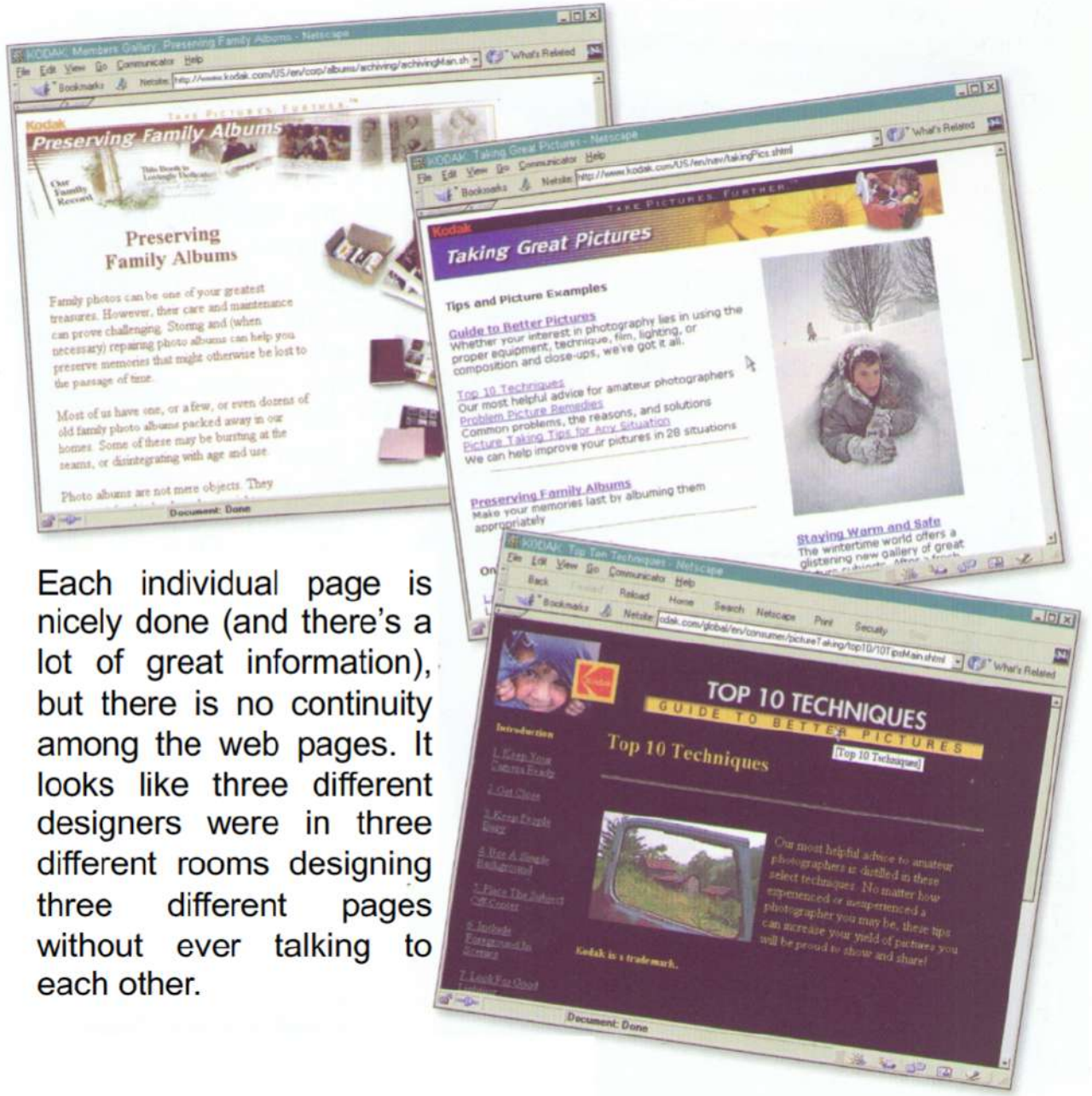
✧The black type has red accents

✧The layout format is repeated on each page

✧The subheads and visited links are the same pale color

✧The rules (lines) are repeated.

Basic Design Principle – Repetition



Each individual page is nicely done (and there's a lot of great information), but there is no continuity among the web pages. It looks like three different designers were in three different rooms designing three different pages without ever talking to each other.

Basic Design Principle – Repetition

In this site, it's easy to see the repetitive elements – background, typeface, link images, and colors.
Notice the nice, clean alignments.
Notice that the home page is a good example of a page that looks centered.

Contrast

通过增加特定元素对比的方式使得首要信息更加突出，也可以增加设计的视觉丰富度。引导读者视线。

Basic Design Principle – Contrast

The idea behind contrast is to avoid elements on the page that are merely similar. If the elements (type, color, size, line thickness, shape, space, etc.) are not the same, then make them **very different**.

Contrast is often the most important visual attraction on a page.

Basic Design Principle – Contrast

ANOTHER NEWSLETTER!

January First 2005

Exciting Headline

Wants pawn term dare worsted ladle gull hoe hat search putty yowler coils debt pimple colder Guilty Looks. Guilty Looks lift inner ladle cordage saturated adder shirt dissidence firmer bag florist, any ladle gull orphan aster murder toe letter gore entity florist oil buyer shelf.

Thrilling Subhead

"Guilty Looks!" crater murder angularly. "Hominy terms area garner asthma suture stooped quiz-chin? Goiter door florist? Sordidly NUT!"

"Wire nut, murder?" wined Guilty Looks, hoe dint peony tension tore murder's scaldings.

"Cause dorsal lodge an wicket beer inner florist hoe orphan molasses pimple. Ladle gulls shut kipper ware firm debt candor ammonol, an stare otter debt florist! Debt florist's mush toe dentures furry ladle gull!"

Another Exciting Headline

Wail, pimple oil-wares wander doe wart udder pimple dum wampum toe doe. Debt's jest hormone nurture.

Wan moaning, Guilty Looks dissipater murder, an win entity florist. Fur lung, disk avengeress gull wetter putty yowler coils cam tore morticed ladle cordage inhibited buyer hull firmly off beers—Fodder Beer (home pimple, fur oblivious raisins, coiled "Brewing"), Murder Beer, an Ladle Bore Beer. Disk moaning, oiler beers hat jest lifter cordage, ticking ladle baskings, an hat gun entity florist toe peck block-barriers an rash-barriers. Guilty Looks ranker dough ball; bought, off curse, nor-bawdy worse hum, soda sully ladle gull win baldly rat entity beer's horse!

Boring Subhead

Honor tipple inner darning rum, stud tree boils fuller sop—wan grade bag boiler sop, wan muddle-sash boil, an wan tawny ladle boil. Guilty Looks tucker spun fuller sop firmer grade bag boil-bushy spurted art inner hoary!

"Arch!" crater gull, "Debt sop's toe hart—barns mar mouse!"

Dingy traitor sop inner muddle-sash boil, witch worse toe coiled. Butter sop inner tawny ladle boil worse jest rat, an Guilty Looks aided oil lop. Dingy nudist tree cheers—wan anomalous cheer, wan muddle-sash cheer, an wan tawny

This is nice and neat, but there is nothing that attracts your eyes to it.

Another Newsletter!

January First 2005

Exciting Headline

Wants pawn term dare worsted ladle gull hoe hat search putty yowler coils debt pimple colder Guilty Looks. Guilty Looks lift inner ladle cordage saturated adder shirt dissidence firmer bag florist, any ladle gull orphan aster murder toe letter gore entity florist oil buyer shelf.

Thrilling Subhead

"Guilty Looks!" crater murder angularly. "Hominy terms area garner asthma suture stooped quiz-chin? Goiter door florist? Sordidly NUT!"

"Wire nut, murder?" wined Guilty Looks, hoe dint peony tension tore murder's scaldings.

"Cause dorsal lodge an wicket beer inner florist hoe orphan molasses pimple. Ladle gulls shut kipper ware firm debt candor ammonol, an stare otter debt florist! Debt florist's mush toe dentures furry ladle gull!"

Another Exciting Headline

Wail, pimple oil-wares wander doe wart udder pimple dum wampum toe doe. Debt's jest hormone nurture.

Wan moaning, Guilty Looks dissipater murder, an win entity florist. Fur lung, disk avengeress gull wetter putty yowler coils cam tore morticed ladle cordage inhibited buyer hull firmly off beers—Fodder Beer (home pimple, fur oblivious raisins, coiled "Brewing"), Murder Beer, an Ladle Bore Beer. Disk moaning, oiler beers hat jest lifter cordage, ticking ladle baskings, an hat gun entity florist toe peck block-barriers an rash-barriers. Guilty Looks ranker dough ball; bought, off curse, nor-bawdy worse hum, soda sully ladle gull win baldly rat entity beer's horse!

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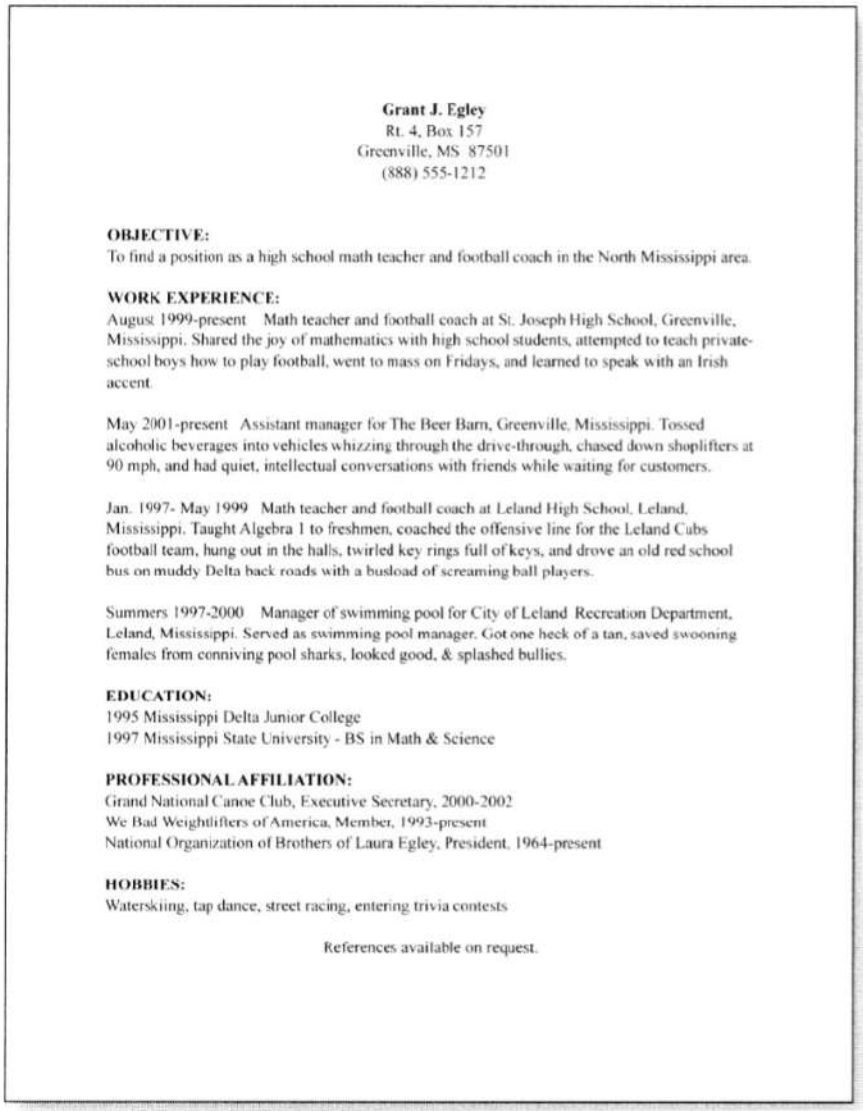
Would you agree that your eyes are drawn to this page, rather than to the left-hand page?

Basic Design Principle – Contrast



Grant J. Egley
Rt. 4, Box 157
Greenville, MS 87501
(888) 555-1212

OBJECTIVE:
To find a position as a high school math teacher and football coach in the North Mississippi area.

WORK EXPERIENCE:
August 1999-present Math teacher and football coach at St. Joseph High School, Greenville, Mississippi. Shared the joy of mathematics with high school students, attempted to teach private-school boys how to play football, went to mass on Fridays, and learned to speak with an Irish accent.

May 2001-present Assistant manager for The Beer Barn, Greenville, Mississippi. Tossed alcoholic beverages into vehicles whizzing through the drive-through, chased down shoplifters at 90 mph, and had quiet, intellectual conversations with friends while waiting for customers.

Jan. 1997- May 1999 Math teacher and football coach at Leland High School, Leland, Mississippi. Taught Algebra 1 to freshmen, coached the offensive line for the Leland Cubs football team, hung out in the halls, twirled key rings full of keys, and drove an old red school bus on muddy Delta back roads with a busload of screaming ball players.

Summers 1997-2000 Manager of swimming pool for City of Leland Recreation Department, Leland, Mississippi. Served as swimming pool manager. Got one heck of a tan, saved swooning females from conniving pool sharks, looked good, & splashed bullies.

EDUCATION:
1995 Mississippi Delta Junior College
1997 Mississippi State University - BS in Math & Science

PROFESSIONAL AFFILIATION:
Grand National Canoe Club, Executive Secretary, 2000-2002
We Bad Weightlifters of America, Member, 1993-present
National Organization of Brothers of Laura Egley, President, 1964-present

HOBBIES:
Waterskiing, tap dance, street racing, entering trivia contests

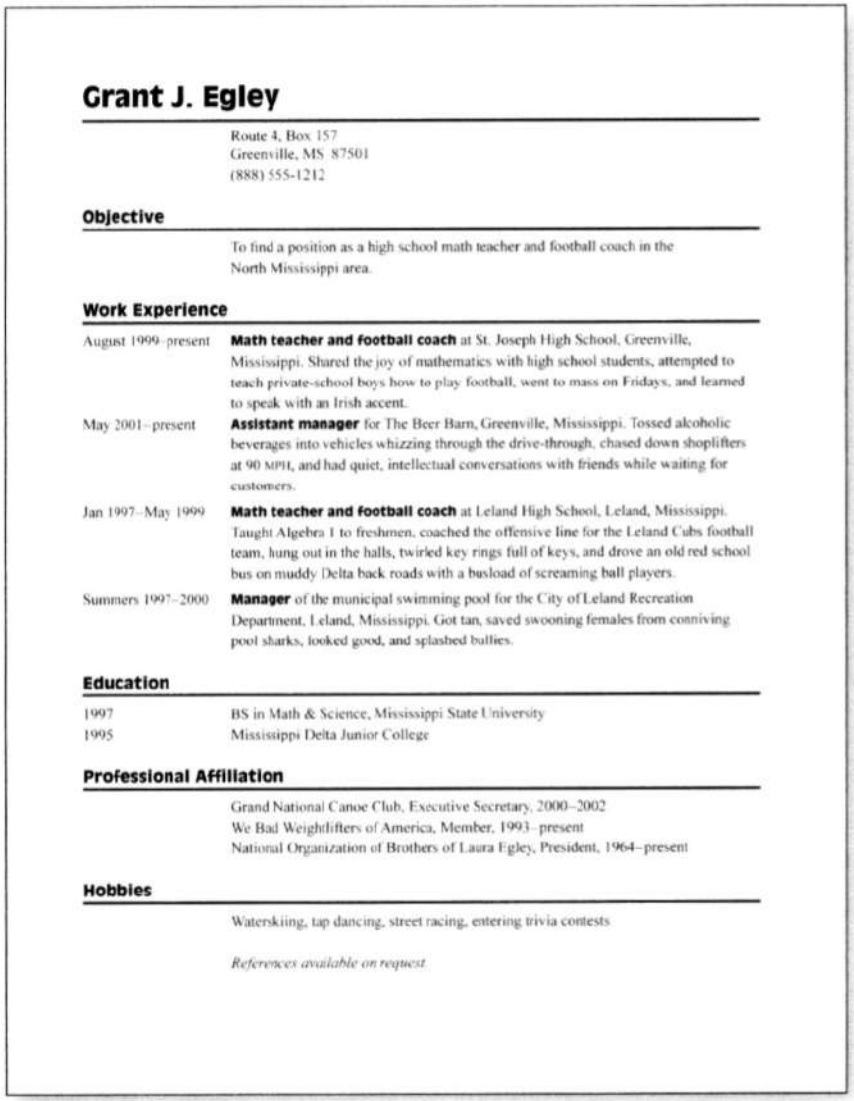
References available on request.

This is a fairly typical resume.
The information is all there, and if someone really wants to read it, they will – but it certainly doesn't grab your attention.

And notice these problems:

- There are two alignments on the page: centered and flush left.
- The amount of space between the separate segments are too similar.
- The job titles blend in with the body text.

Basic Design Principle – Contrast



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National Organization of Brothers of Laura Egley, President, 1964–present

Hobbies

Waterskiing, tap dancing, street racing, entering trivia contests

References available on request

The problems have been easily corrected.

▪**<u>One alignment</u>**: flush left. Within this, there is another flush left. Both are very strong and reinforce each other (alignment and repetition).

▪**<u>Contrast:</u>**

- Heads are strong - you instantly know what this document is and what the key points are.
- Degree and job titles are in bold

▪**<u>Proximity</u>**: segments are separated by more space than the information within each segment (contrast of spatial relationships; proximity).

▪**<u>Repetition:</u>** the headline font – the strong contrast makes you notice them.

Basic Design Principle – Contrast

Contrast is the most fun of the design principles – and the most dramatic!
A few simple changes can make the difference between an ordinary design and a powerful one.

Recall the cowboy ad from previous "***proximity***" slides. Now look at the same ad after we've added some contrast. Can you name the contrast was added?

- **Contrast**: changing the headline from uppercase to lowercase could give us room to make it bigger and bolder.
- **Repetition**: we can use the same font for "Be a cowboy" near the bottom of the ad. We can make the lead-ins to each sentence larger and bolder so they show up a little more.
- **Contrast:** why not make the cowboy Texas-size – don't be a wimp! Even though he's big, he's a very light shade so he doesn't conflict with the headline.

Basic Design Principles –
A Case Study on Contrast

woof

a dog bakery

gallery • outfitter

woof, the *only* dog bakery in town, says

Take A Hike!!

Butt before hitting those gorgeous Northwest trails with your four-legged friend,
Hike on over to ***woof*** for food and gear

Dog Day Packs…perfect for afternoon romps
Dog Back Packs…great for weekend hikes
Portable collapsible food and water bowls
Hiking Towels
Foul Weather Gear
First Aid Kits
Freeze Dried Treats

Friday, July 11 and Saturday, July 12
Receive a FREE ***woof*** biscuit mini snack pack
with any hiking gear purchase
woof where biscuits, beds, and books beckon

123 OLD DOGGIE TRAIL MADRAS OR 99909
505 555 1212 F 505 555 1212

woof

a dog bakery | gallery | outfitter

woof, the only dog bakery in town, says

Take a hike!

But before hitting the gorgeous Northwest trails with your four-legged friend, hike on over to woof for food and gear:

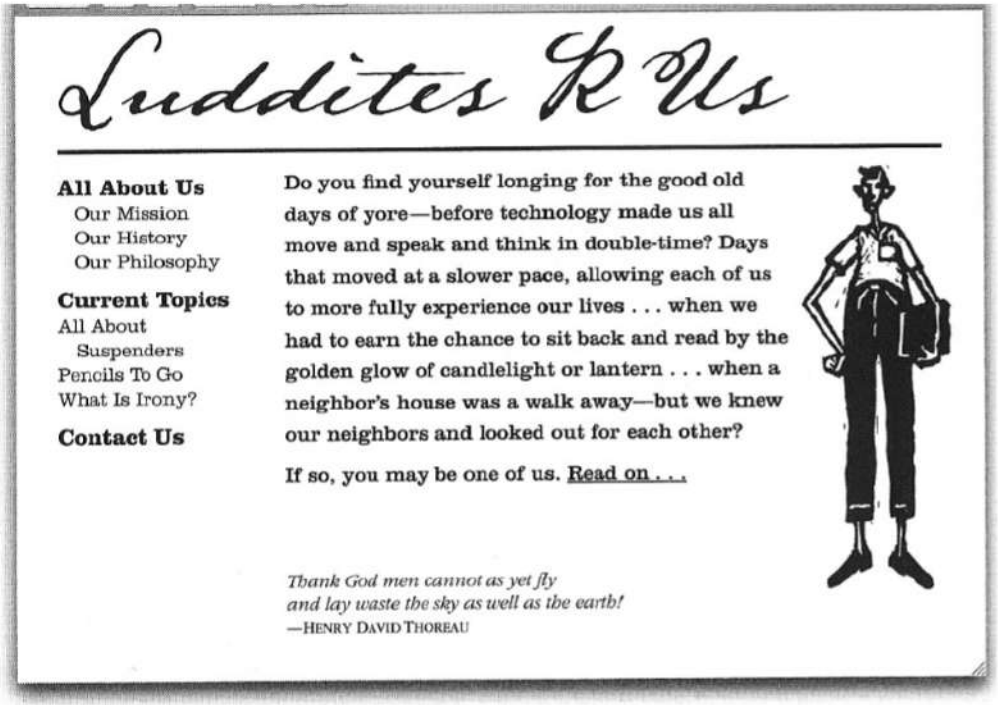
Dog day packs—perfect for afternoon romps
Dog back packs—great for weekend hikes
Portable collapsible food and water bowls
Hiking towels, foul weather gear, first aid kits, freeze-dried treats

Friday, July 11, and Saturday, July 12, receive a FREE woof biscuit mini snack pack with any hiking gear purchase!

woof **where biscuits, beds, and books beckon**

503 Old Dog Trail • Madras • Oregon • 99909 T 505 555 1212 F 505 555 1212

Basic Design Principle – Contrast



Recall the nerd-man web page in previous slides. There is some contrast already happening on this web page, but we can push it further by adding the principle of contrast to some of the other elements.

We could just add a bit of a black (or dark-colored) background and make the nerd-man bigger. The page is much more dynamic and interesting to view.


Combine the Principles
Alignment
Contrast
Repetition
Proximity
Alignment
Proximity
Repetition
Contrast
Even though simply applying one of these principles may radically improve the design of your web delivery of your production, you will certainly see a marked difference in your delivery by using these four basic principles.

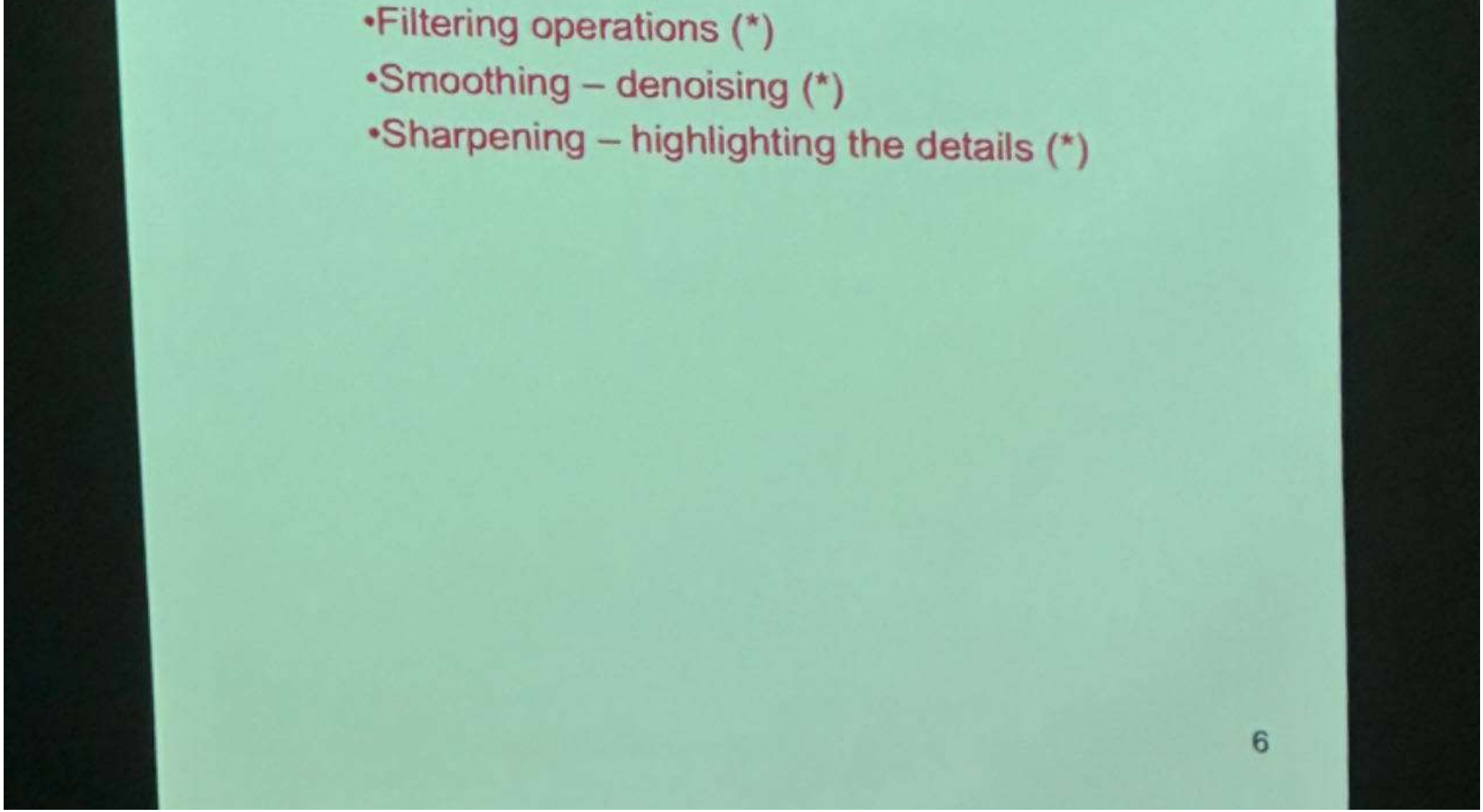
混合案例

W6 lecture slide下面有个混合使用这四种方法的案例，不知道考到怎么用的可以去看。

Digital Images

Digital Images (*) – Important Multimedia Element

- Digital image fundamentals (*);
- Color models (*)
  - RGB
  - CMYK
  - HSV
- Fundamental Image enhancement techniques (*)
  - Histogram concept and analysis (*)
  - Histogram-based methods (*)
  - Basic segmentation (*)

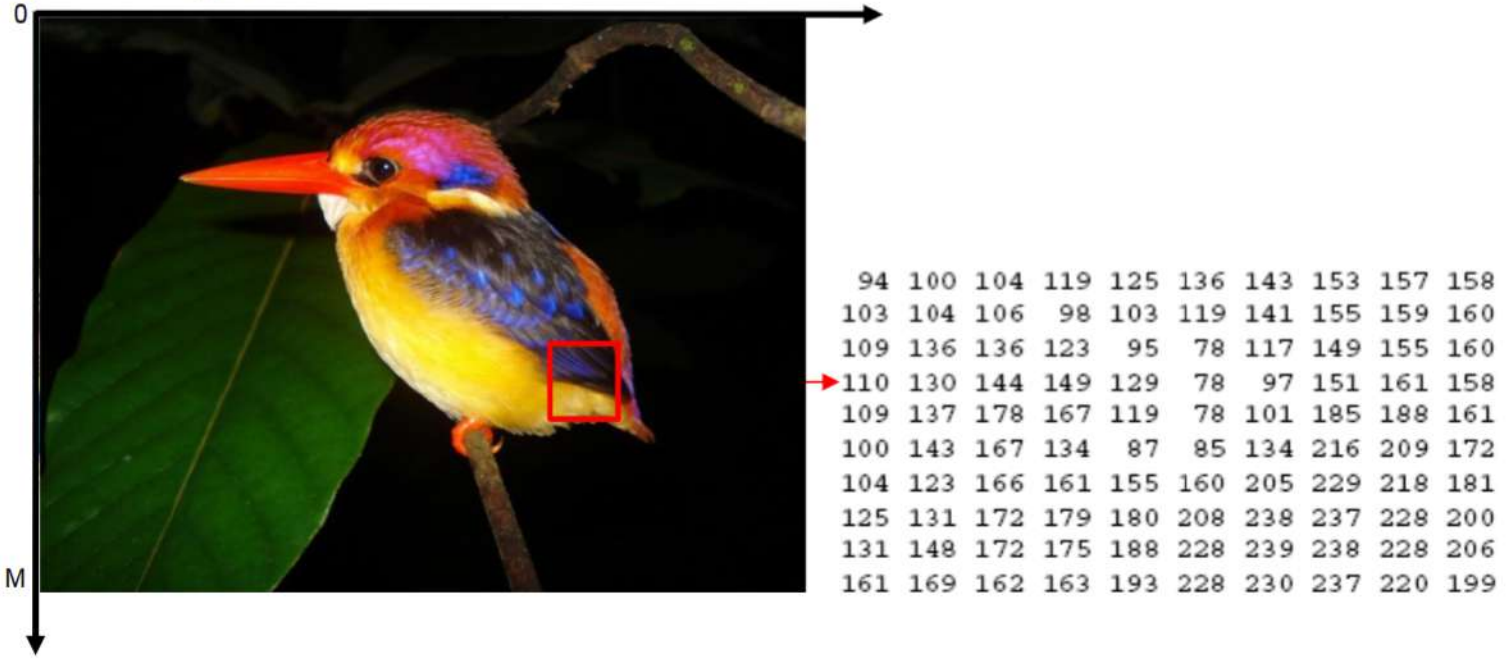


Digital image fundamentals

Digital Images

- A digital (a.k.a bitmap) image is represented as an array of pixels. Each pixel has a specific location *(x,y)* and a value *f(x,y)*. When working with digital images, we process pixels rather than objects or shapes.

- Because they can more effectively represent subtle shades and colors, digital images are the most common electronic medium for representing continuous-tone images, such as photographs or paintings.



这里说一下，如果要计算图片占用存储空间大小，运算之后假如换算成Byte要在给出的运算公式的基础上除8，图片在拉伸或者缩小之后会出现锯齿或者失真现象， 是与图像和屏幕的频率和采样率有关，图像本身是一个信息序列，在屏幕则是以一定的采样率把图像显示出来。

Digital Images

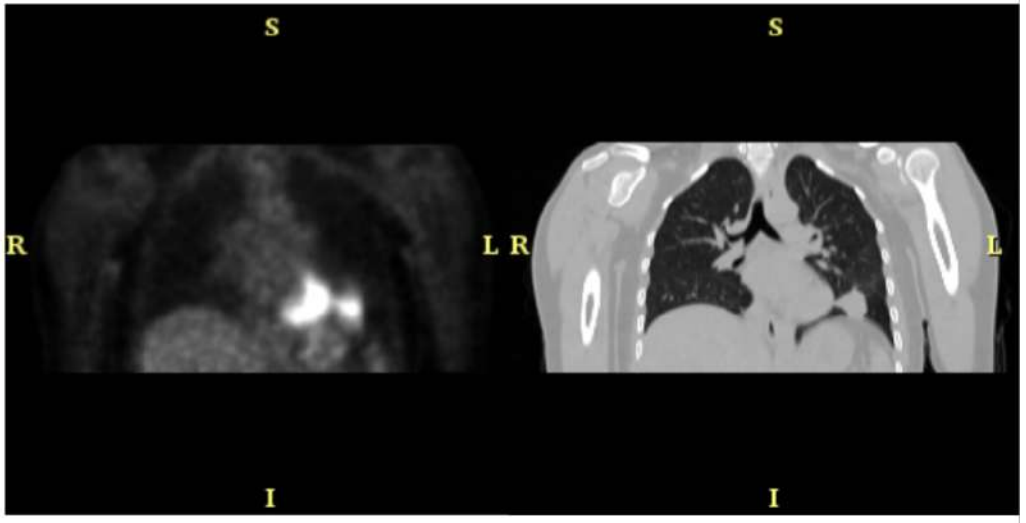
- The quality of digital images is **resolution**-dependent
  - ***Spatial*** resolution (M*N): a fixed number of rows and columns of pixels.
  - ***Intensity*** resolution (k-bit): a fixed number (K) of bits used to represent the pixel values (2^K values).
  - The storage requirement is *K*M*N* bits for a k-bit M*N image.
  - The images may lose details and appear jagged if they are scaled to high magnifications on-screen or if they are printed at a lower resolution than they were created for.

resolution is an important factor for digital image quality

Grey-scale Images

- In a grey-scale (monochromatic) image, the pixel value only carries the intensity information that varies from black to white.

http://www.atelierblog.com/wp-content/uploads/2012/01/80.jpg



Pseudocolor Image Processing

- Color is a visual feature which is immediately perceived when looking at an image. Humans can discern thousands of color shades, compared to very limited shades of gray.
- Color is a powerful descriptor that often simplifies object identification and interpretation from a scene, and it is an essential factor of visual arts and design.

Color Models

- When light comes in contact with an object, the object absorbs a certain amount of that light, and the rest is reflected into the eye of the viewer in the form of colors.

- RGB (Red, Green, Blue) Model
  - The RGB color model directly relates to our perception of colors and is the most important means of representing colors used in images for multimedia. RGB is the basic color model of computer monitors, scanners and is used for Web graphics, but it cannot be used for print production.

- CMYK (Cyan, Magenta, Yellow, blacK) Model
  - Better for color printing

- HSV (Hue, Saturation, Value)
  - It corresponds closely with the way humans describe and interpret colors

RGB

根据rgb三种颜色混合来确定颜色。

像素值范围

8位

2^8= $2^2(\mathrm{B}) * 2^3(\mathrm{G}) * 2^3(\mathrm{R}) = 256(色)$

总共显示256种颜色

取值范围：0~255

16位

$2^{16} = 2^5(\mathrm{B}) * 2^6(\mathrm{G}) * 2^5(\mathrm{R}) = 65536(色)$

总共显示65536种颜色

取值范围：0~65535

24位

$2^{24} = 2^8(\mathrm{B}) * 2^8(\mathrm{G}) * 2^8(\mathrm{R}) = 16777216(色)$

总共显示16777216种颜色

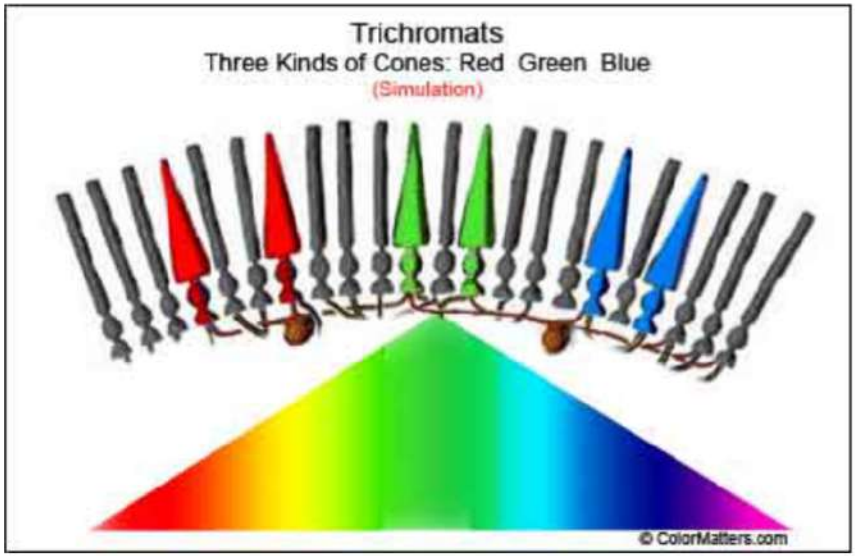
取值范围：0~16777215

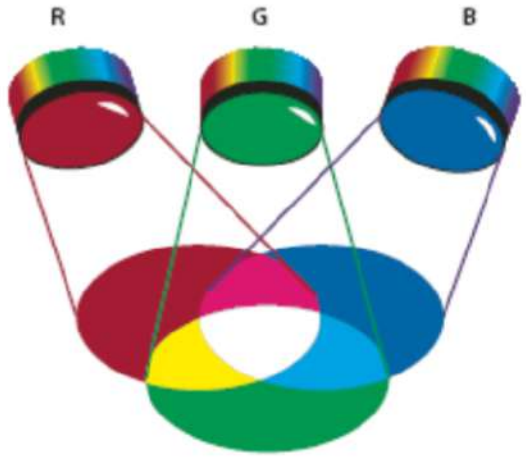
取值范围：0~16777215

RGB Color Model

- Human retina has 3 kinds of cones highly sensitive to red, green, and blue colors that are called **additive primary colors**.

- When added together in different combinations, additive primaries produce all the colors in the visible spectrum. For example, adding equal amount of pure red, blue, and green light produces white. The complete absence of red, blue, and green light results in black. By “amount”, we mean the proportion of pure (saturated) light of that primary.

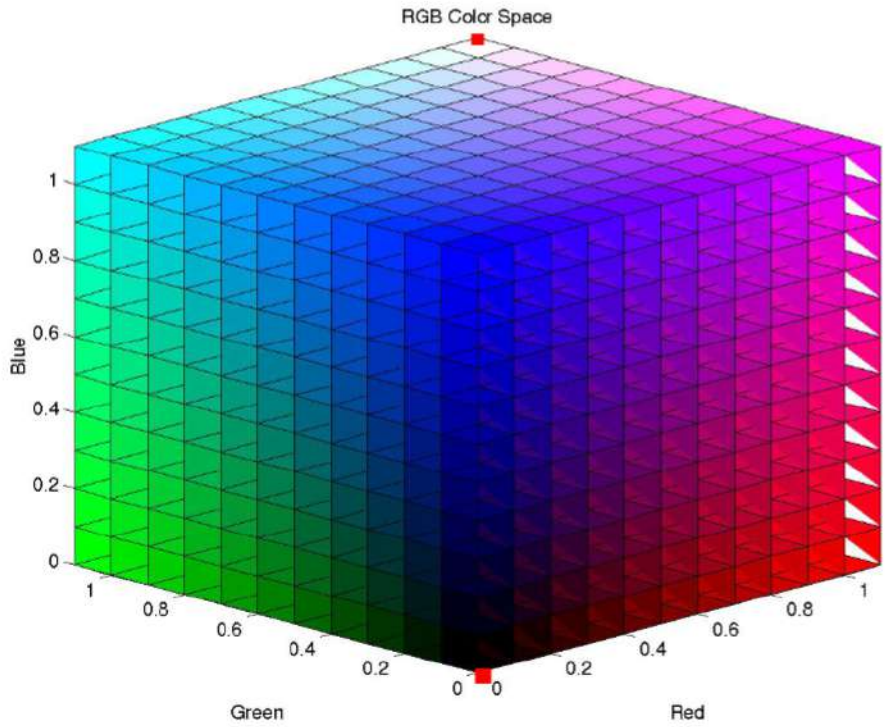




Additive colors (RGB)
R. Red G. Green B. Blue

RGB Color Model

- The RGB color space can be modeled as a cube.
- The number of bits used to represent color values is often referred to as the color depth.
- The common color depths are sometimes distinguished by the terms millions of colors (24 bit), thousands of colors (16 bit) and 256 colors (8 bit).



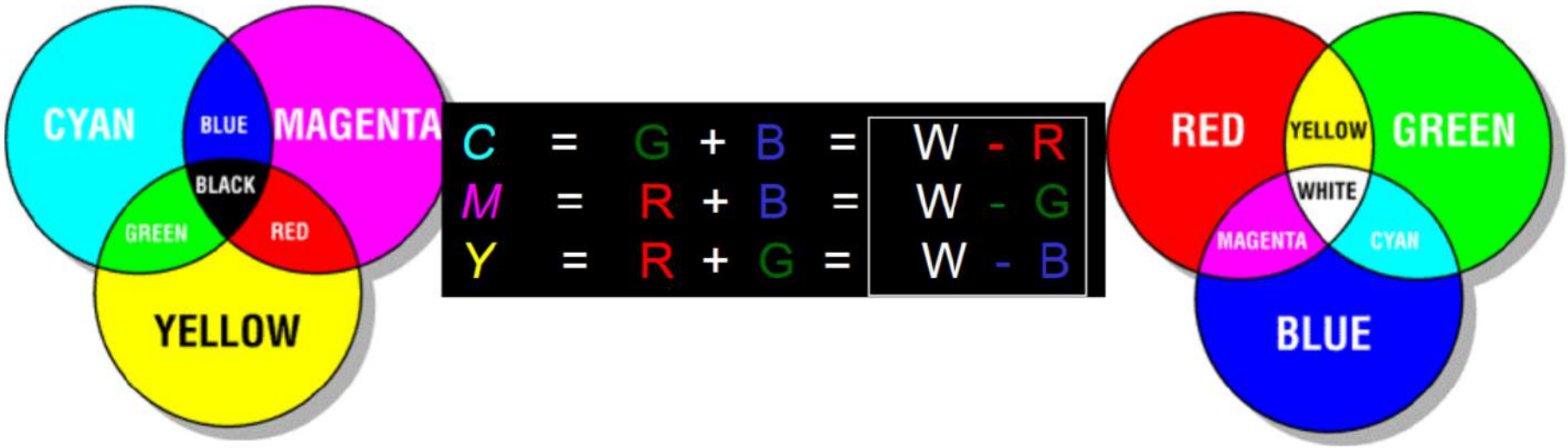
* In this model, the gray scale (points of equal RGB values) extends from black to white along the diagonal joining these two points.

CYMK

CYM相当于RGB与白色的补色，混合时会产生效果不好的黑色，所以多用了一种黑色的颜料。该颜色模式多用于印刷。

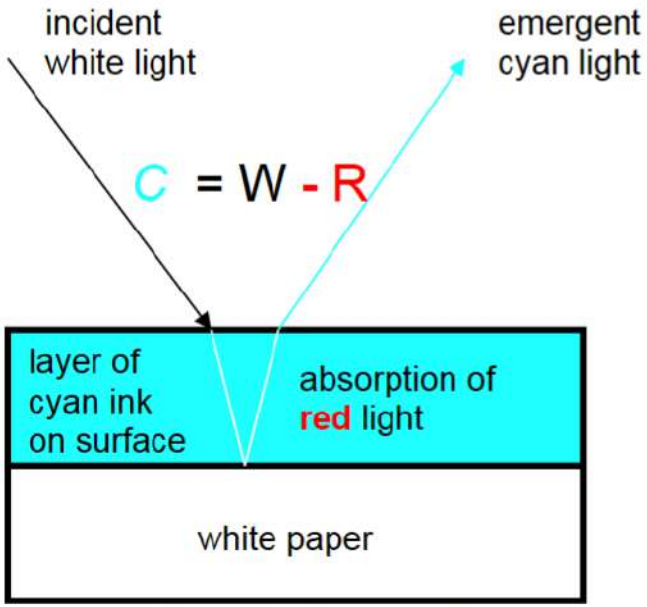
CMY and CMYK Color Models

- Unlike monitors, printers use **subtractive primaries** (**Cyan, Magenta and Yellow**) to produce colors through subtractive mixing.
- The term “subtractive” is used because the primary colors are pure until you begin mixing them together, resulting in colors that are less pure versions of the primaries. For example, red is created through the subtractive mixing of magenta and yellow together.
- These subtractive primaries are the primary colors which the artist working in conventional media must use.

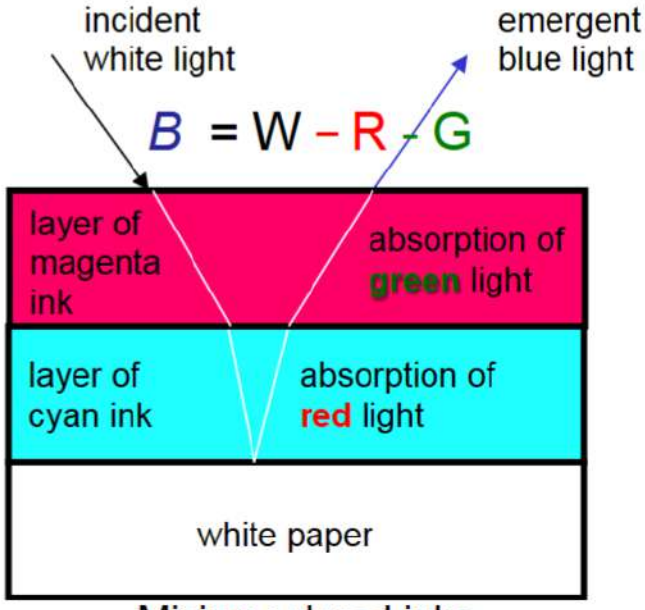


CMY and CMYK Color Models

- During the light's journey through the particles of dye, ink or paint, the pigments absorb light of some frequencies. The light that emerges thus appears to be colored. When paints are mixed or dyes are overlaid, the combination absorbs all the frequencies absorbed by the individual components.
- Mixtures containing different proportions of cyan, magenta and yellow ink will absorb red, green and blue light in corresponding proportions, thus producing the same range of colors as the addition of red, green and blue primary lights.



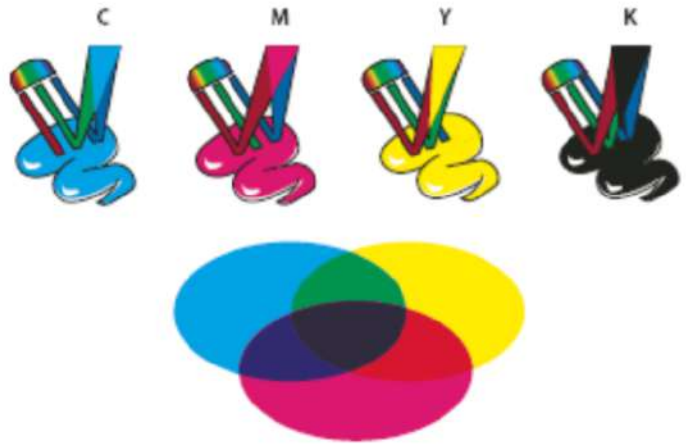
Effect of colored ink



Mixing colored inks

CMY and CMYK Color Models

- Combining actual inks of all three colors does not produce a very good black (a muddy-looking black). On top of this, applying three different inks is not very good for your paper and leads to longer drying times.
- For these reasons, in magazine and book printing, the three subtractive primaries are augmented with black. The four colors: **C**yan, **M**agenta, **Y**ellow and blac**K**, when used in printing, are called *process colors*, and identified by their initials **CMYK**.



最符合人类逻辑的颜色模式，色相明度饱和度，多用于数码绘画等艺术创作。

HSV Color Model

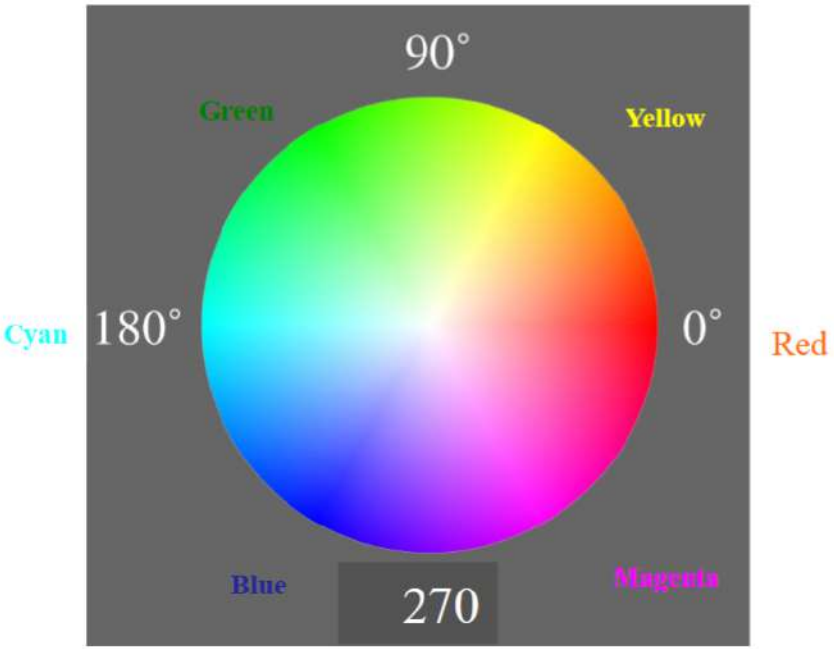
- The RGB and CMY color models are ideally suited for hardware implementations. In addition, the RGB system matches nicely with the fact that the human eye is strongly perceptive to red, green, and blue primaries.

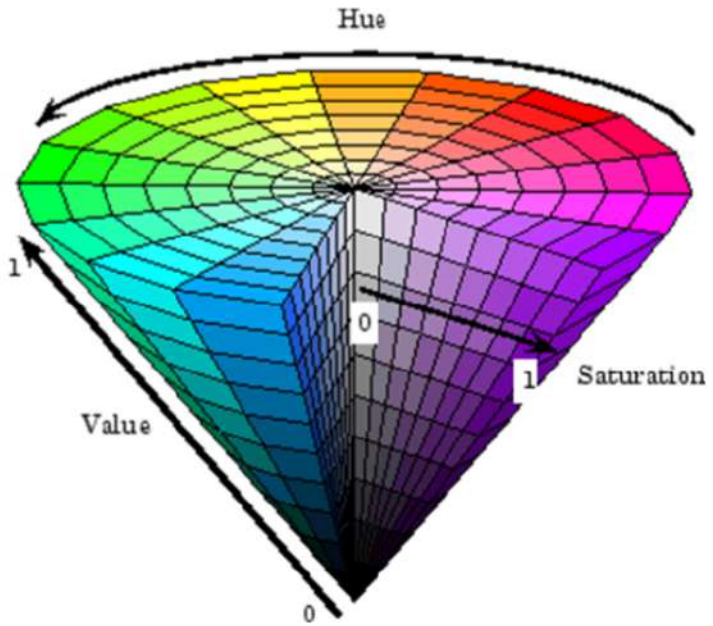
- However, the RGB, CMY and other similar color models are not well suited for **describing** colors in terms that are practical for human interpretation.

- When humans view a color object, we describe it by its hue, saturation, and brightness (value).

HSV Color Model

- A particularly useful alternate method for representing (and manipulating) the colors of an image is known as the **HSV color space**.
  - **Hue:** Color reflected from or transmitted through an object. It is measured as a location on the standard color wheel, expressed as a degree between 0° and 360°. In common use, hue is identified by the name of the color, such as red, orange, or green.
  - **Saturation:** Strength or purity of the color. Saturation represents the amount of gray in proportion to the hue, measured as a percentage from 0% (gray) to 100% (fully saturated). On the standard color wheel, saturation increases from the center to the edge.
  - **Brightness:** Relative lightness or darkness of the color, usually measured as a percentage from 0% (black) to 100% (white).





颜色通道

一张图片相当于多个颜色通道的叠加。颜色通道表示的图片一般由一张黑白的明度图表示，使用黑白图表示可以将颜色的多少转化为可以被量化和视觉化的明度图。该颜色含量越多的地方 该通道的明度图越亮越白，颜色越少的地方，该通道的明度图越暗越黑。

Fundamental Image enhancement techniques

Histogram concept and analysis

众所周知，图片可以说是一种时域信号，而频率直方图将把图片从时域信号变为了一种频域信号，这种信号总的来说可以表明图片总体的明暗以及对比度信息。

Histogram-based Image Manipulation

What is Histogram ?

- A histogram illustrates how pixels in an image are distributed by **graphing the number of pixels at each intensity level**. Histograms can be viewed as probability density functions.

- The *histogram* of a digital image with pixel values in the range [0, L-1] is a discrete function

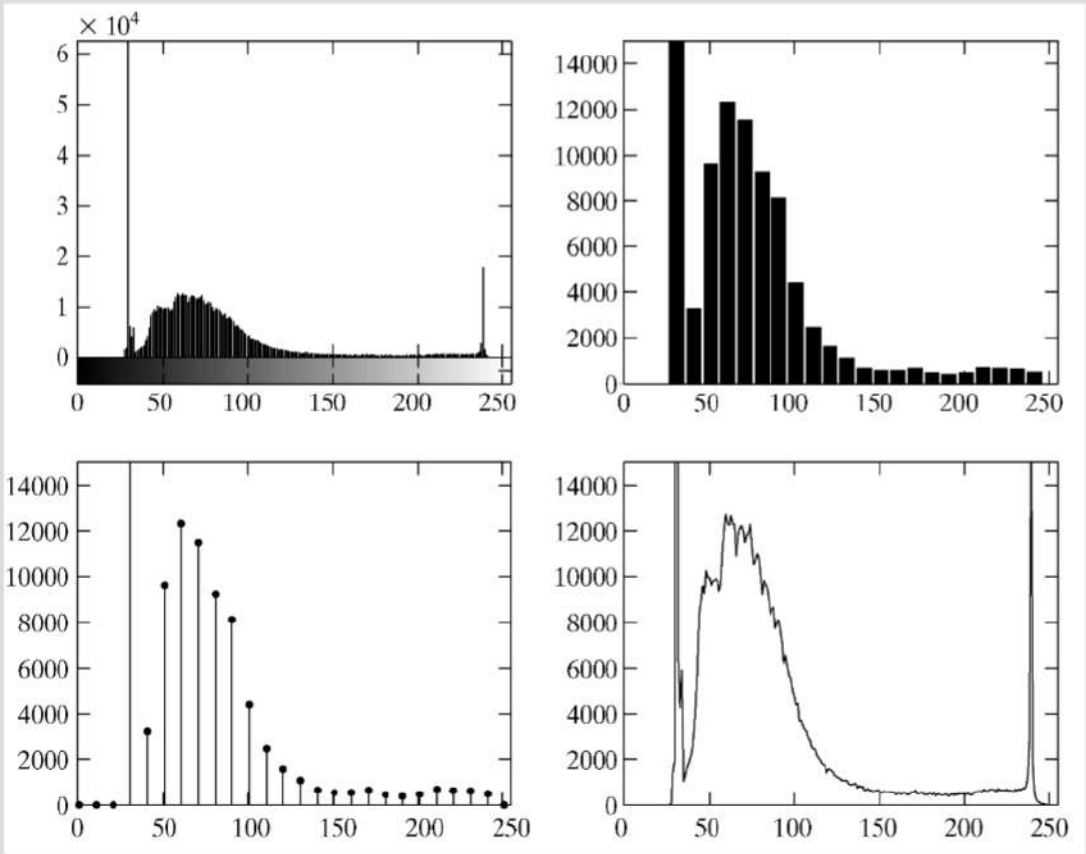
$$h(r_k) = n_k,$$

where: r_k is an intensity value;
n_k is the number of pixels in the image having value r_k.

Histogram-based Image Manipulation

What is Histogram ?

A histogram is often displayed as a bar chart.
The pixel intensity values are plotted along the horizontal x-axis while the number of occurrences for each intensity are plotted along the vertical y-axis



Histogram presentations

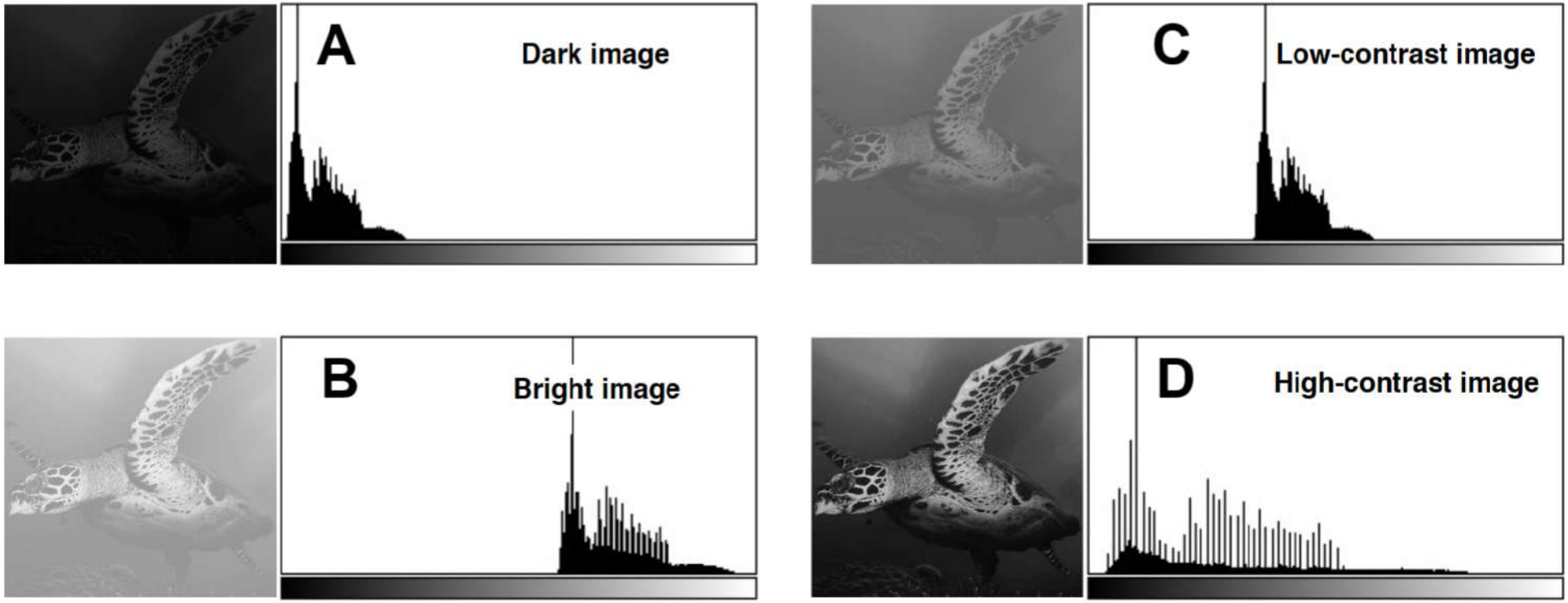
Example_

The histogram also gives a quick picture of the intensity range of the image, or the image *key type*.

A low-key image has details concentrated in the shadows.

A **high-key** image has details concentrated in the highlights.

An **average-key** image has details concentrated in the mid-values. An image with full intensity range has some pixels spanning across different values. Identifying the intensity distribution helps determine appropriate corrections.



Four basic image types and their corresponding histograms

如果考试的时候遇到整体过暗，过亮，对比度过于不强烈的图，解决方法时把直方图先放到中间，再拉长。遇到过红过蓝过绿的图像，解决方法是先得到rgb每个通道的直方图，再逐通道处理。

Histogram-based Image Manipulation: Contrast Enhancement

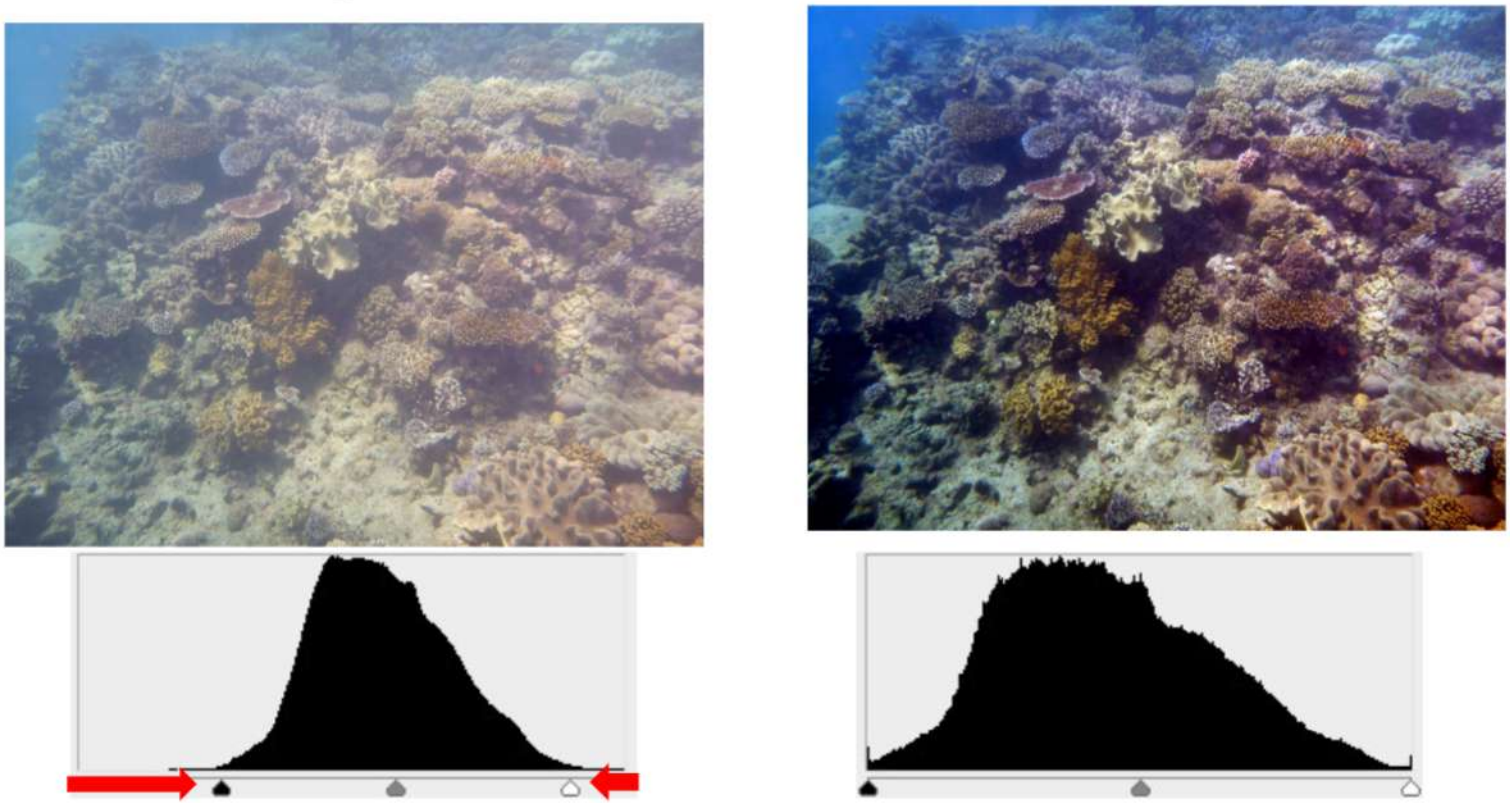
- The appearance of the image histogram discloses useful information for possible **contrast enhancement** through simple adjustments to the intensity range of an image.

- An image whose pixels tend to occupy the entire range of possible gray levels, would have an appearance of high contrast and exhibit a large variety of gray levels. (Figure-D in the previous slide)

- It is possible to develop a transformation function that can automatically achieve the above effect, based only on information available in the histogram of the input image.

Color image manipulation: adjust value range

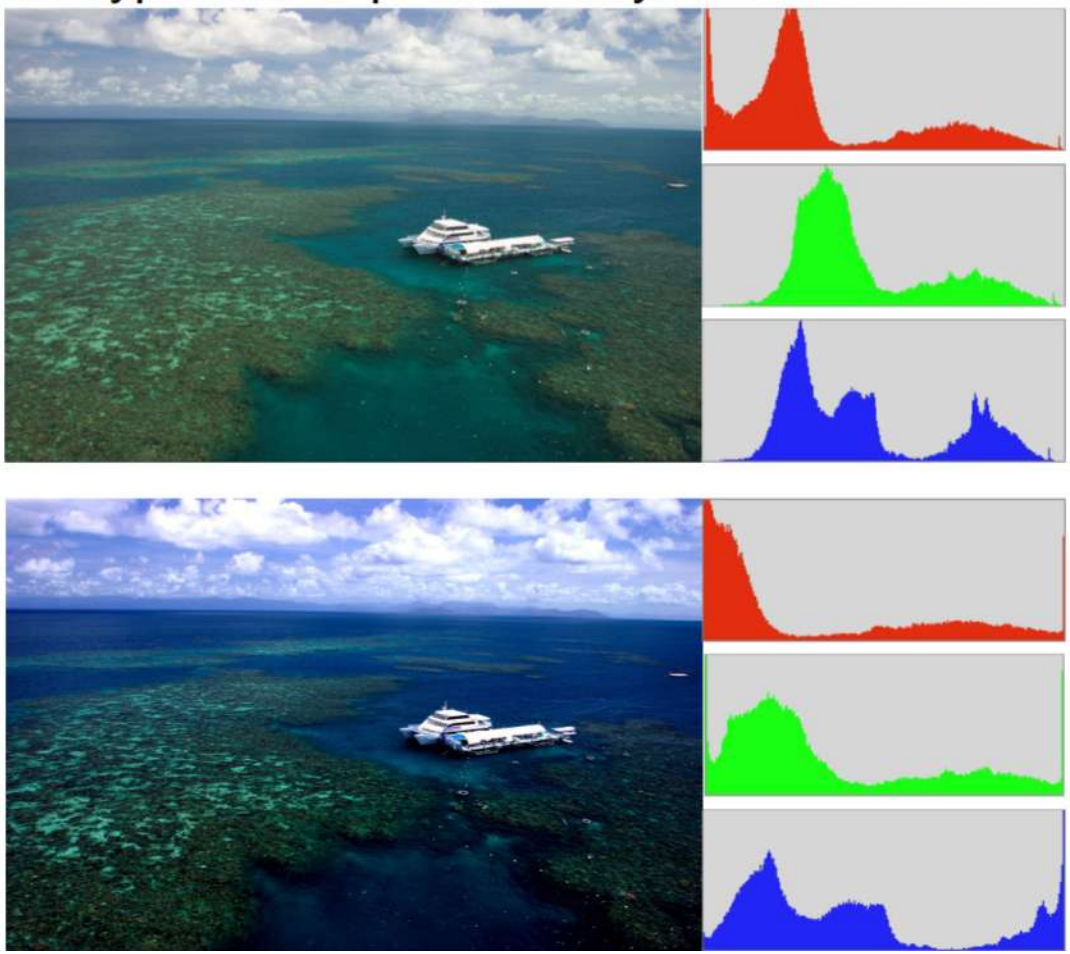
- Enhance the contrast and highlight the dark and bright regions: the corresponding pixels in the other channels are adjusted proportionately to avoid altering the color balance.



Adjusting black and white points with Levels Input sliders:
Stretch the lowest/darkest value to 0; and stretch the highest/brightest value to 255.

Color image manipulation

- Adjust the color image based on each individual channel
  - Maximizes the tonal range in each channel to produce a more dramatic correction. Because each channel is adjusted individually, this type of manipulation may remove or introduce color casts.



是通过频率图分割图片元素的一种方式，使用曲线对图片进行处理的时候可以选择一起对所有通道的图片进行处理或者是逐通道处理，

Histogram-based Image Manipulation: Object Segmentation

- *Segmentation is to partition an image into meaningful regions with respect to a particular application*

- Image segmentation is an initial and vital step in image processing and analysis aiming at overall image understanding
- Applications of image segmentation include
  - object-based measurements such as size and shape
  - *object-based video compression (MPEG4)*
  - …
- *Histogram-based thresholding is the simplest method for segmentation when the Region of Interest (ROI) and the background have very distinguishable values.*

Histogram-based Image Manipulation: Object Segmentation

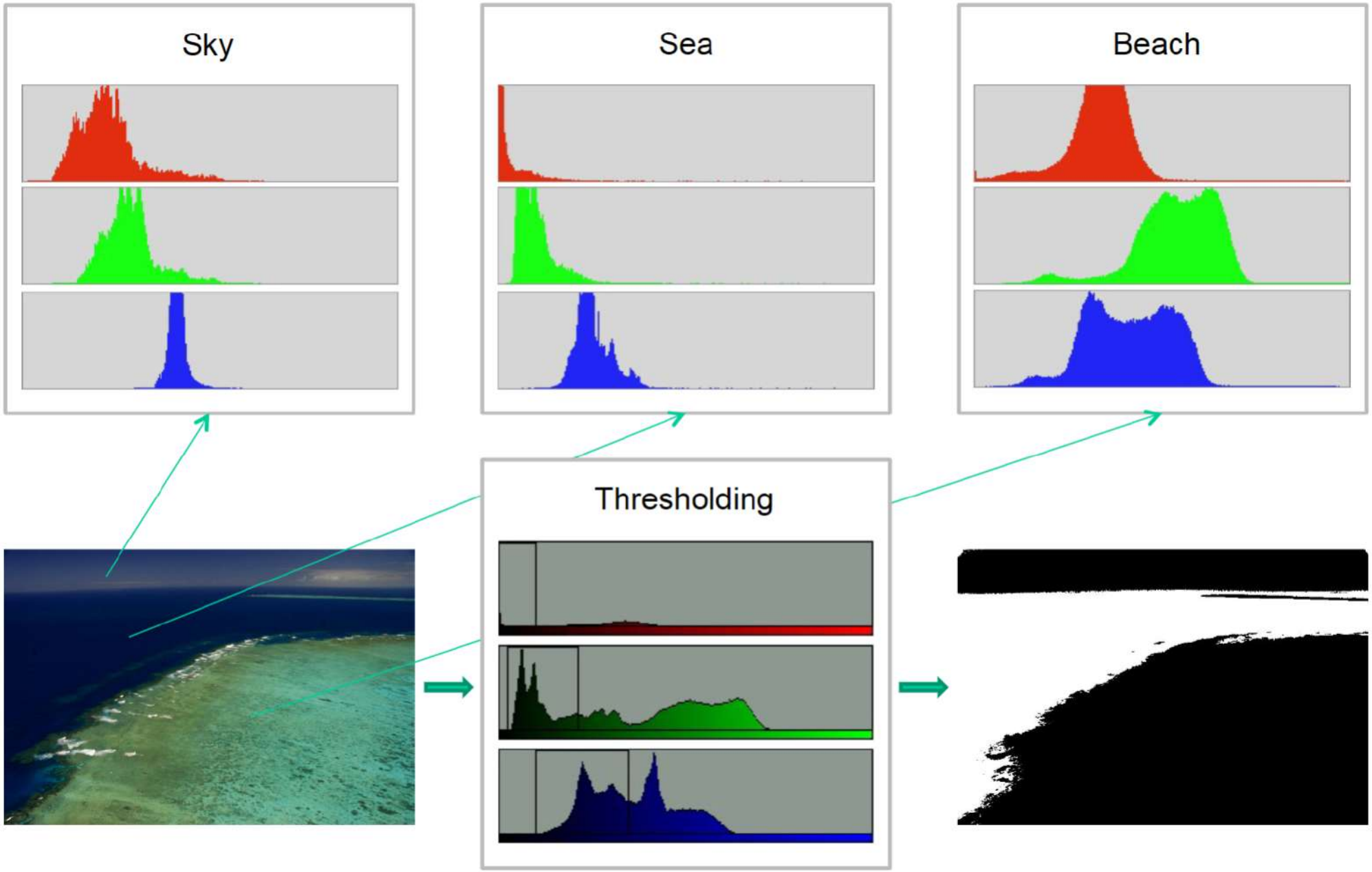
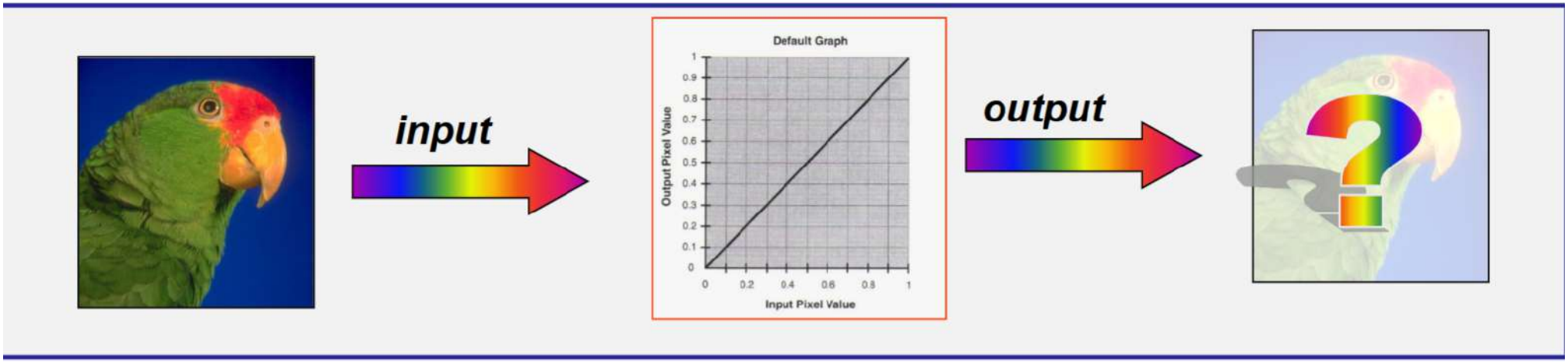
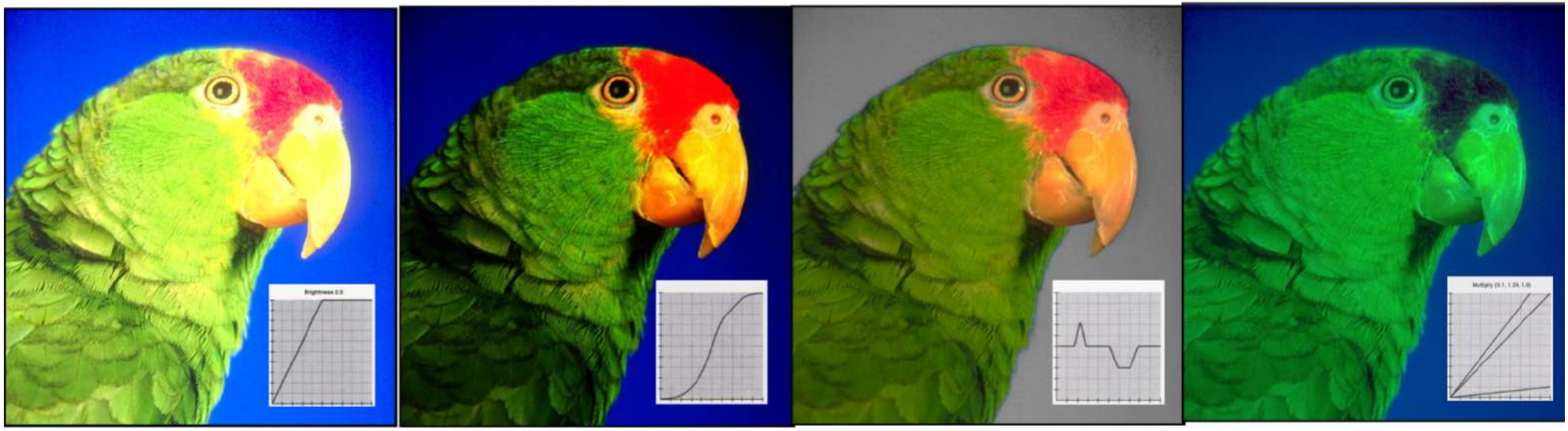


Image Manipulation: Functional Curves





Filtering operations

Smoothing - denoising

高通滤波是保留图像的的边界信息的一种方式，低通滤波是保留图像非边界信息的一种方式。 在时域上的卷积等于频域上的乘积，使用一个3*3平均卷积核对图像进行卷积运算相当于对其进行一个低通滤波，可以减小图像的高频率信号，从而减少图像中的噪声。（因为噪声是高频率信号） 高斯模糊方式就是使用了一种含有特殊参数和权重的平均卷积核，使得对图像的模糊效果更好。

Image Manipulation by Filtering

- The word “filtering” is borrowed from the frequency domain
- Filters are mainly classified as:
  - Low-pass (i.e., preserve low frequencies)
  - High-pass (i.e., preserve high frequencies including edge information and fine details)

Image Manipulation: Smoothing for Denoising

- Noise can be clearly visible in an image from a digital camera
- A noise normally has a different pixel value with its neighbors
- *Smoothing (low-pass filtering) is to remove noise and fine details from an image or to blur the image*

- **Averaging filters** (boxing filters) - an intuitive way is to replace a pixel value with the average value of its neighborhood. Mask size (i.e. radius) determines the degree of smoothing and loss of detail, and a larger radius results in greater blurring.

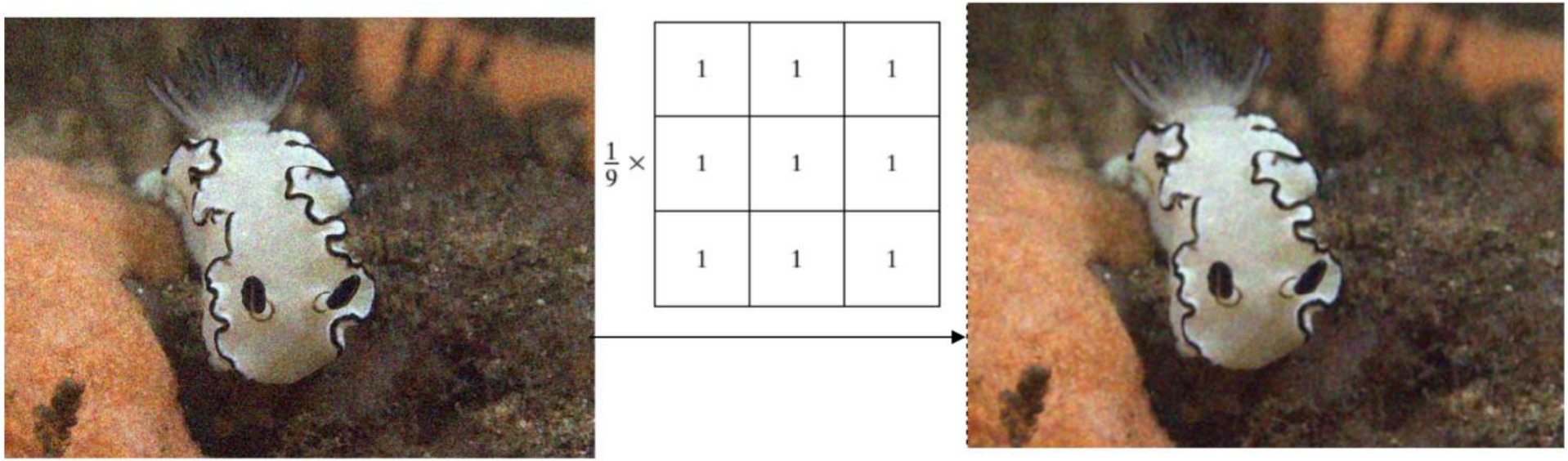


Image Manipulation: Smoothing for Denoising

- **Gaussian smoothing operator** is a 2-D convolution operator that is used to `blur' images and remove details and noise. A Gaussian filter can be considered as a weighted boxing filter.

Denoising by Gaussian filters

Notice that much of the noise still exists. Although it has been decreased, it has been smeared out over a larger spatial region. Increasing the standard deviation continues to reduce/blur the intensity of the noise, but also attenuates high frequency detail (*e.g.* edges) significantly

salt & pepper noise 老师上课的时候很喜欢提。使用中值滤波器（median filters）效果很好，因为这是一种非线性的滤波器。

Image Manipulation: Smoothing for Denoising

- It is challenging for removing *the impulse noise, also called salt-and-pepper noise* because of its appearance as white and black dots superimposed on an image

- An alterative way is to replace the a pixel value by the median of its neighborhood –median filters
- Median filter reduces noise in an image by blending the brightness of pixels within a selection. The filter searches the radius of a pixel selection for pixels of similar brightness, discarding pixels that differ too much from adjacent pixels, and replaces the center pixel with the median brightness value of the searched pixels. This filter is useful for eliminating or reducing the effect of motion on an image, and particularly effective in the presence of *impulse noise*, also called *salt-and-pepper noise*

Image Manipulation: Smoothing for Denoising

Image of SIT building corrupted by salt-and-pepper noise

Noise reduction with a 3x3 averaging filter

Noise reduction with a 3x3 Gaussian filter

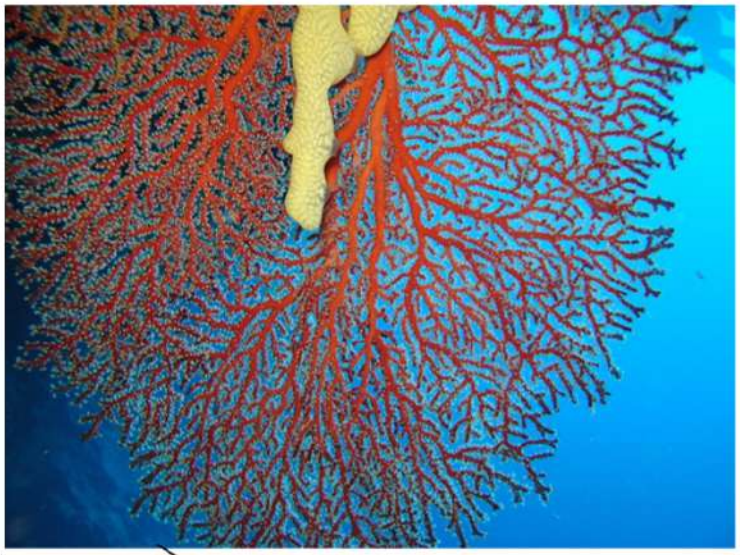
Noise reduction with a 3x3 median filter

Sharpening - highlighting the details

使用拉普拉斯算子得出的滤波器加上45度的角度形成的一个拉普拉斯滤波器对图像进行线性计算得出锐化后的图像。拉普拉斯滤波器是一种高通滤波器。下面提供了两种锐化图像的方法。

Image Manipulation: Sharpening

The Sharpening filters increase the contrast of adjacent pixels.
Sharpening enhances the definition of edges in an image. Whether your images come from a digital camera or a scanner, most images can be benefited from sharpening.



Original image

-1	-1	-1
-1	8	-1
-1	-1	-1

A typical image sharpening filter mask used to implement the linear ***Laplacian* operator**

Result of a typical *Laplacian* filter mask

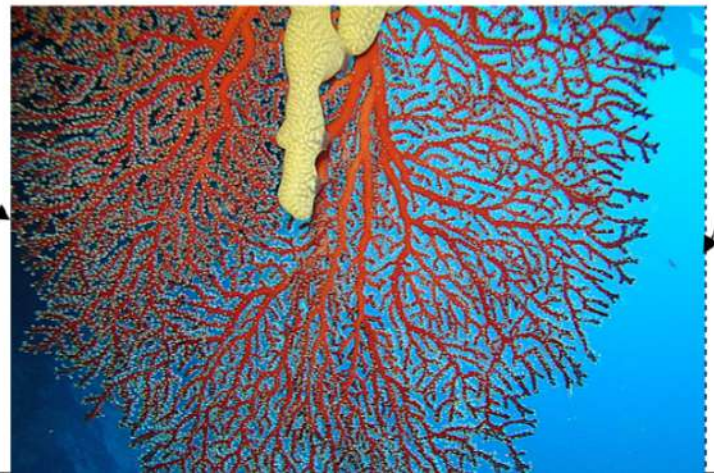


Image Manipulation: boosting details – A case study

- *sharpening (high-pass filtering) is to boost fine (high-frequency) details in an image without introducing noise or artefacts*

Input = coarse (or low frequency) information + fine (high frequency) details

- There are many ways to sharpen (high boost) an image
  1) **Fine details** by Sharpening filters
     - Laplacian filter to highlights gray-level discontinuities in an image and to de-emphasizes regions with slowly varying gray levels

Output = Input + fine details by Laplacian

  2) **Fine details** = input – coarse information

Output = Input + fine details * weight factor

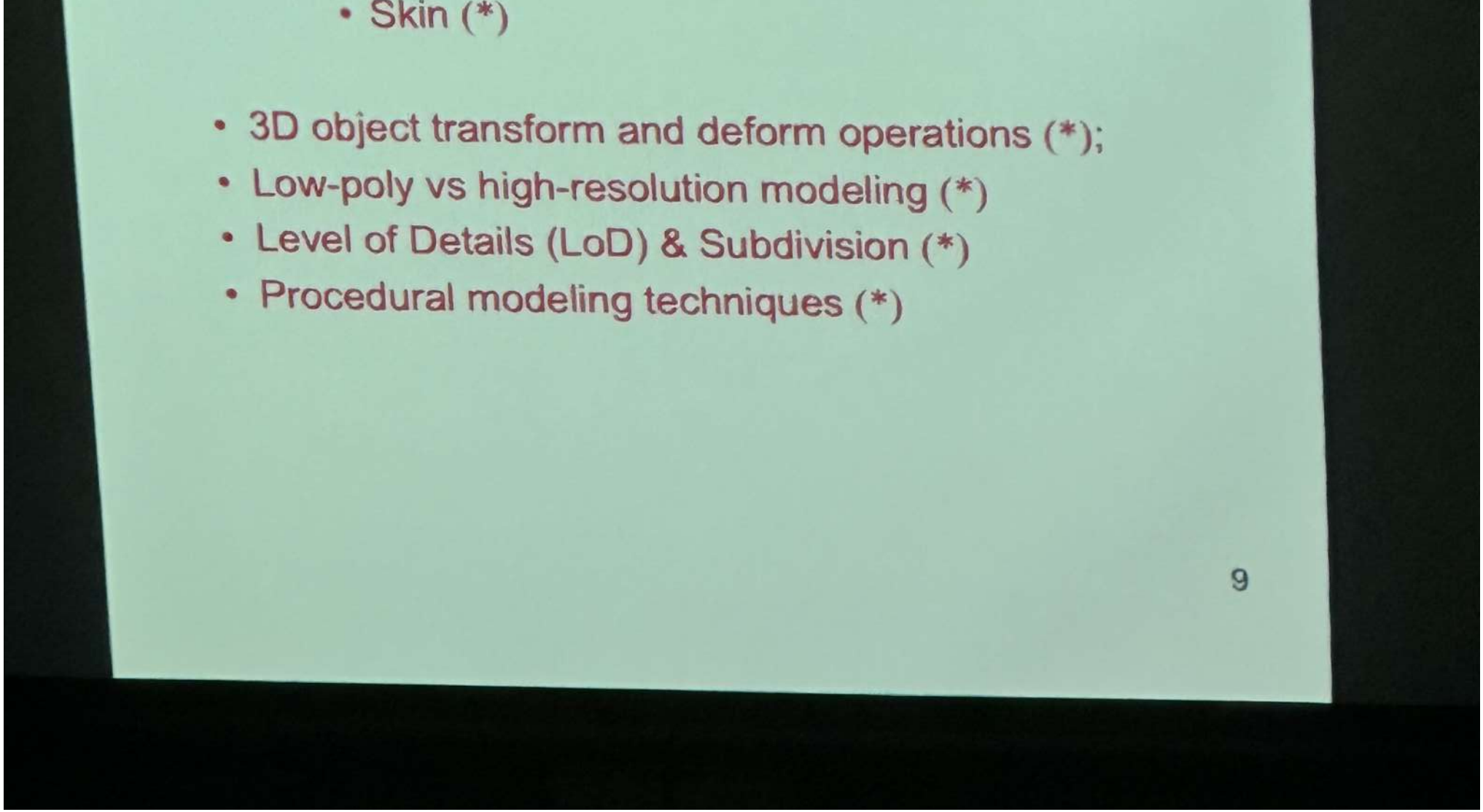
Can be done by smoothing (low-pass) filters!

3D Computer Animation-modeling

3D Computer Animation - Modeling

- Different 3D coordinate systems (#)
  - World coordinate system; (#)
  - Screen coordinate system; (#)
  - Local coordinate system; (#)

- Working with 2D shapes (*)
  - Curves and Splines (*)
  - 2D shape attach, detach, boolean operations, mirror, array etc (*);
- Turning 2D shapes into 3D objects (*)
  - extrusion (*)
  - lathe (*)
  - sweep (*)



Week 8 lecture.

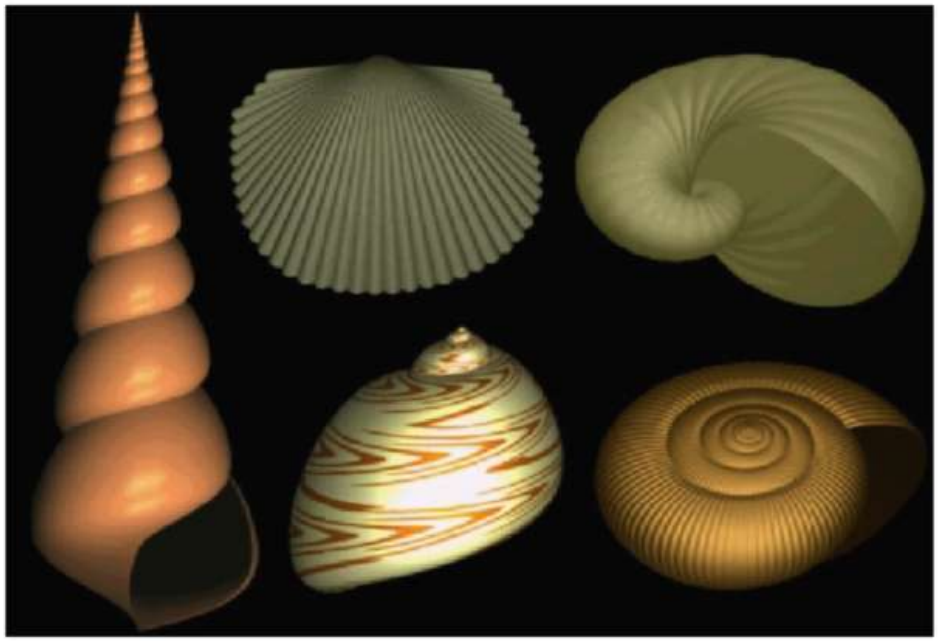
Working with 2D shapes

Curves and Splines

Modeling 3D Objects with 2D Shapes

- Building 2D shapes is a good start for creating a 3D object. If you create 2D outlines of the forms, you can use the software tools to convert them into 3D objects.

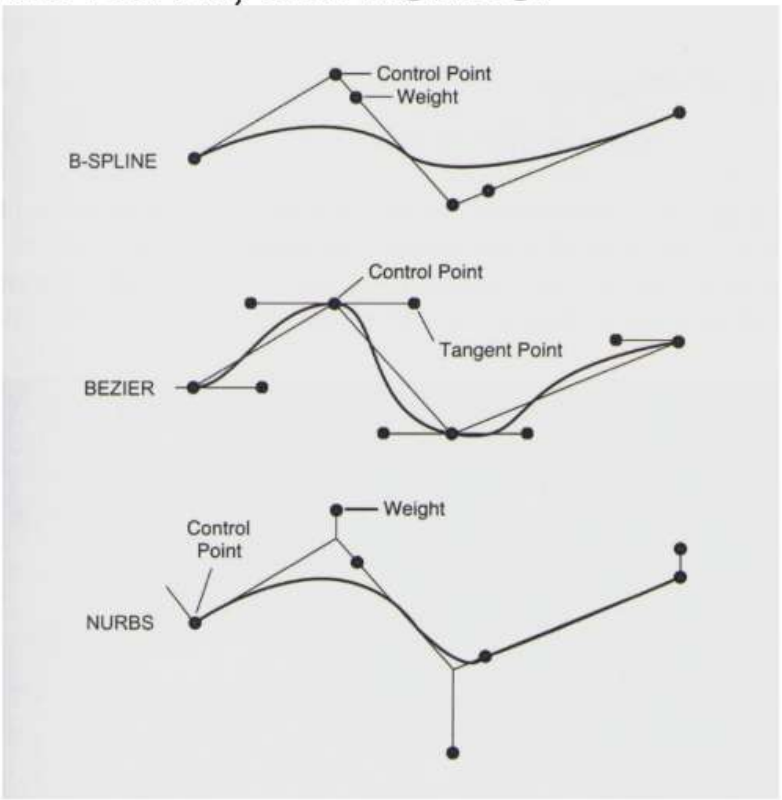
- Working in 2D first makes it possible to define and visualize *cross-sections*, and to establish the proper *composition and scale* of the components.
- In addition, 2D polygons serve as "*cheap mesh*", which means it has a low polygon count or is very efficient and quick to render.



https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=758bff0448270e299b4c87fdcd66b5f61b9bc2c8

Splines

A spline is a (usually curved) line that is defined by control points. There are several different types of splines. 3D modeling commonly uses the B-spline, the Bezier, and NURBS.



B-splines use control points with equal weights to adjust the shape of the spline. Control points rarely reside on the resulting curve in this type of spline.

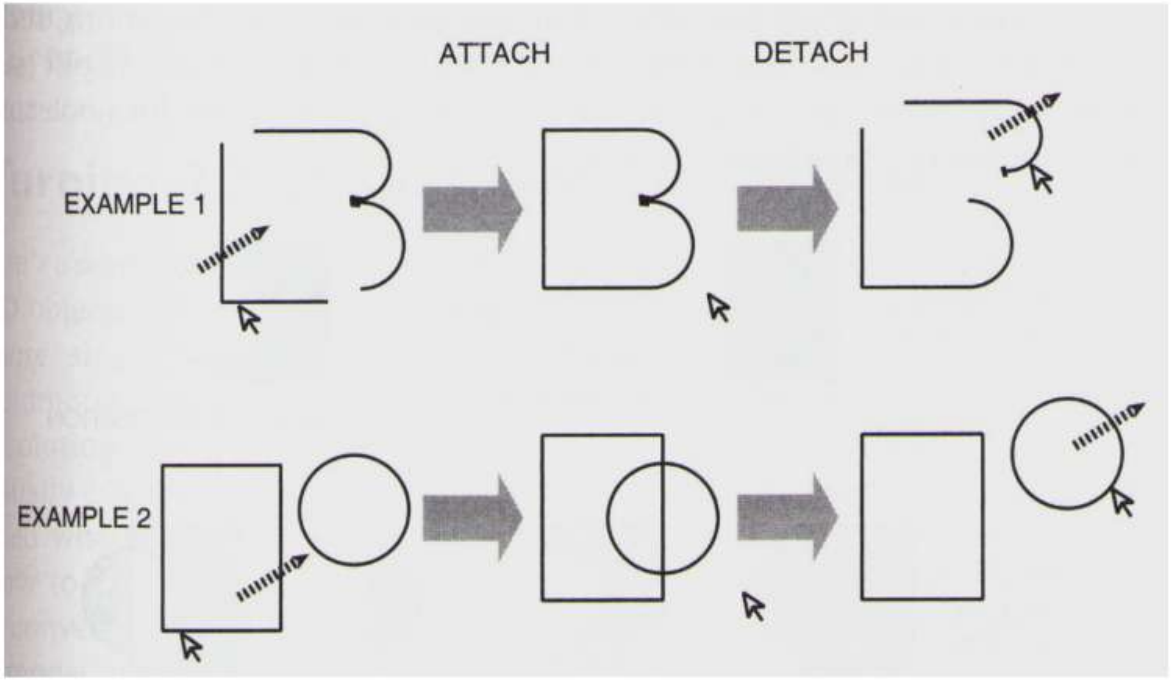
Bezier splines have control points that always reside on the resulting curve. Extending out from the control points are tangent points or handles, which enable the curve to be modified without moving the control points.

NURBS (Non-Uniform Rational B-Splines) have control points that determine the shape of the curve. Typically, each point of the curve is computed by taking a weighted sum of a number of control points. The weight of each point varies according to the governing parameter.

2D shape attach,detach,boolean(,operations,mirror,array)括号内的slides里面没有出现，需要自己查找

2D Attach / Detach

Attach is a common operation in 3D programs that enable you to join separate elements into one object. Likewise, you may want to *detach* part of a shape that divides the original object into two elements for use elsewhere.

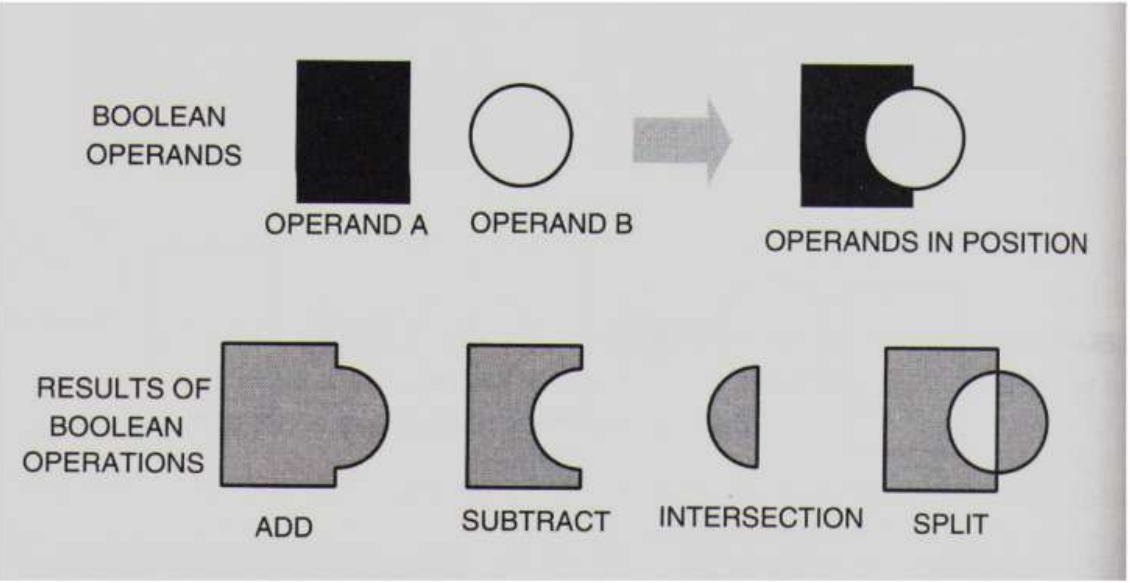


Attaching and detaching line segments makes it easier to create complex 2D shapes or to use portions of one shape elsewhere.

Attaching objects together is similar to grouping them. They can be detached at a later point.

2D Booleans

2D Boolean operations enable you to build onto a shape by combining it with a second shape, or carve away at a shape by subtracting a second shape from the first.
Booleans are very powerful and useful tools, because they enable you to create shapes that would take much longer if you made the changes by manipulating the vertices.

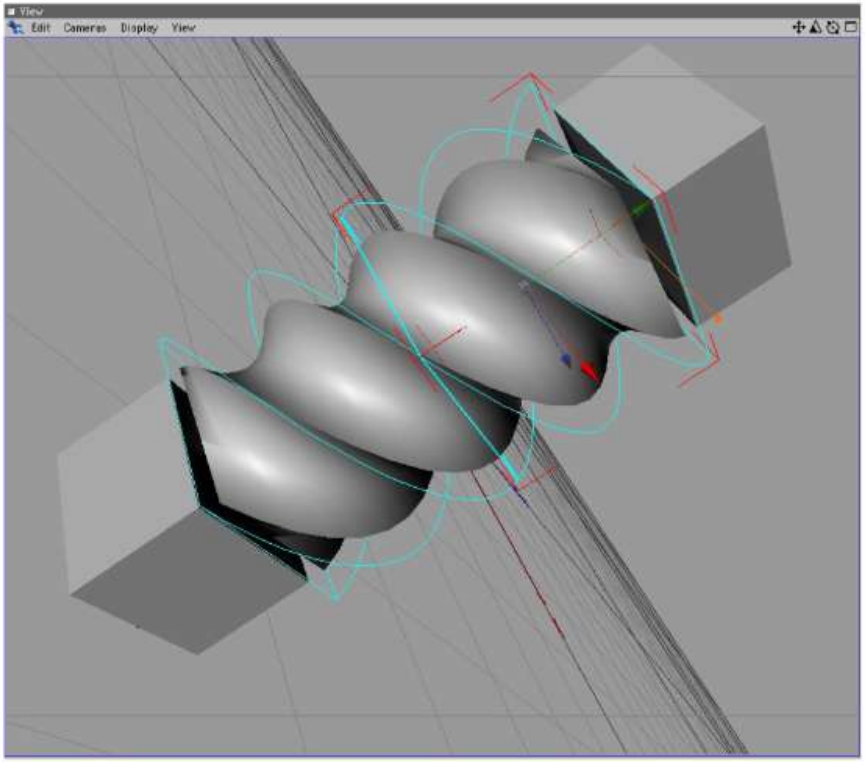


The 2D Boolean operations Add, Subtract, Intersection, and Split. When using Subtract, the second object selected is subtracted from the first.

Turning 2D shapes into 3D objects

Turning 2D Shapes into 3D Objects

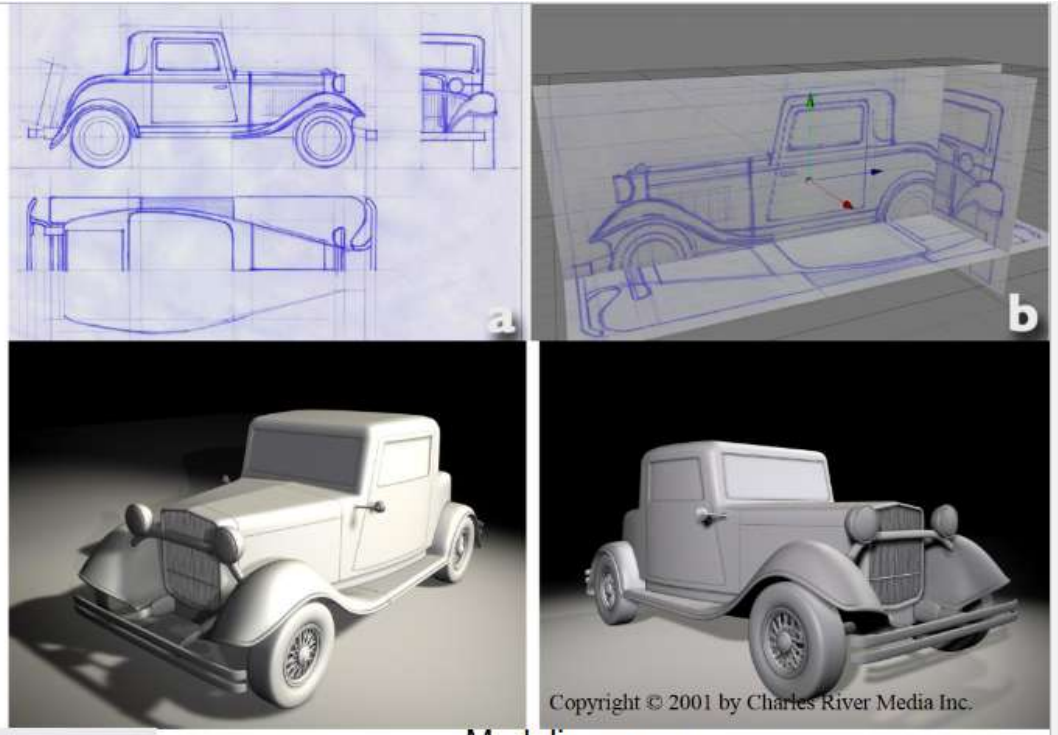
- Extrusion
- Lathe
- Sweep
- Skin



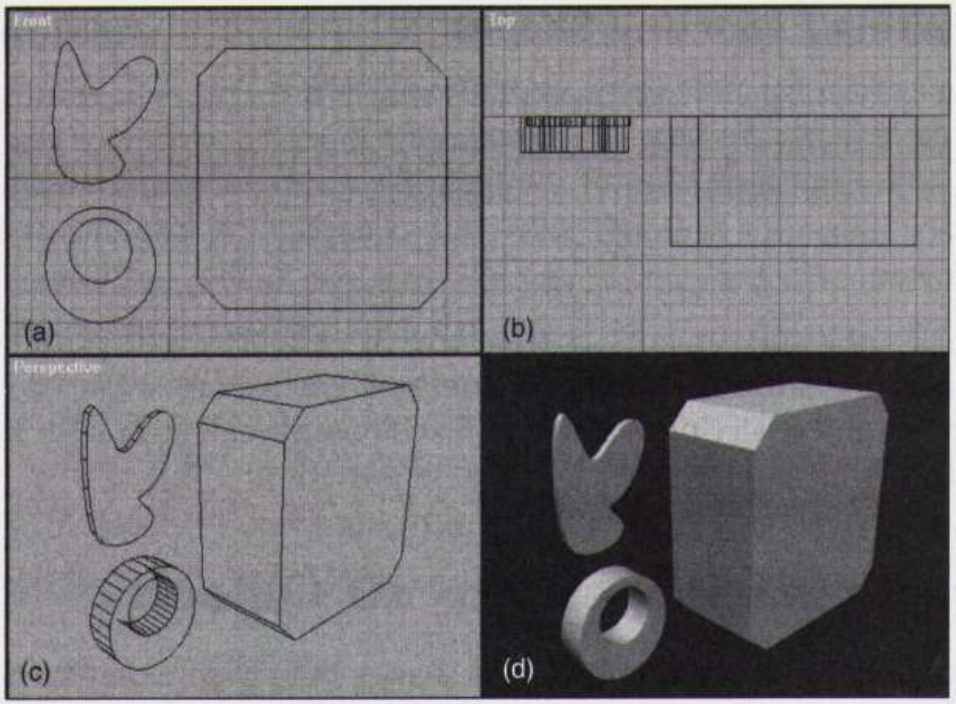
Turning 2D Shapes into 3D Objects

Extrusions

***Extrusion* is simply pushing the 2D shape into the third dimension by giving it a Z-axis depth.** Extrusions are very useful for creating block-like shapes, columns and panels.



Modeling a car



Extrude process:

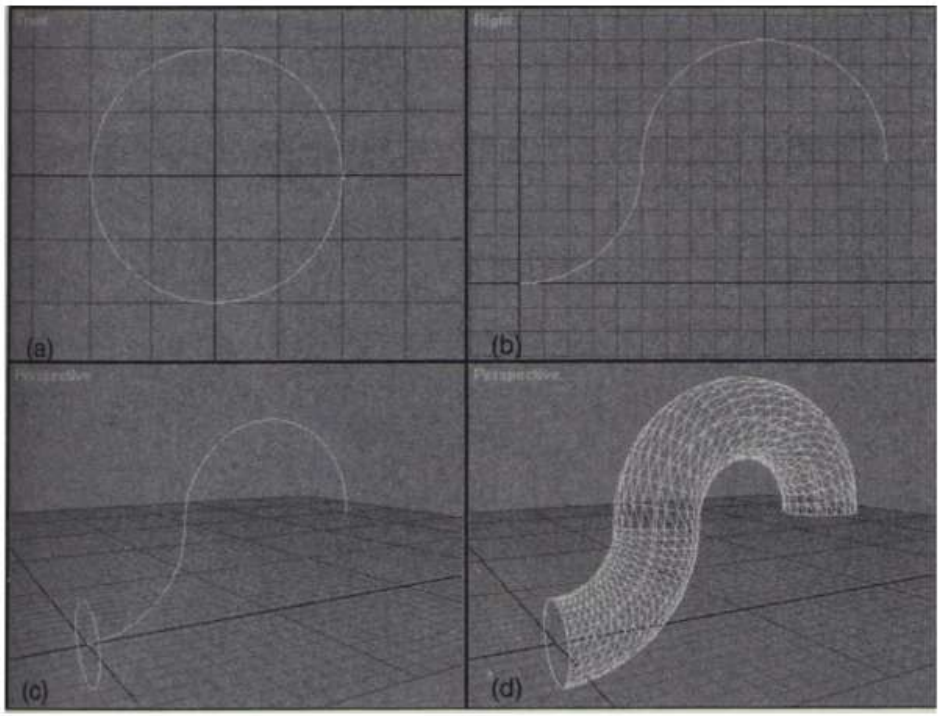
(a) 2D shapes are defined using polylines or splines.

(b)(c)(d) Extrude is applied to the 2D shapes, giving them the depth as defined.

Sweeping

Sweeping

Sweep* is a single 2D cross-section that is extruded *along a path.



Sweep process:

(a) Define a 2D cross-section.

(b) Create a path using polylines or splines.

(c) Assign the cross-section to the path or vice-versa, adjusting its orientation.

(d) Sweep the cross-section along the path to create a 3D object.

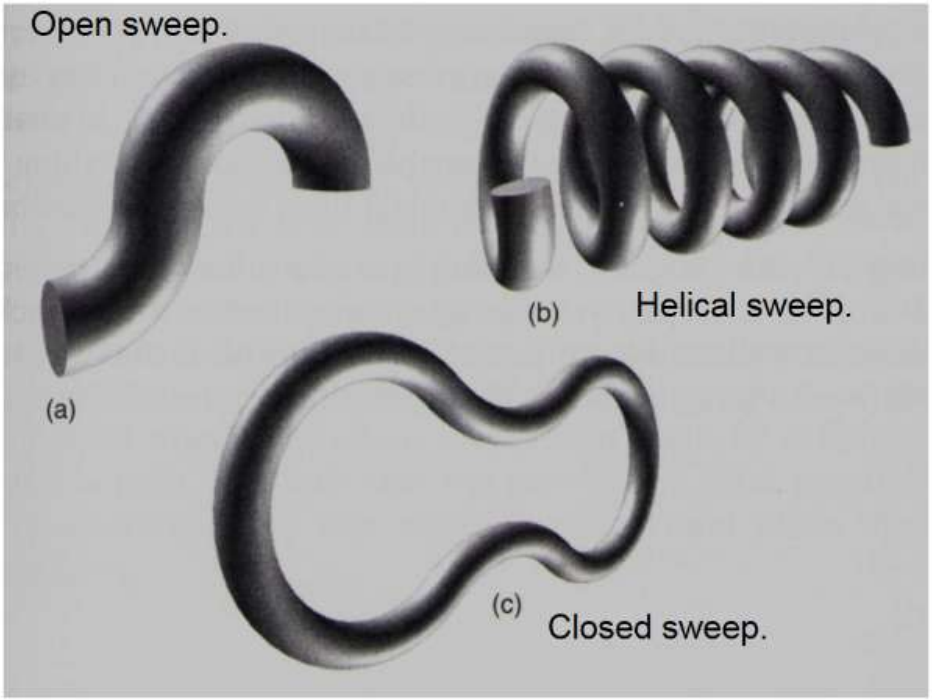
Sweeping

Sweeps come in three basic types: open, closed, and helical.

Open sweeps are created with paths that have two ends, and are ideal for creating a curved extrusion. Obvious uses are creating *wires, rope, tubing, plant stalks, or snakes*, etc.

Helical sweeps are a form of open sweep in which the path coils around like a spring. It is also useful for creating *screw threads*.

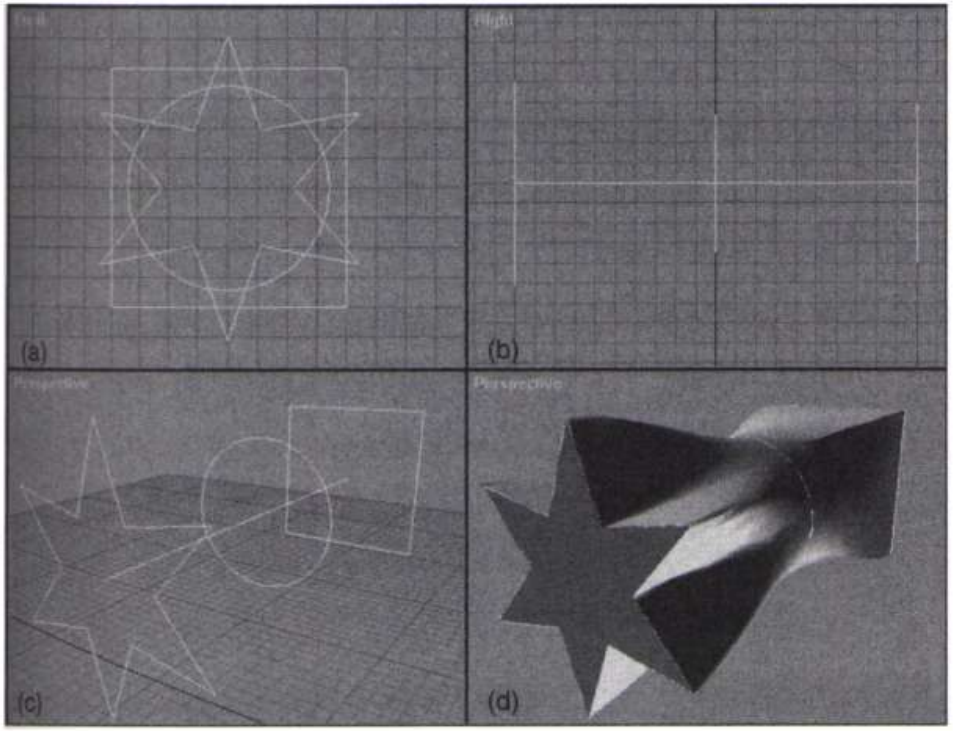
Closed sweeps are created by closing the path, so that the cross-section meets up with itself as it is swept along. Closed sweeps are good for creating such things as *fan belts, picture frames, trim, or bumpers* around other objects.



Turning 2D Shapes into 3D Objects

Skinning

***Skinning* is similar to an open sweep, except that you can *use different cross-sectional shapes along the path*.** In essence, the program creates a "skin" to wrap over this framework, something like the way fabric or plastic is stretched over metal tines to create an umbrella.



Skinning process:

(a) Define the 2D cross-sectional shapes.

(b)(c) Create a path and determine where the cross-sections will be located.

(d) Perform the Skin operation, which creates a surface to bridge the cross-sections.

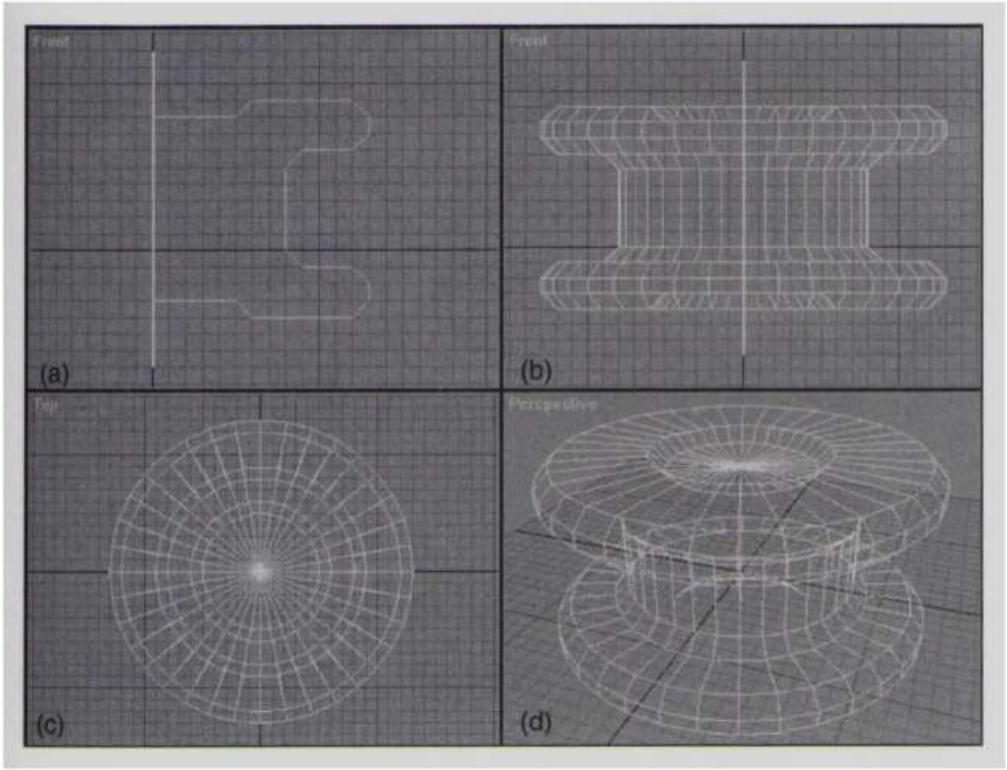
Lathe

Lathe

In woodworking, a lathe is a device that rotates a block of wood at high speed, enabling you to trim away at the wood with a sharp gouge.

Lathed objects are symmetrical about an axis of rotation.

Lathes are used to create carved cylindrical objects such as chair legs and bedposts.



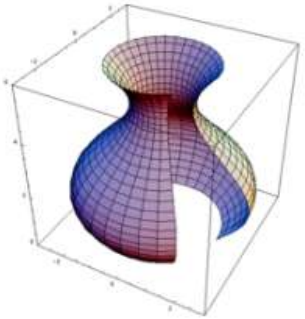
Lathe process:

(a) A 2D cross-section is created, and the lathe axis selected.

(b)(c)(d) The Lathe operation spins the cross-section around the axis.

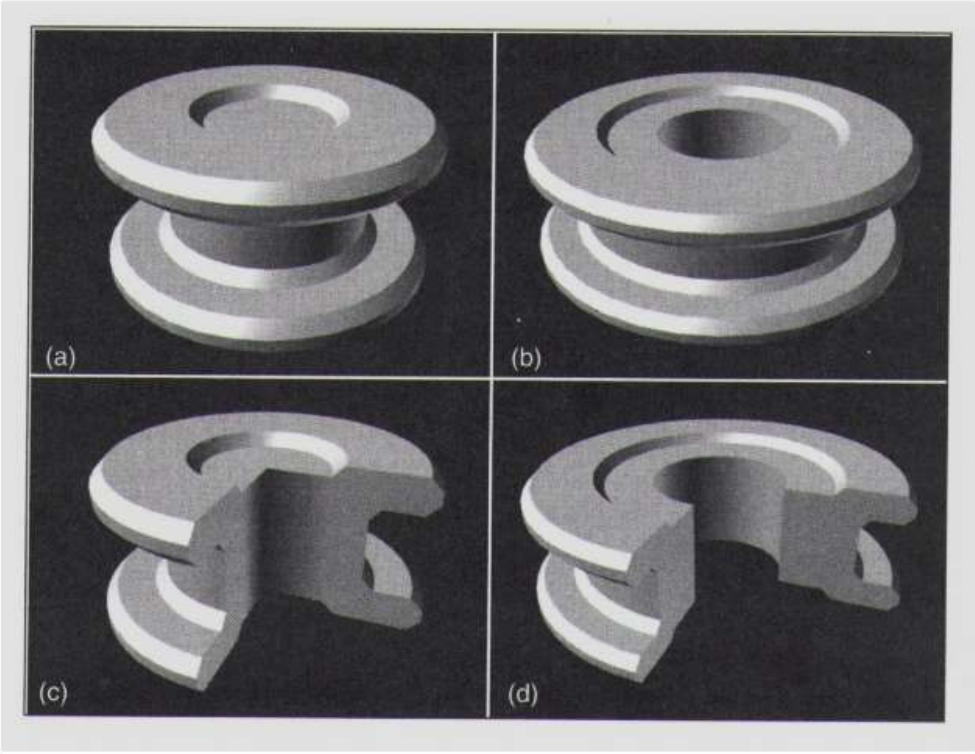
Turning 2D Shapes into 3D Objects

Lathe



Lathe offers significantly different results depending on how you set your axis. If the axis is located in the center of the cross-section, it results in a *closed lathe*, whereas an *open lathe* results if the axis is moved away from the center point.

Lathes don't have to be a full 360° -- they could just as easily be 90°, 180°, Or 272°, resulting in a *partial lathe*.



Lathe types:
(a) Closed lathe;
(b) Open lathe;
(c) Closed partial lathe;
(d) Open partial lathe

transform and Deform

3D Transforms and Deforms

- In general, ***transforms*** are operations that *alter the position, size, or orientation* of an 3D object. Such basic transforms as *Scale, Rotate, Mirror and Align* are essential to any modeling task, because you have to be able to adjust the position and orientation of the separate objects to make a scene.

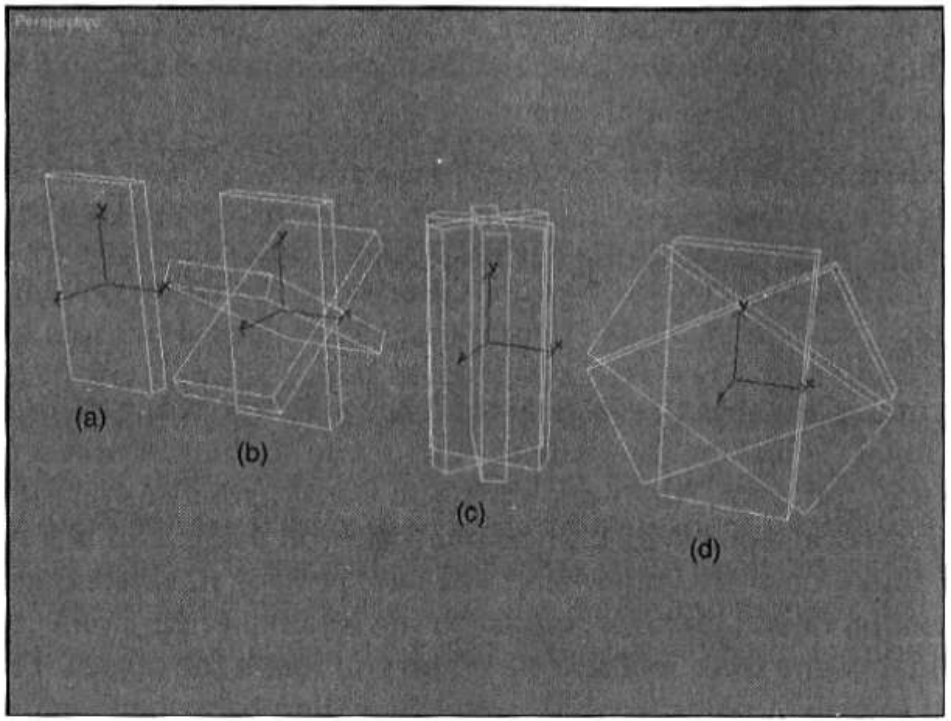
- ***Deforms*** enable you to easily alter primitives and other objects *in subtle or dramatic ways*, such as *Bend, Taper, Skew, Twist, Squash and Stretch*.

3D Transforms

Rotate

Rotate makes an object revolve around the selected axis.

- The pivot point of an object is located at the junction of its local axes, similar to the way the origin point resides at the center of the three world axes.



Rotate revolves objects around the desired axis.

(a) The base object.

(b) Rotation around the X-axis.

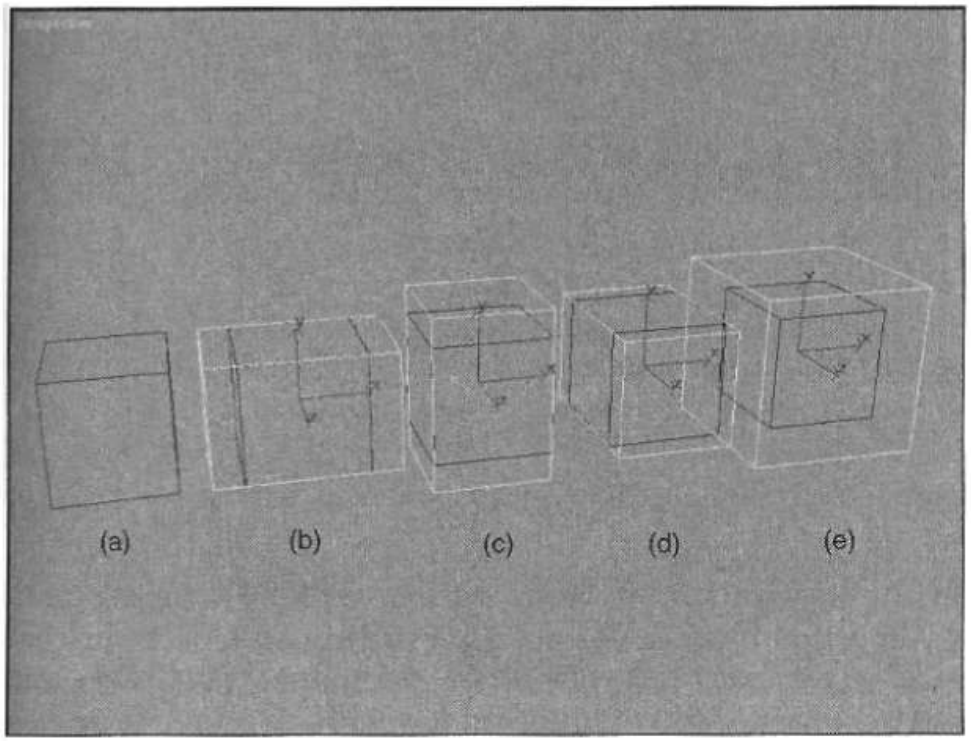
(c) Rotation around the Y-axis.

(d) Rotation around the Z-axis.

3D Transforms

Scale

Scale can be used to adjust the overall size of an object.



The Scale command re-sizes objects along the desired axes.

(a) The base object.

(b) Scaling the X-axis.

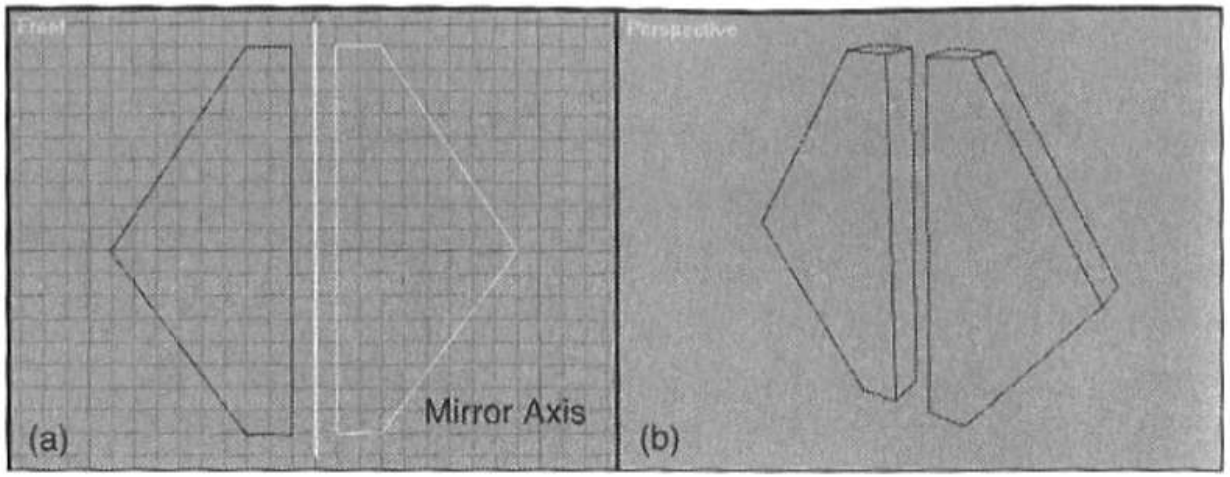
(c) Scaling the Y-axis.

(d) Scaling the Z-axis.

3D Transforms

Mirror

The transform command *Mirror* either reverses an object or copies a reversed version of it along the selected axis.

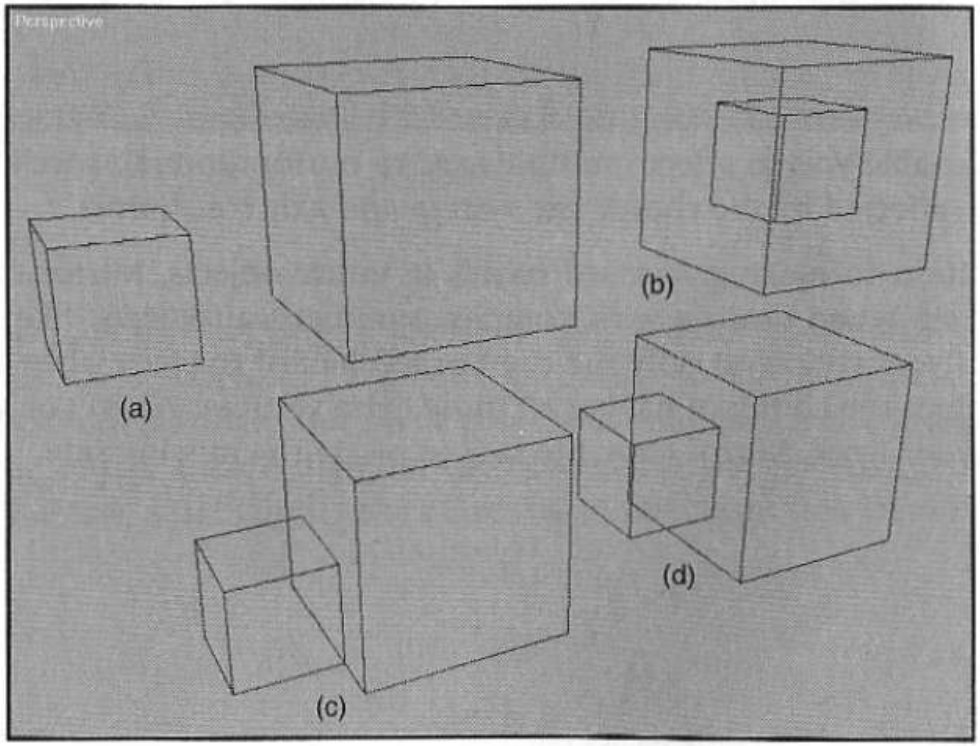


Effects of mirror: (a) The object is selected, and a mirror axis defined. (b) If the user elects to Mirror-copy the object, a second reversed version is created.

3D Transforms

Align

Align enables you to bring object surfaces flush with each other or center multiple objects along one or more axes.



Typical Align types:

(a) The base objects are currently centered on the Z-axis, and the bottoms are aligned with each other. In the following examples, the small cube will be aligned to the larger one.

(b) Align Center, on both the X- and Y-axis.

(c) Align Left on the X-axis.

(d) Align Left on the X-axis, plus Align Center on the Y-axis.

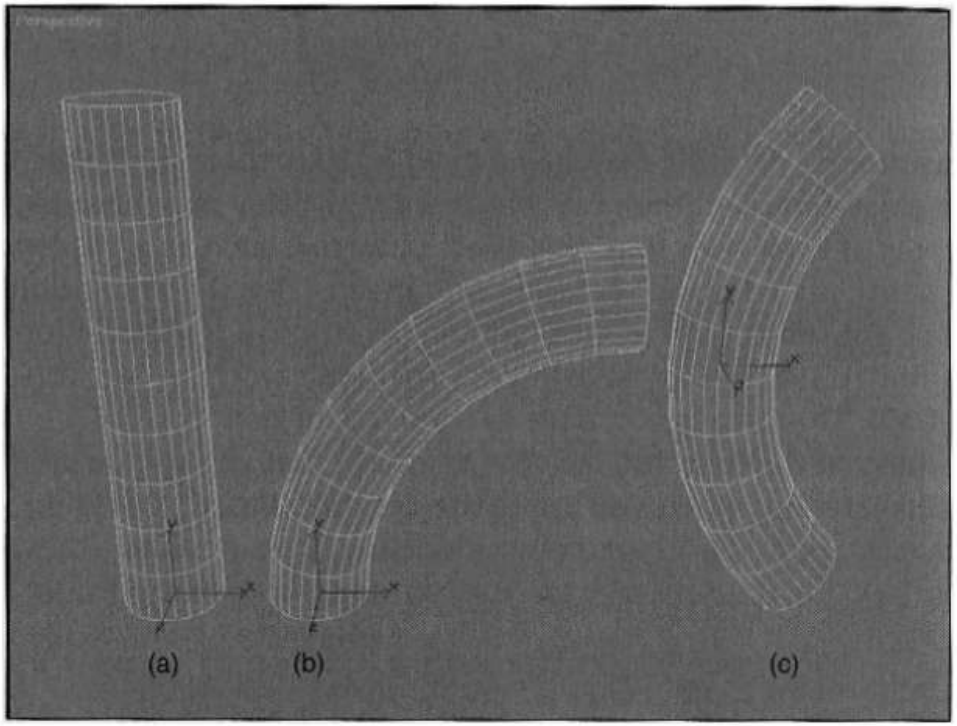
Deforms

Deforms enable you to easily alter primitives and other objects in subtle or dramatic ways, such as Bend, Taper, Skew, Twist, Squash and Stretch.

3D Deforms

Bend

The *Bend* deform distorts an object evenly around the selected axis.



Bend distorts an object around an axis.

(a) The base object.

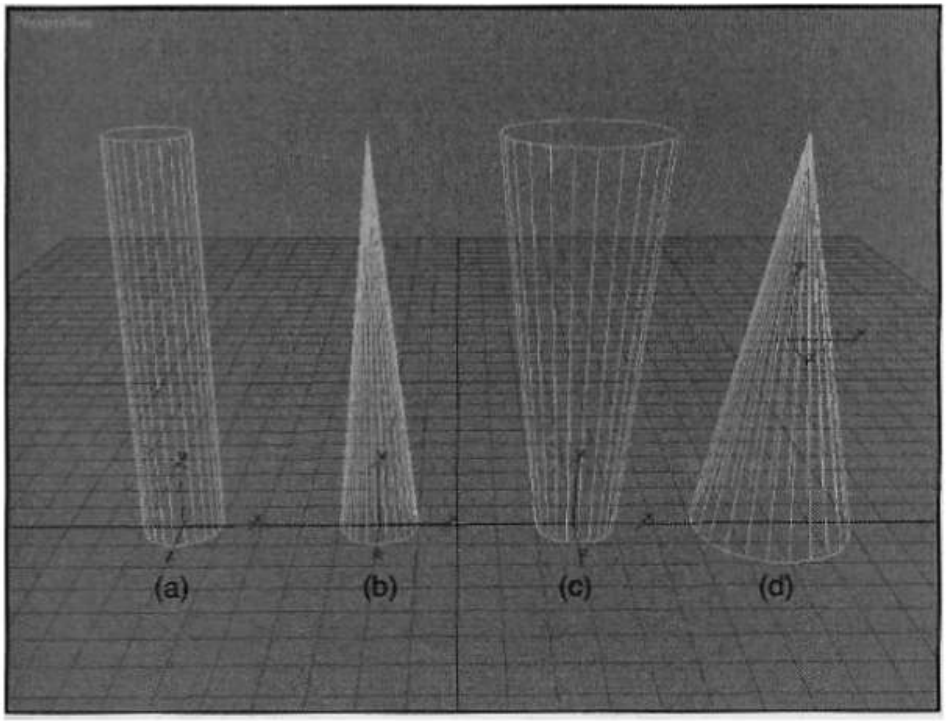
(b) 90-degree bend with pivot point at base of object.

(c) 90-degree bend with pivot point in center of object.

3D Deforms

Taper

The *Taper* command compresses and expands an object along the selected axis.



Effects of pivot point location on Taper:

(a) The base object.

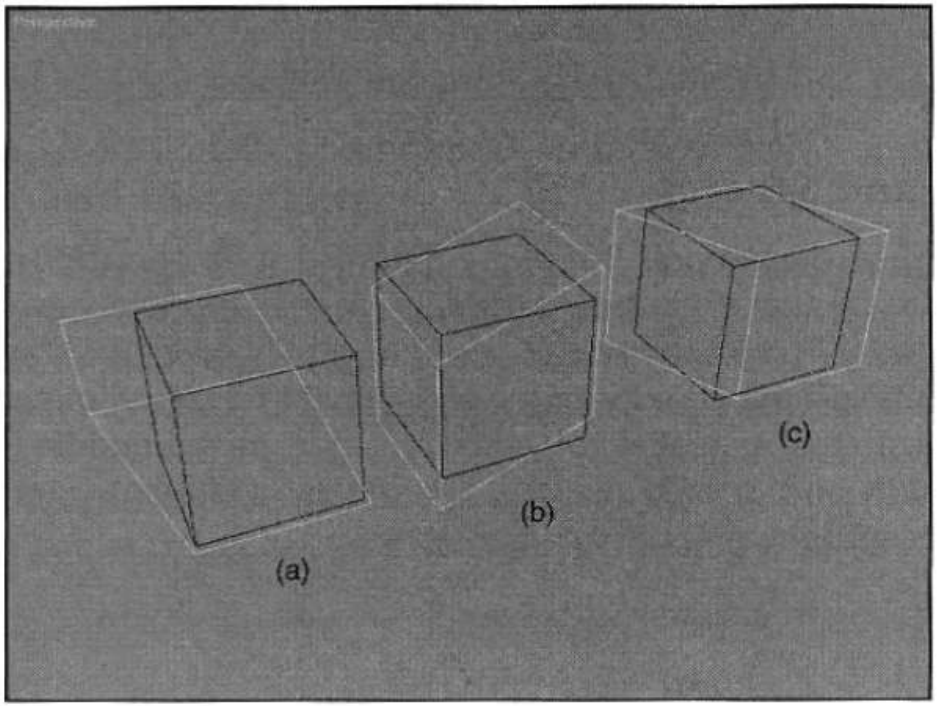
(b)(c) If the pivot is at one end of the object, that end is unaffected.

(d) If the pivot is centered in the object, both ends are affected in opposite ways.

3D Deforms

Skew

***Skew* forces one side of the object in one direction along the selected axis, and the other side in the opposite direction.**



The effects of Skew (the affected object has been scaled a bit larger than the original for clarity):

(a) Skewing on the X-axis.

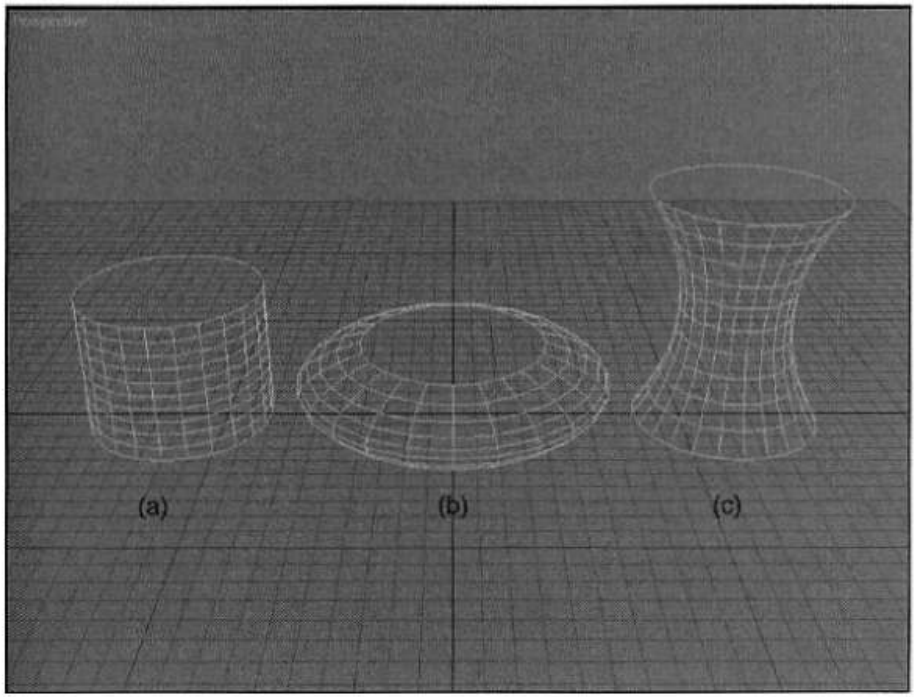
(b) Skewing on the Y-axis.

(c) Skewing on the Z-axis.

3D Deforms

Squash and Stretch

•*Squash* and *Stretch* are modified scale operations that treat the object as though it has liquid inside it. The volume of a squashing and stretching object remains constant.



Squash and stretch in action:

(a) The base object.

(b) Squash makes the object spread out around the edges.

(c) Stretch makes the object thinner in the middle, as if you were pulling gum apart.

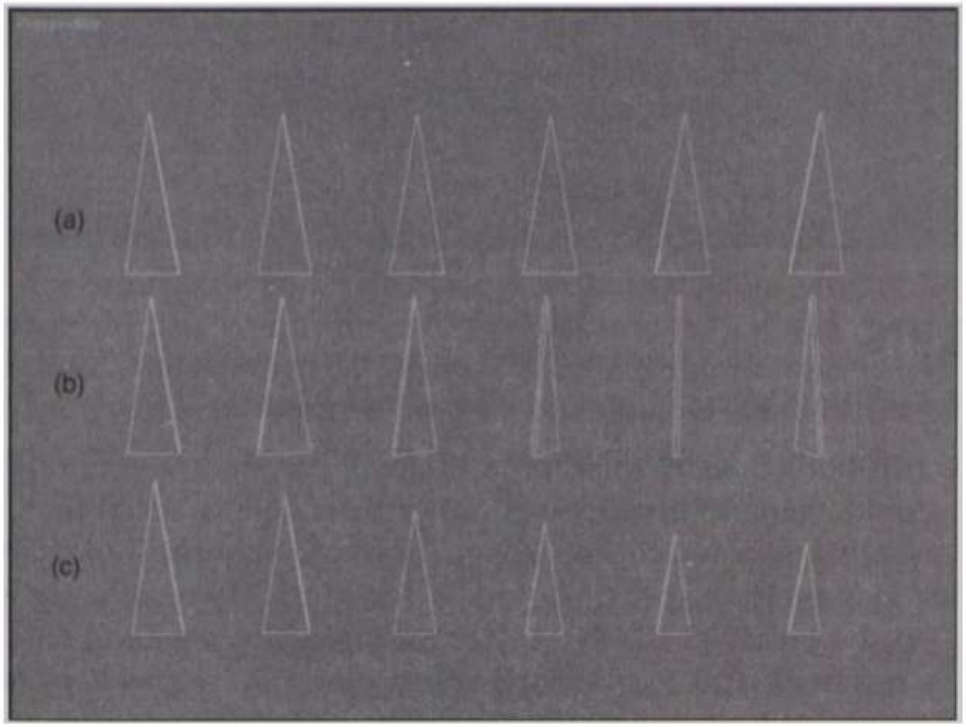
Array

这个array的方法在上面2D里面有提到但是slides里面没有讲解，与3D同理

3D Duplication

Array

The ***array*** *creates a matrix or pattern of objects* based on the one you have selected. A *linear array* is a series of copies made in a line along a selected axis.



Examples of linear arrays:

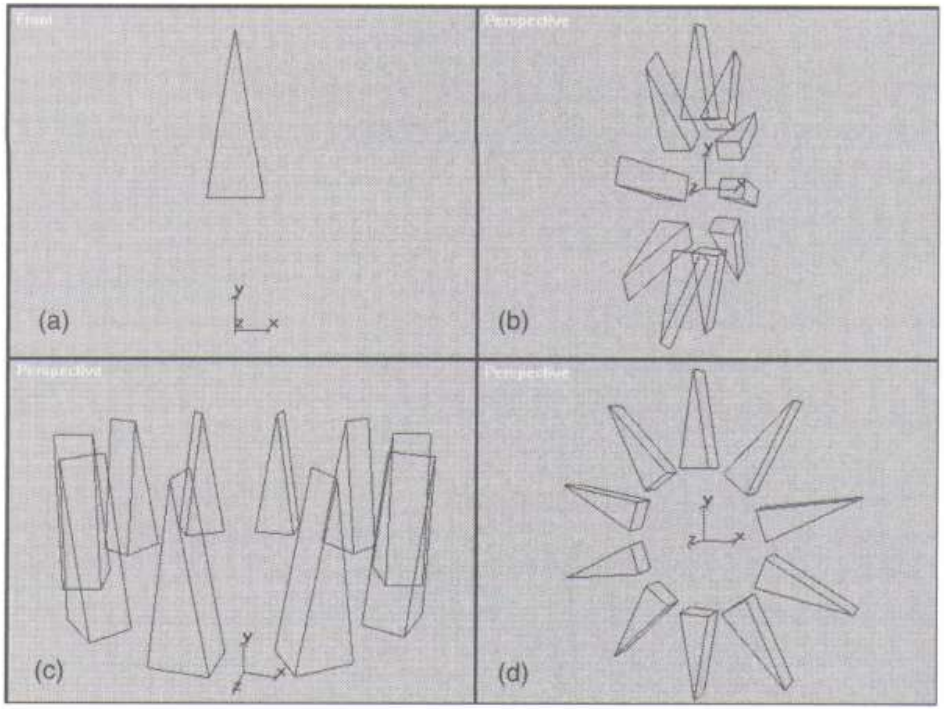
(a) A basic linear array.

(b) A linear array with rotation applied.

(c) A linear array with scaling applied.

Array

Arrays don't have to be linear. They also can be rotation-based, resulting in a *radial array*.



Rotational arrays:

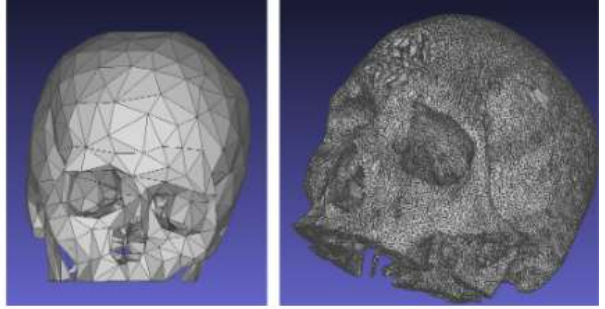
(a) Object with pivot point offset along Y and Z axes.

(b) X-axis array.

(c) Y-axis array.

(d) Z-axis array.

Poly Counts



- A **poly count** is the total number of polygons that model a given object.

- 3D engines have limits as to how many polygons they can move around within a given time period, and this limit basically determines how complex the geometry can be in a given scene.
  - Let's assume that an engine has a practical limit of moving 5000 polygons per frame of animation. If gameplay calls for having only five objects in the scene, each can be modeled with 1000 polys apiece.

- Most 3D engines prefer 4-sided polys – quads – but work fine with 3-sided triangular polys as well. The difference is that it takes two triangular polys to make up a quad, so you can keep the poly count lower by using quads rather than tris wherever possible.

Low-Poly Modeling

Low poly *is a term to describe a polygon mesh in 3D computer graphics which has a small (low) number of polygons.*

Low-Poly modeling is very useful in 3D real-time game.
If the poly count of models is too high in a 3D game, it can impact the performance of the game, even to the point where it is unplayable.

http://www.poopinmymouth.com/3d/naruto.jpg.

pencilgym.com

Low-Poly Stand-ins

- Low-poly models have applications in high-resolution animation. Building a low-poly version of a character or vehicle and using it as a ***stand-in*** during animation can be a great time-saver.

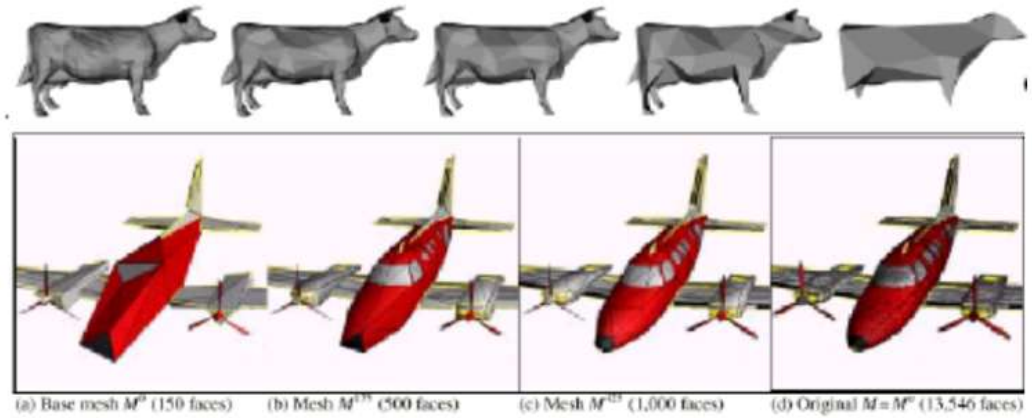
- Using low-poly stand-ins may enable you to **preview** the animation in real-time, and test renders get done in a flash. When the animation is refined as much as possible with the stand-in, the animator can replace it with the hi-res mesh.

Level of Details(LoD) & Subdivision

LoD

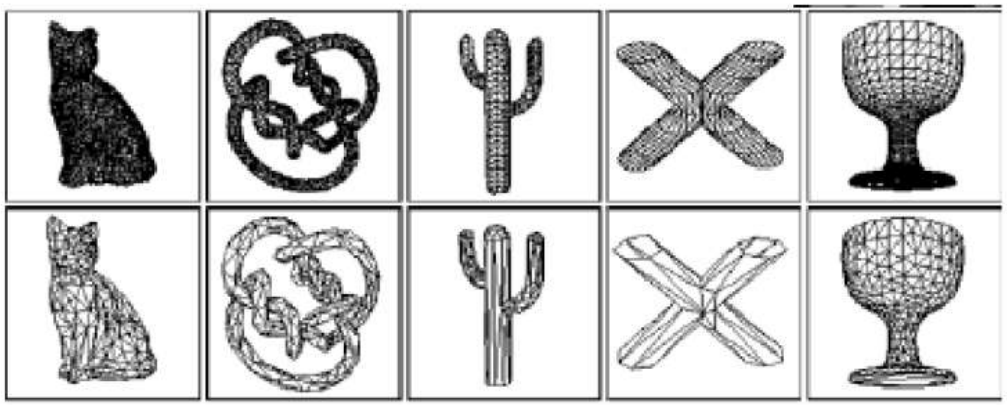
Level of Detail (LOD)

To milk more performance and the appearance of greater scene complexity out of a 3D engine, models are often created in two or three versions, each with a different poly count, or *level of detail (LOD)*.



Hoppe 96

3D assets for games are often produced with multiple mesh and mapping resolutions called LODs. 3D engines swap out objects farther from the camera with less-detailed versions.

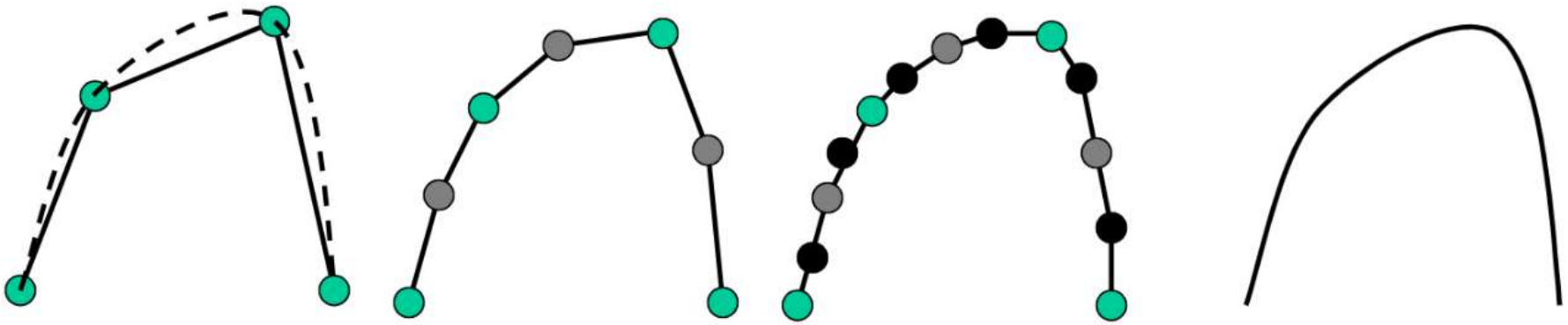


(a) First Row: Full-res model with high-res maps.

(b) Second Rwo: Lower-res model and maps.

Subdivision

How do you make a smooth curve?



The "**base mesh + subdivision process"** representation allows, for instance:

- simple implementation
- automatic LOD
- variable resolutions in a same model
- multi-resolution editing

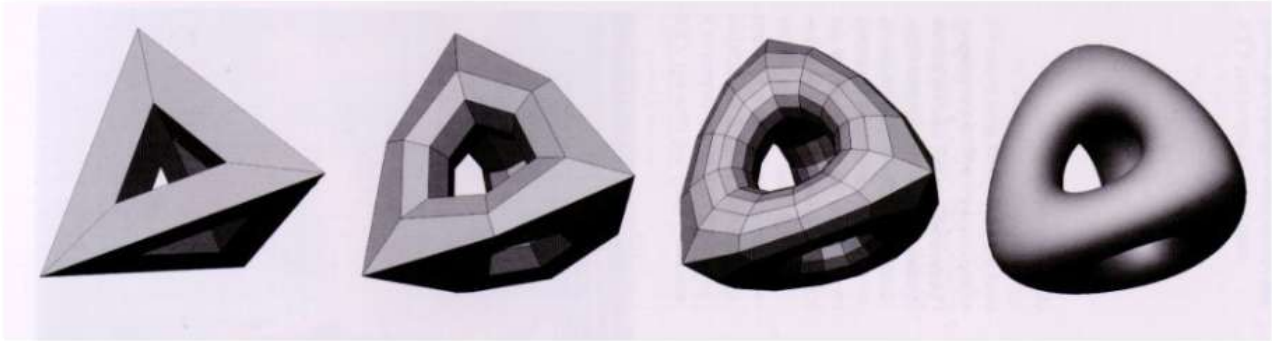
D. Zorin, P. Schroder, \Subdivision for Modeling and Animation", 2000

Subdivision Surfaces

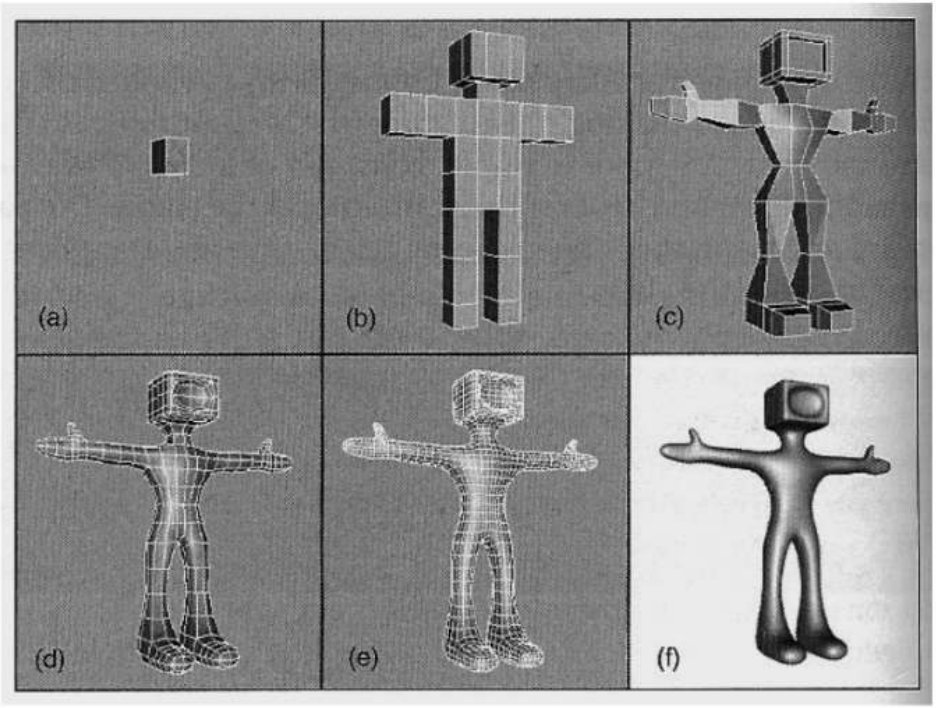
The *subdivision surfaces* process consists of a **mesh smoothing operation** that analyzes the lower-resolution base object and uses **splitting** and **averaging** techniques to **add additional faces that smooth out rough edges and emphasize details**.

In essence, you work in a relatively low-poly manner, but get high-poly results.

The advantages of using the subdivision surfaces process for modeling is that this method enables the user to build and manipulate relatively low- to medium-poly mesh, yet have the mesh increase in resolution and smoothness at any time.



Subdivision Surfaces



Subdivision surfaces in action:

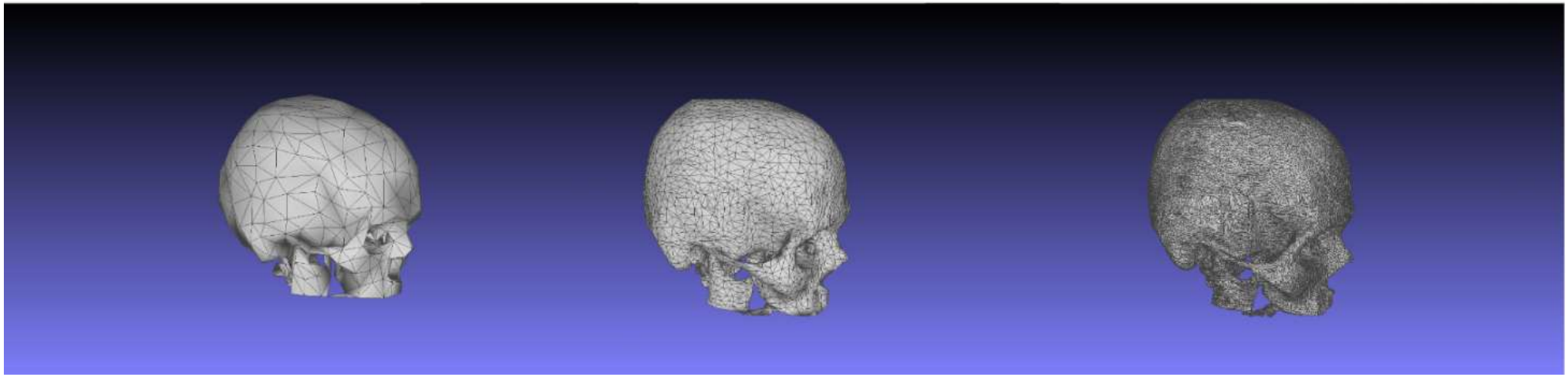
(a) A single rectangular box was created.

(b) The faces of the box were extruded to create this simple human form.

(c) Additional face extrusion and some point pulling were used to refine the character.

(d)(e) Applying multiple iterations of mesh smooth added additional faces and smoothed out the form.

(f) The resulting TV-headed character.

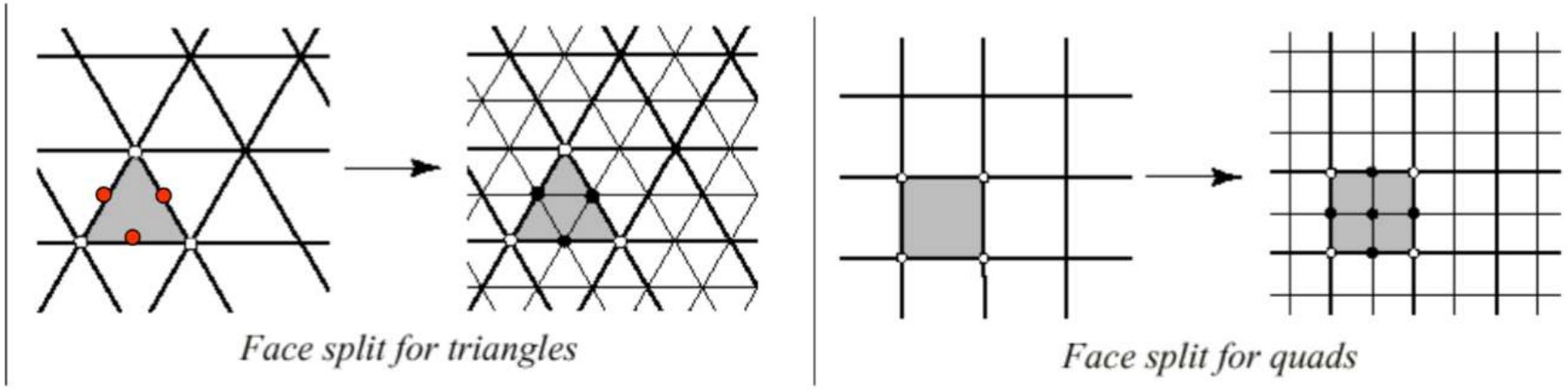


Advanced Modeling Techniques

Subdivision Surfaces

Types of subdivision surfaces

- Chaikin (1974), quadratic B-spline
- **Catmull-Clark (1978), B-spline surface**
- Doo-Sabin (1978), bi-quadratic surfaces
- Loop (1987), triangular subdivision
- Dyn et al. (1990), “butterfly" scheme
- Zorin et al. (1996), modied buttery
- **DeRose and Kass (1998), subdivision surfaces in animation**
- ……



D. Zorin, P. Schroder, Subdivision for Modeling and Animation", 2000

还有一些其他技术可以了解一下（Mesh Tessellation ,Partical Systems)

Procedural Modeling techniques

Particle System

Procedural Modeling—Particle System

Modeling phenomena such as *clouds, smoke, water, and fire*.
These "fuzzy" objects do not have smooth, well-defined, and shiny surfaces; instead their surfaces are *irregular, complex, and ill defined*; and have dynamic and fluid changes in shape and appearance.

The representation of ***particle systems*** differs in three basic ways from representations normally used in image synthesis.

- First, an object is represented not by a set of primitive surface elements (such as polygons or patches that define its boundary) but as clouds of primitive particles that define its volume.
- Second, a particle system is not a static entity. Its particles change form and move with the passage of time. New particles are "born" and old particles "die."
- Third, an object represented by a particle system is not deterministic, since its shape and form are not completely specified. Instead, stochastic processes are used to create and change an object's shape and appearance.

Particle SystemsmA Technique for Modeling a Class of Fuzzy Objects
WILLIAM T. REEVES
Lucasfilm Ltd

Particle Systems

EXAMPLE – For gushing water, we want a material that appears like foamy water. Facing particles with a soft radial gradient map causes rendered particles to blend together into a foamy stream that approximates the look of water.

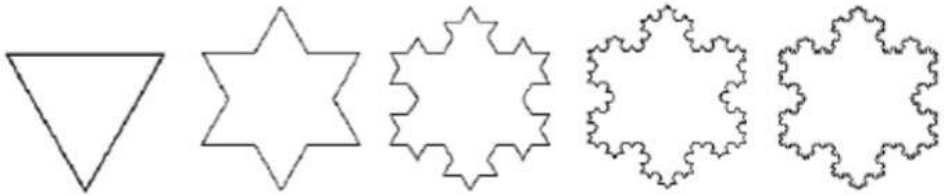
The particles are displayed as square facings. We need to soften their edges to make them appear more amorphous.

A soft radial gradient map causes rendered particles to blend together quite nicely. But they still look a bit "blobby," for water.

To improve this, we can use Image Motion Blur.

Procedural Modeling—Fractal

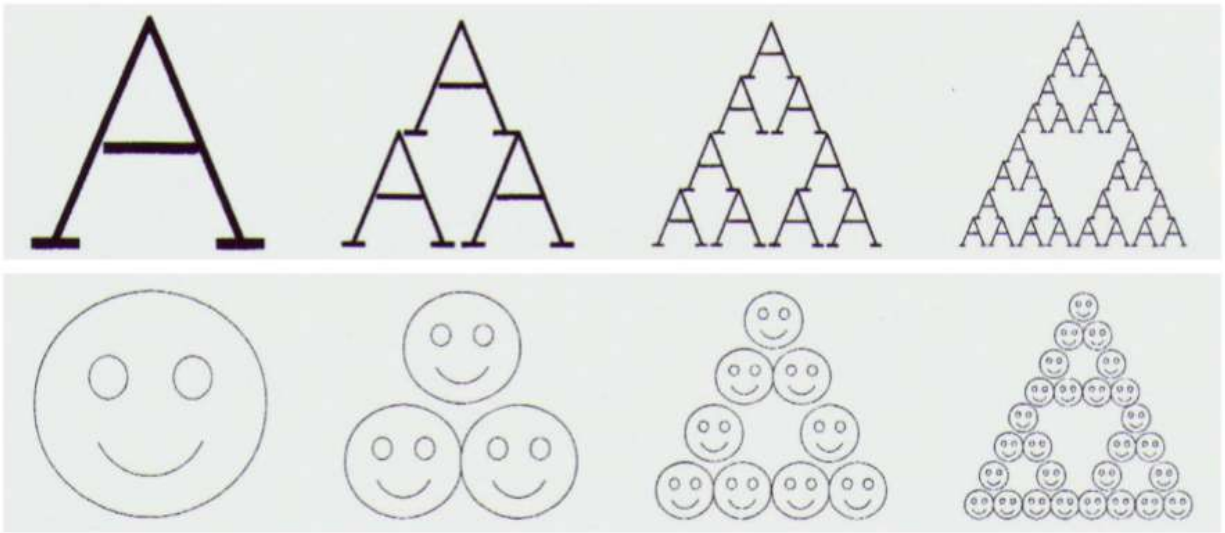
- Describe 3D models algorithmically
- Best for models resulting from
  - Repeating processes
  - Self-similar processes
  - Random processes
- Advantages:
  - Automatic generation
  - Concise representation
  - Parameterized classes of models

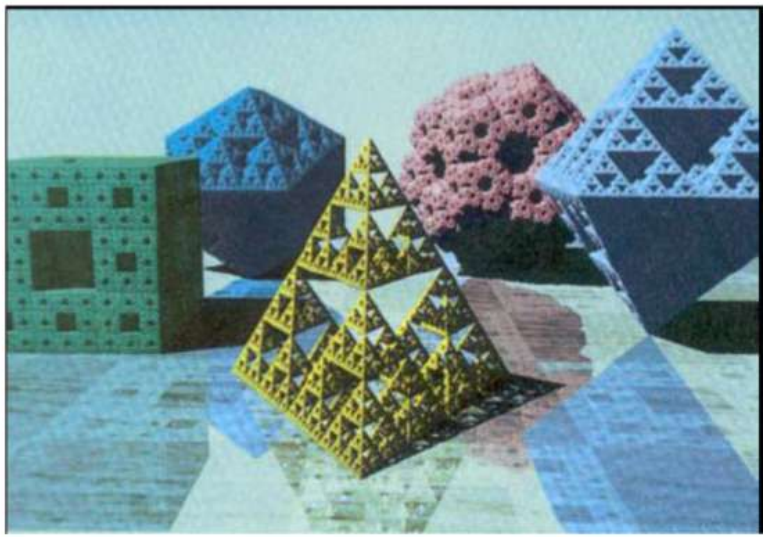


Procedural Modeling—Fractal

Procedure:
- Initiator: start with a shape
- Generator: replace subparts with transformed copies of the original shape

- Each image is formed from transformed (and reduced) copies of itself
- The images are **fractals**
- Can be applied to generate trees, mountains, clouds…

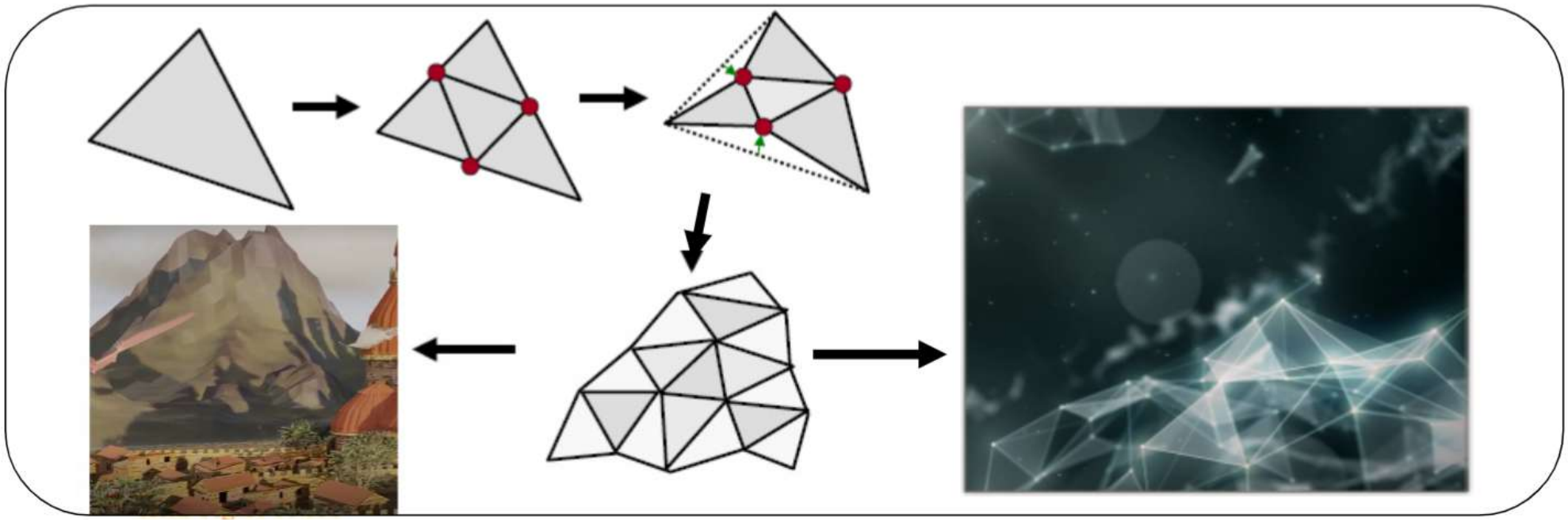




Initial Image First Copy Second Copy Third Copy

H&B Figures 75 & 109

Procedural Modeling—Fractal

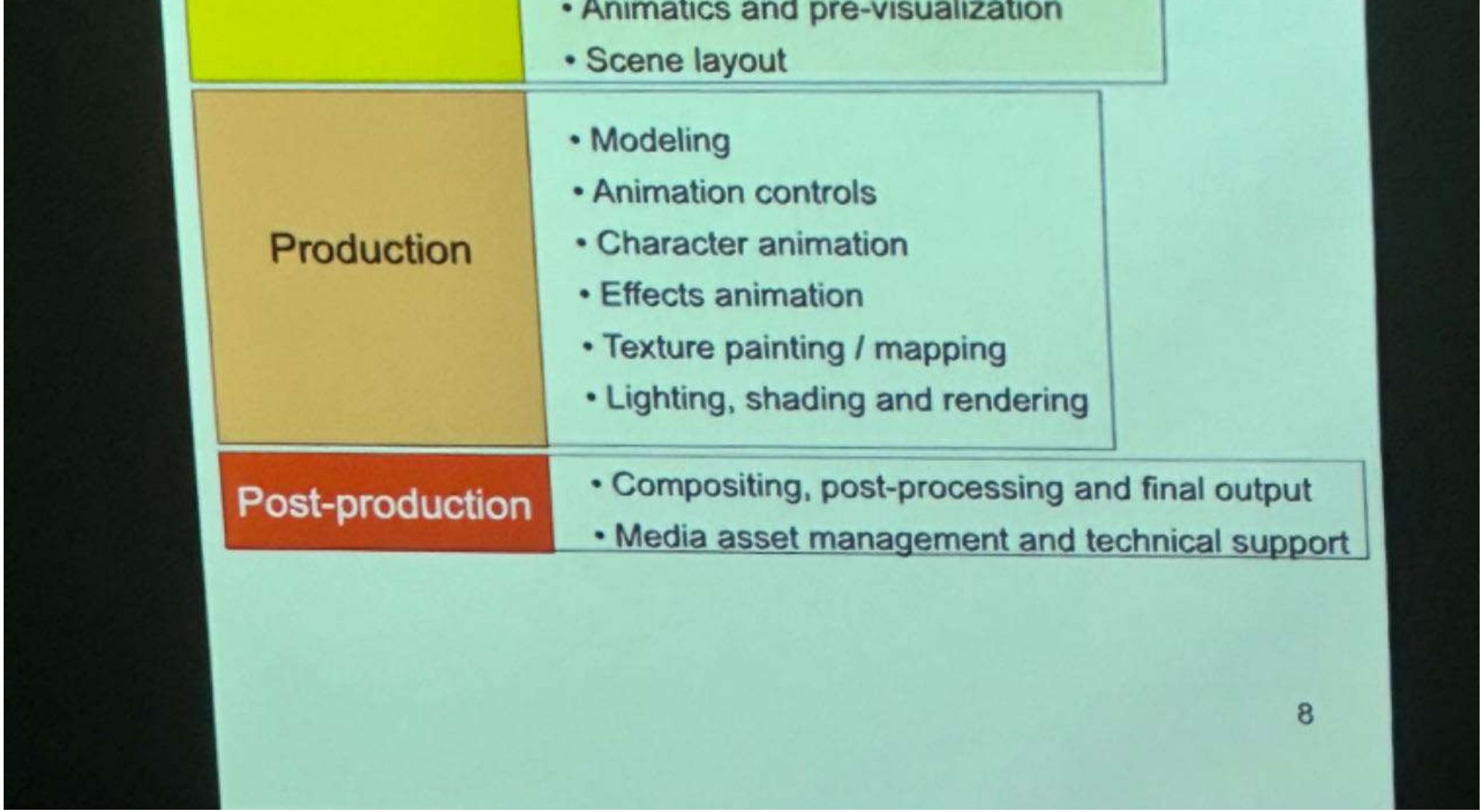


Animation Fundamentals

Animation Fundamentals

- Types of conventional animation; (#)
- Computer animation (*)
- The process of creating computer animations (*)
  - Pre-production (*);
  - Production (*);
  - Post-production (#);

Pre-production	• Story development and scriptwriting • Storyboards • Visual development • Character design



Computer Animation

Computer Animation

- Computer animation is the art of creating moving images via the use of computers.
- In computer animation, any element can be changed and animated.
  - An object's position and orientation are obvious candidates for animation, but all of the following can be animated as well: the object's shape, its shading parameters, its texture coordinates, the lighting parameters, as well as the camera parameters.
  - Further, integrating live-action with virtual images and graphics, and combining motion and performance of a live actor with an animated character.

Types of Animation

2D Computer Animation

- In 2D computer animation, figures are created and/or edited using 2D bitmap images or created and edited using 2D vector graphics.
- This includes automated computerized versions of traditional animation techniques such as of tweening, morphing, onion skinning as son on.
- **2D Flash animation / …**

3D Computer Animation

3D Computer Animation

- **In 3D computer animation, figures are often created in the computer using *polygons*.** *These meshes can be changed according to the given parameters and controls.*
- Various techniques can be applied, such as mathematical functions.

King Kong (1933 film

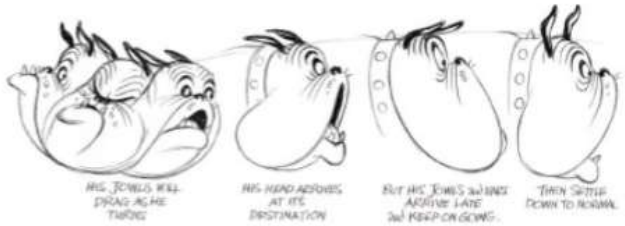
King Kong 2005

3D Computer Animation

Character Animation vs Effects Animation

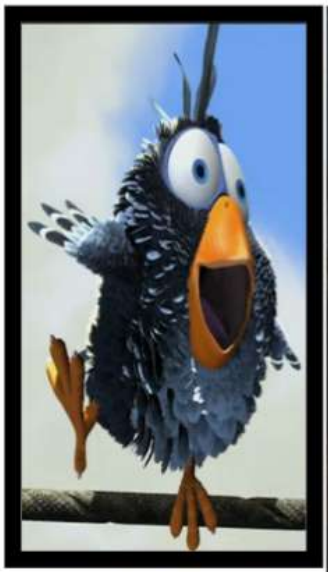
- **Character animation** is artistically unique which involves the creation of ***apparent thoughts and emotions***, in addition to ***physical actions***.

- **Effects animation** creates anything that is *not* a character; most commonly vehicles, machinery, and natural phenomena such as rain, snow, and water.



Character Animation

▪**Character animation**: Any 3D object – including a simple cube – can have ***personality***, depending on how the animator makes it moves. By the same token, even the most detailed and accurate human models can come off as being lifeless if its motions are dull or mechanical. ***The key to compelling characters is making them act naturally.***



Copyright © For-the-Birds_320X180.mov / Pixar.

Brainy, Papa, Grouchy, Gutsy and Smurfette in Columbia Pictures' *The Smurfs*
http://www.youtube.com/watch?v=ae6WLq9it30&feature=related

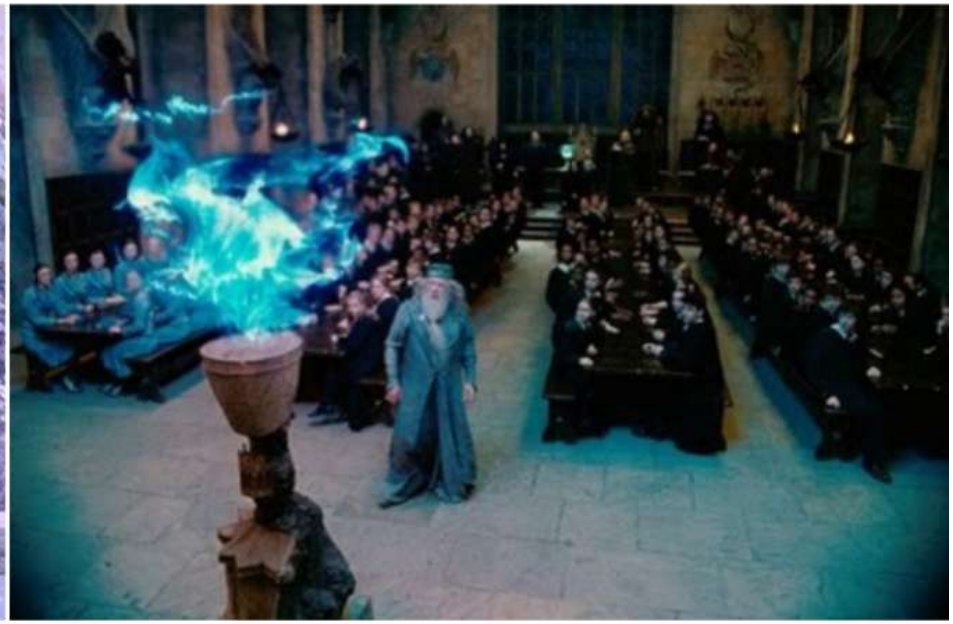
Copyright © Walt Disney .

Types of Animation

Effects Animation

Most of the animation that is not character-oriented falls within the specialty of *effects animation*. This usually includes natural phenomena like fire, smoke, wind, dust, and water in its many forms (rain, snow, clouds, rivers, water falls, oceans), as well as special lighting effects like sparks and shadows.

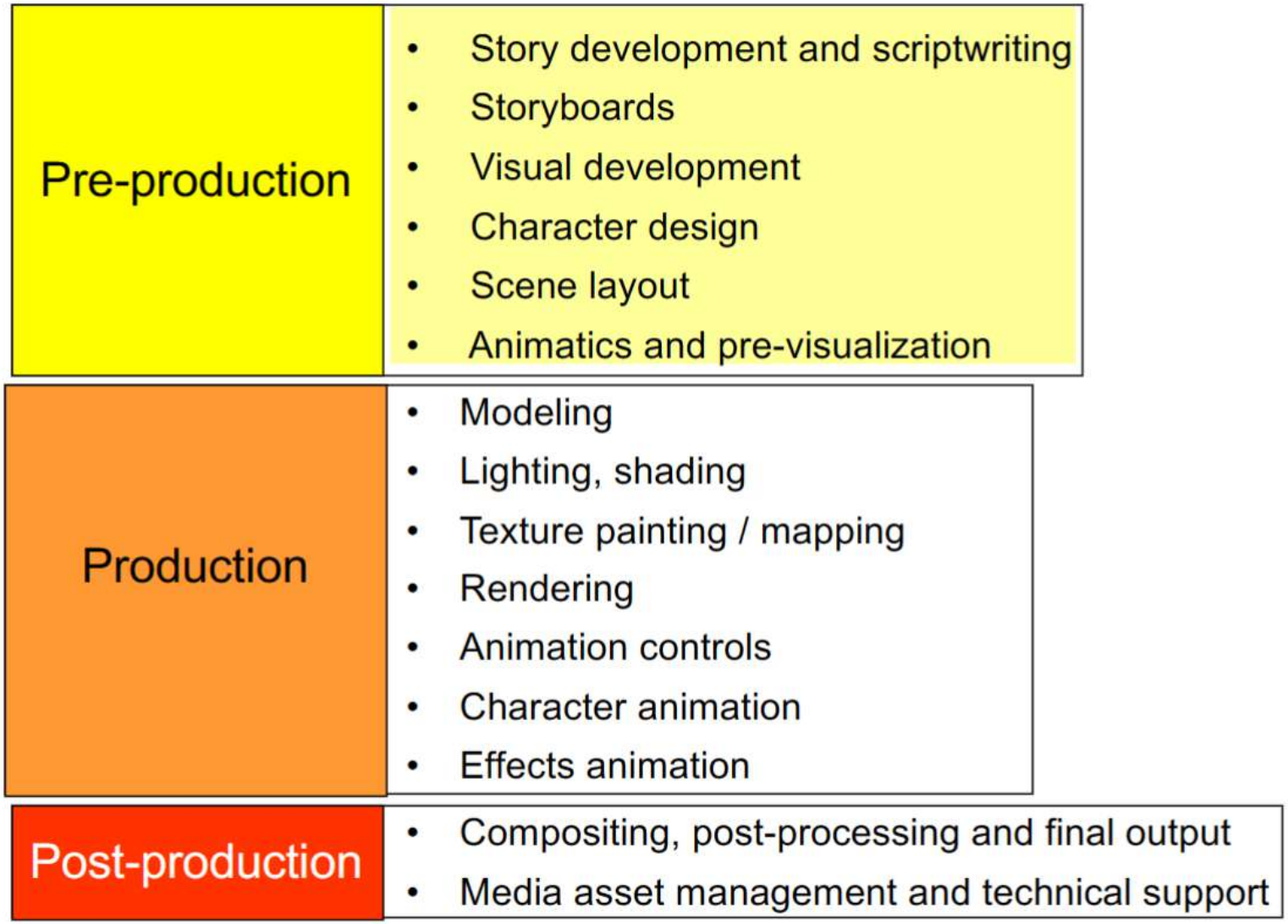
http://www.lisakeene.com/frozen.html



Harry Potter and the Goblet of Fire

The process of creating computer animations

The Process of Creating 3D Computer Animation



Pre-production

Storyboards

The creation of ***storyboards is usually the first attempt to translate the story and the idea/plan into images/graphical representation***. It is an important tool for ***breaking down the plan/concept into manageable production units***, and it is also an indispensable tool for ***technical breakdown***.

For example, characters need to design, and make a list of props, backgrounds and anything else that needs to be drawn or modeled, sounds *need to record etc.* ***Animation storyboards*** *can be as detailed as* ***key-frames*** *of* the animation itself.

A storyboard is a visual interpretation of the story and contains many ***images/graphics*** and ***production notes of the scenes & explanations***.
Storyboard could be considered as a comic book version of the script.

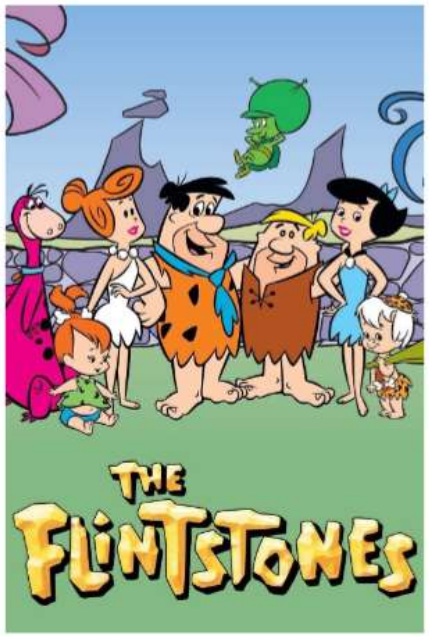
Visual Development

Visual development is about setting a visual direction and style for the animation project.

This stage includes the **creation of the characters**, the **types of environments** and props, the **overall styling, atmosphere and "look"**, and the **color schemes** for the project.

Setting color schemes and the color keys for every scene of the project is an important aspect of the visual development that will create much of the visual mood of the project.

The color keys must visually complement the goals of each part of the story.

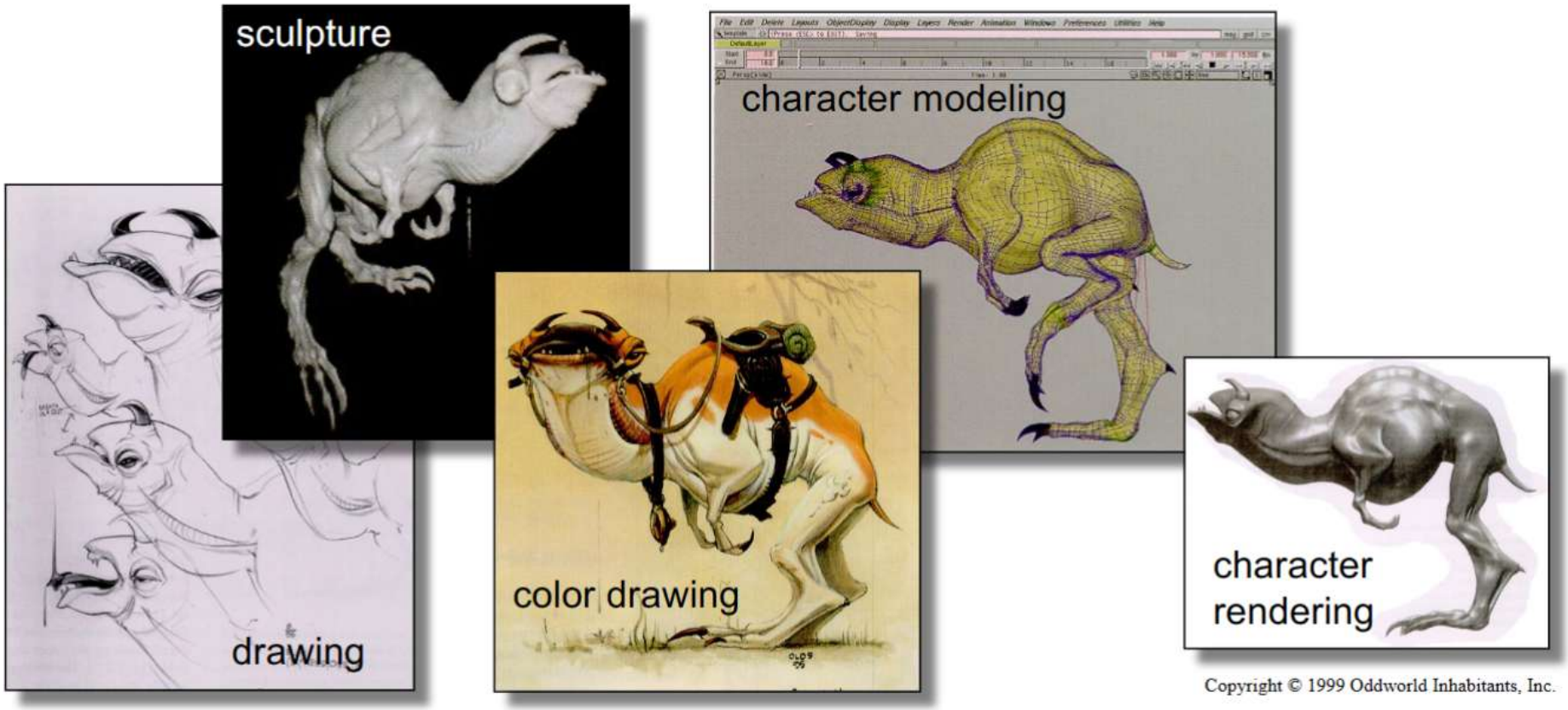


Computer Animation Process

Character Design

Pixar

Apart from story/idea, the characters are the second most important aspect of an animated project. The characters is developed through *drawings*, *sculptures, or computer-generated models*.



Animatics and Pre-visualization

- An animatics is a preliminary version or a rough cut of a computer animation and is used to visualize how the final project may be structured.

- Animatics are based on preliminary visual material such as low-resolution motion tests. None of the special effects in an animatic are meant to be final, and often they are implemented with techniques that are cruder and less expensive than techniques that are planned for the finished project.

http://www.youtube.com/watch?v=aQEWINi8tco

THE DARK KNIGHT RISES Animated Teaser Trailer (low res)

Scene Layout

- While models for the characters, props, and environments are being built, the positions and motions of the camera are blocked out.
- The stage that adding and positioning the camera in the scene is called **scene layout** and it is increasingly being done directly in the computer with simplified digital models.

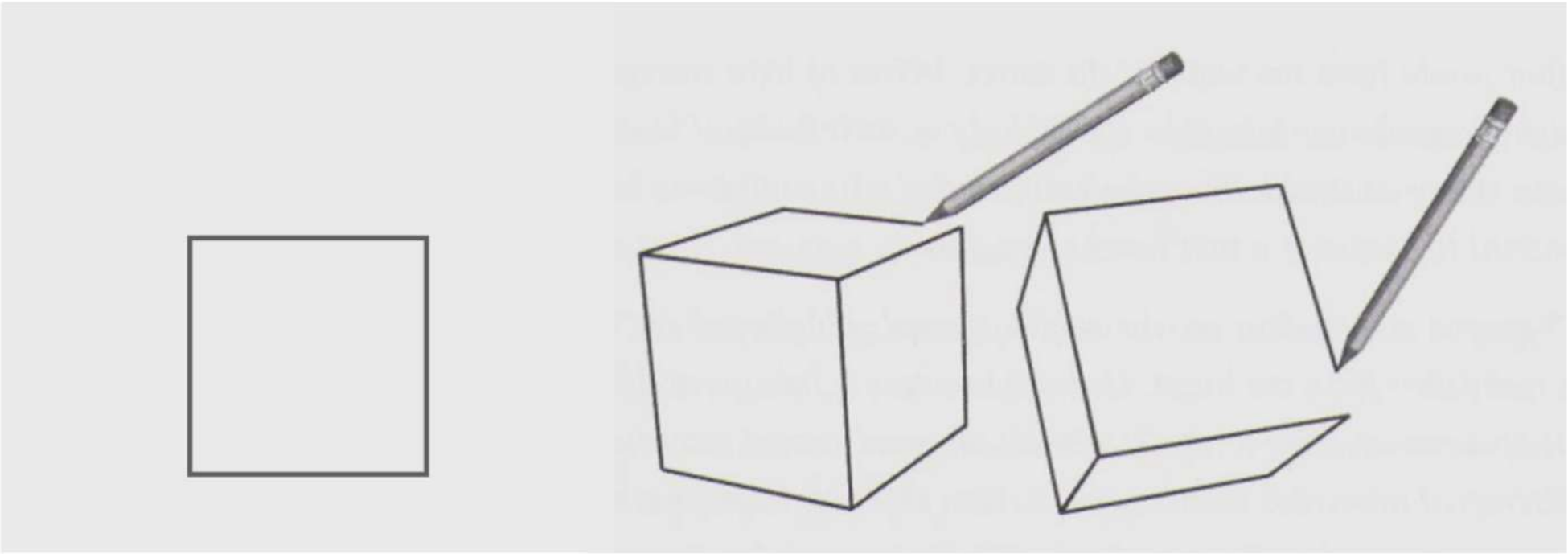
Production(production中的知识点modeling在下面，character animation和effects animation之前提到了，其他的都在rendering部分,Animation control 在下面3D Computer Animation-Animation Control的版块内)

Modeling

包含把2D图形转化为3D模型的方法，三个坐标空间，一个相机位置，还有顶点与片元以及3D物体是怎么组成的问题。

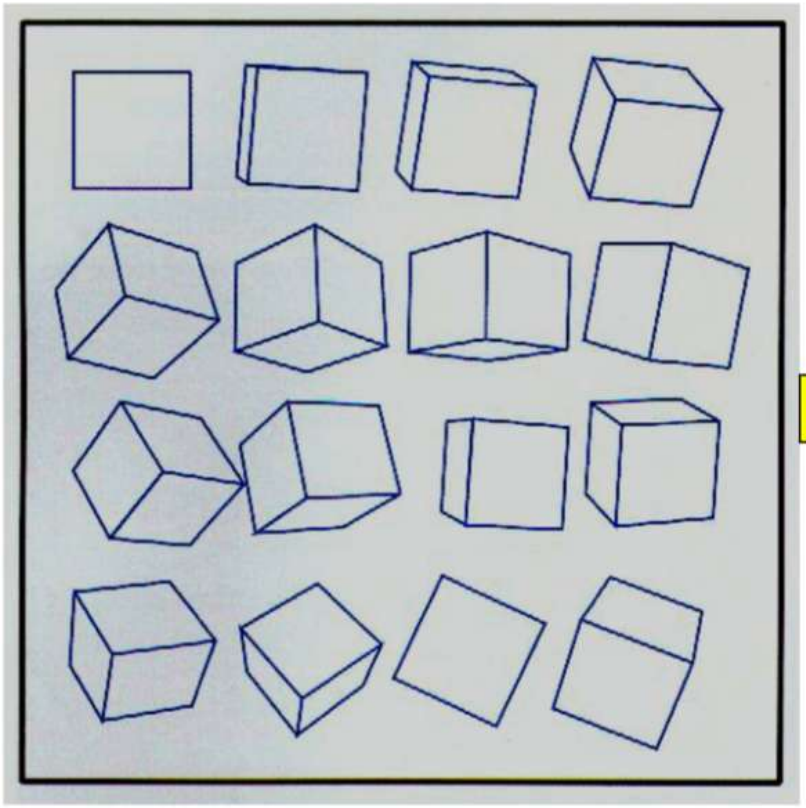
Expanding from 2D to 3D

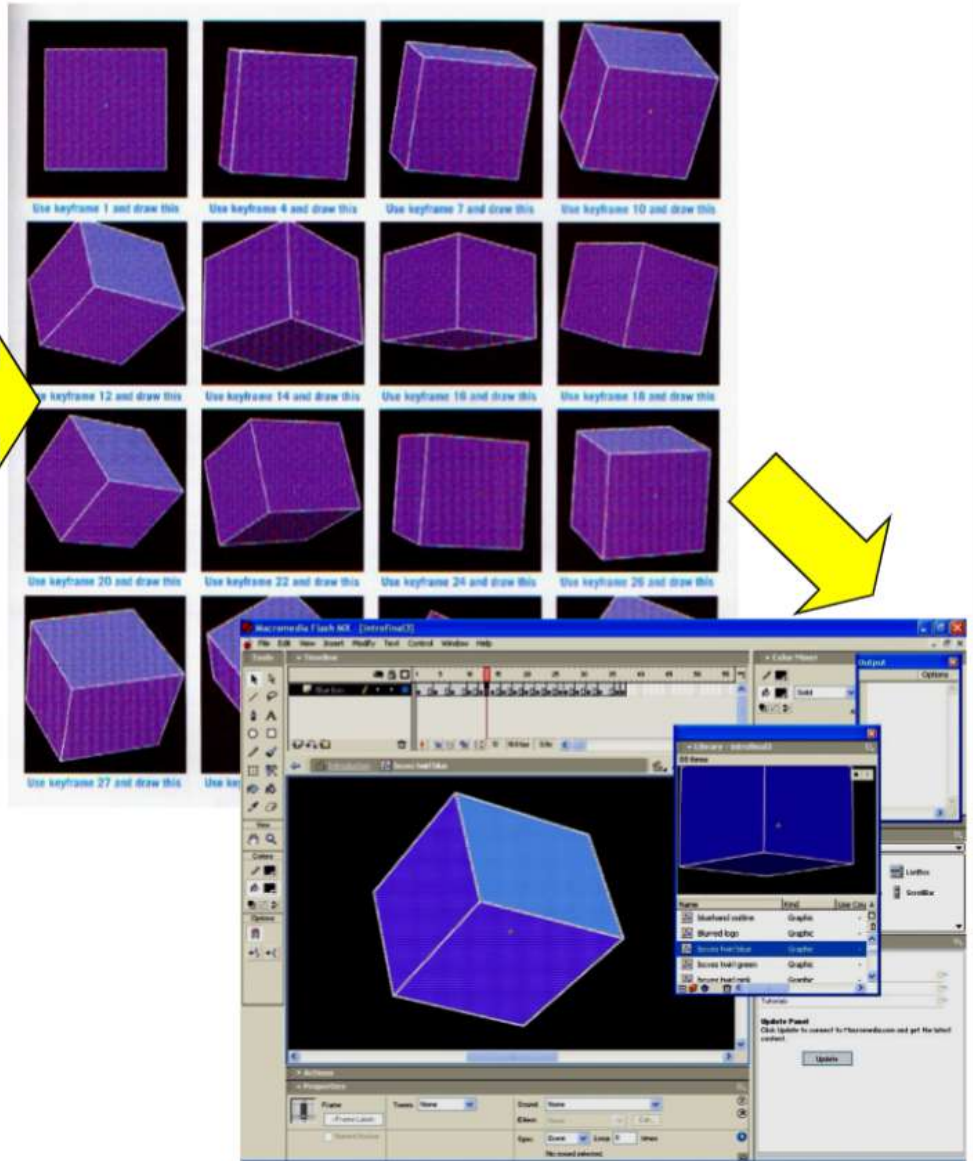
- The main difference between 2D and 3D is depth.
- 2D drawings have only height and width – no depth. Although objects can be drawn in 2D so that they appear as though they are 3D, if you want to change the perspective or viewpoint, you have to redraw the object from scratch.



Example – Mimic 3D Twirl Cubes from 2D drawings

With 2D sketches available, you may imitate the 3D views by using software.

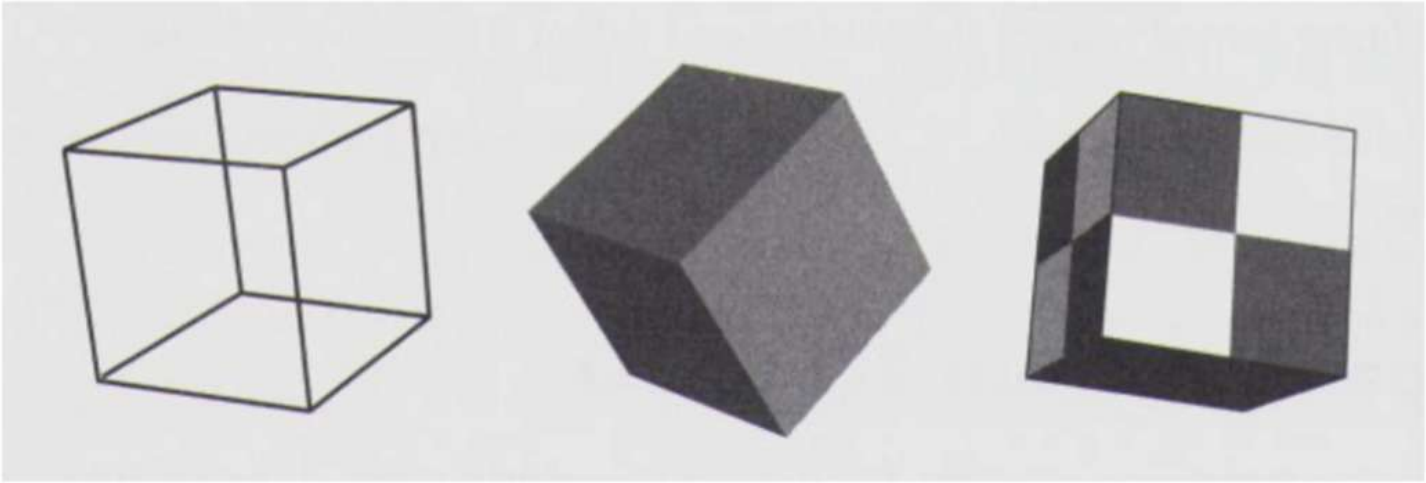




Expanding from 2D to 3D

- In 3D modeling, you create 3D objects **only once**, then you can view them from any angles or perspectives.

- 3D programs automatically calculate the proper highlight and shadow information for a scene based on how you arrange the objects, colors, textures, camera and lighting.



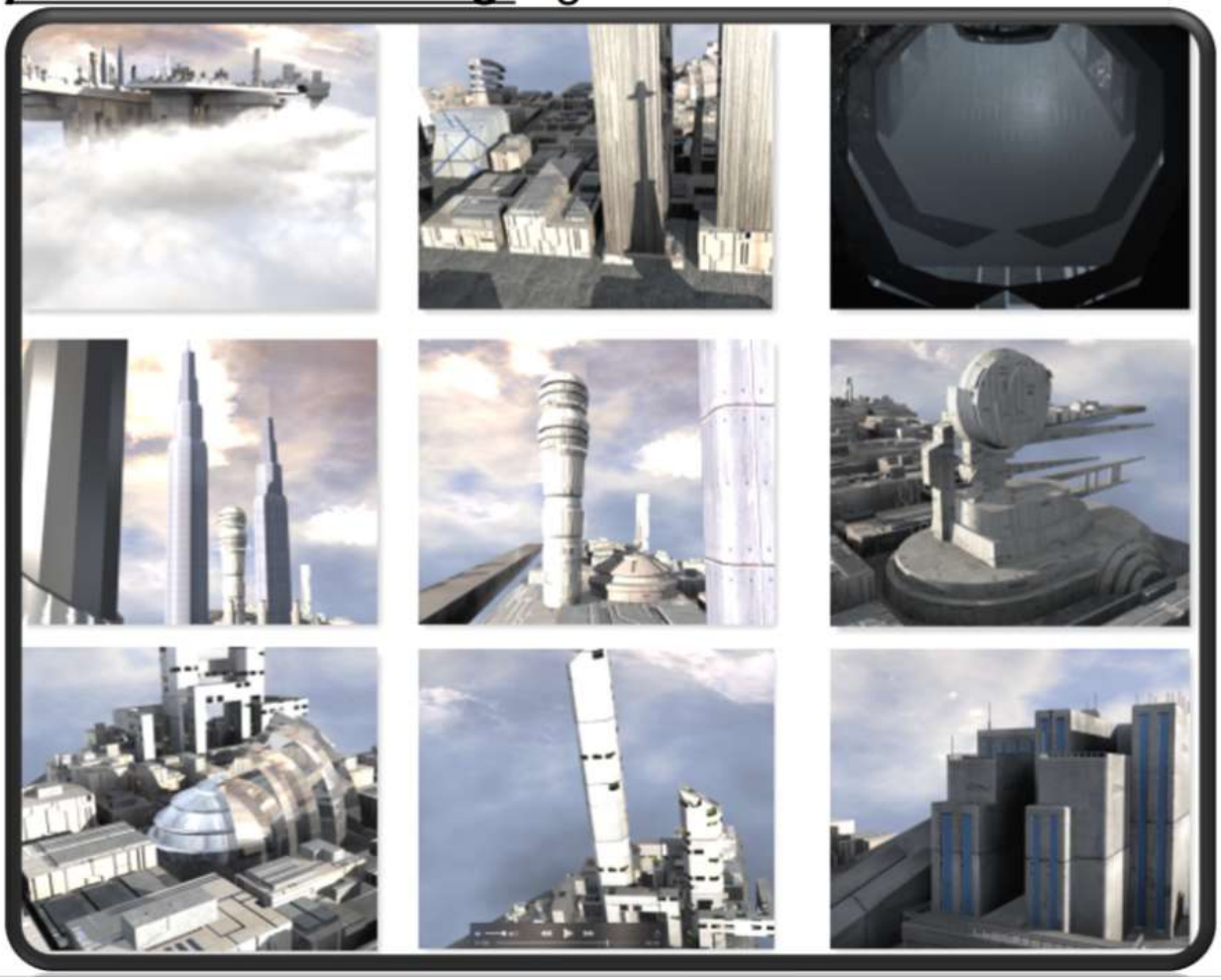
3D Modeling

The spatial description and placement of imaginary/virtual 3D objects, environments, and scenes with a computer system is called 3D modeling.

https://conceptartempire.com/free-blender-models-rigs/

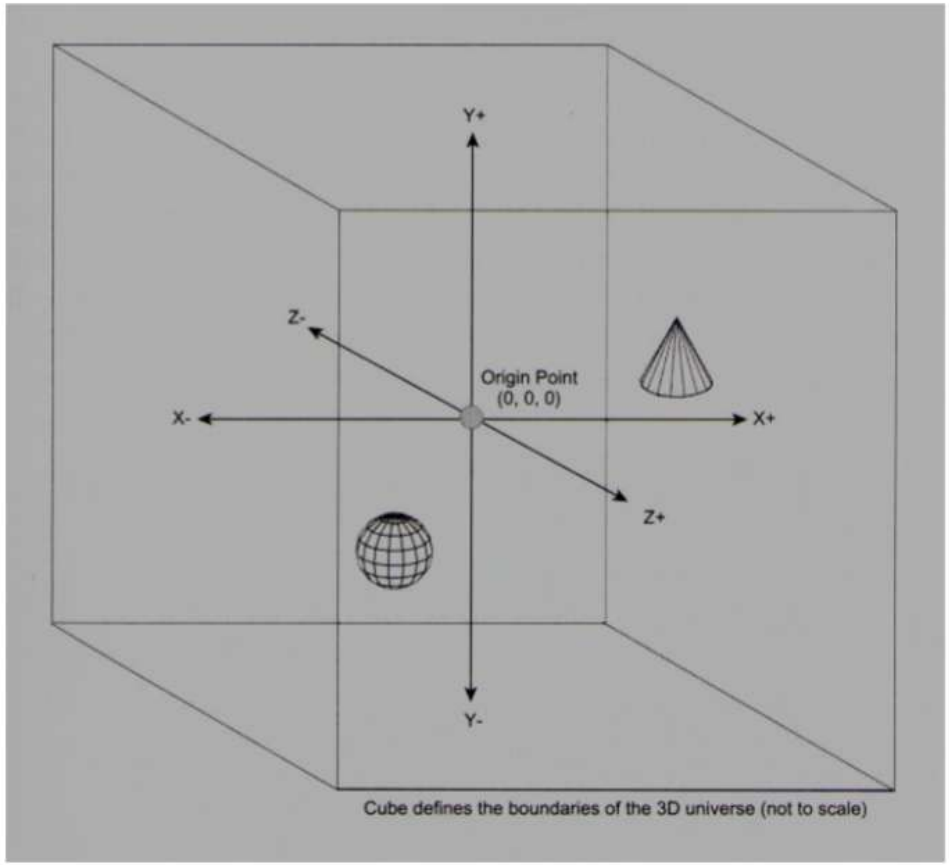
3D Modeling

- Modeling techniques include scanning, creating, editing, and manipulating 3D geometric data.
  - Use of **primitives or curves** to construct objects
  - More complex objects, such as trees, can be constructed with automatic ***procedural modeling*** algorithms



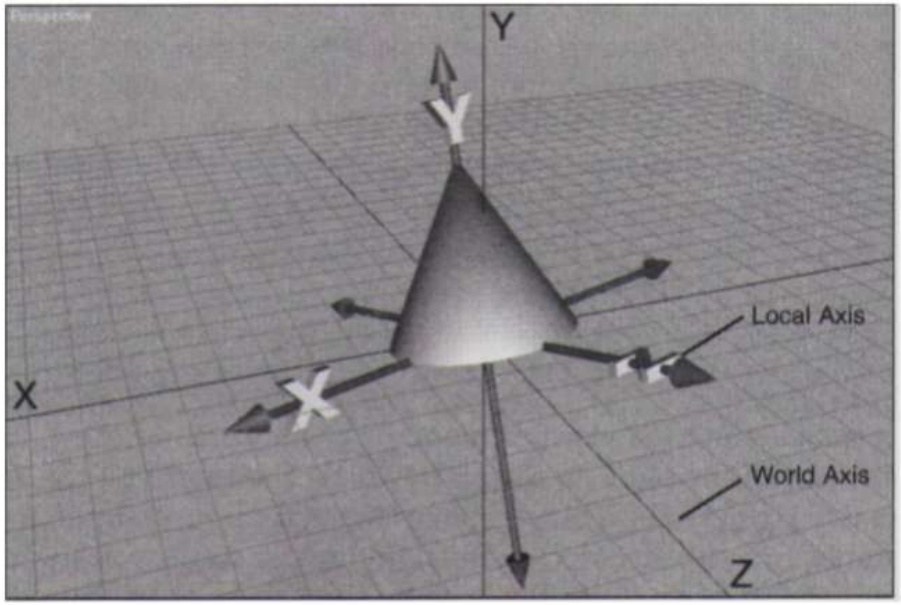
World Coordinate System

The fundamental coordinate system of 3D space is also called the *world coordinate system*, or *global coordinate system*.
It remains the same regardless of the viewpoints.



Local Coordinate System

Local coordinates use the object itself as the basis for the axis, and each object has its own coordinate system.

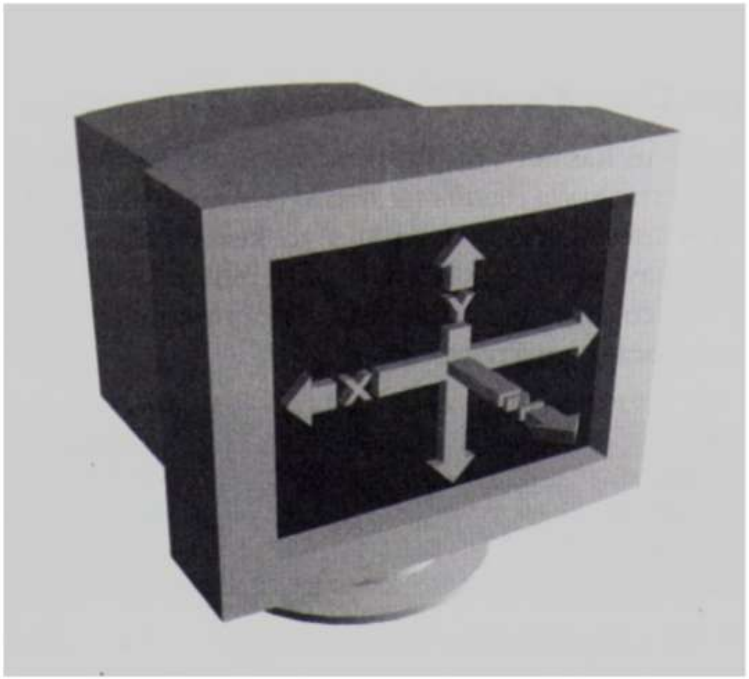


Every object can have its own unique local axis, which is usually related to the viewpoint at the time the object was created. The local axes are locked to the object and come together at the object's pivot point.

The pivot point of an object is located at the junction of its local axes, similar to the way the origin point resides at the center of the three world axes.

Screen Coordinate System

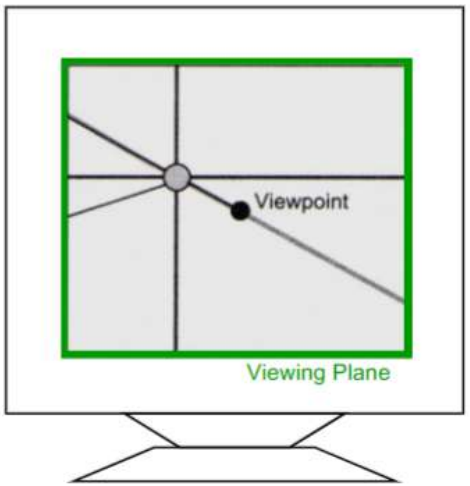
Screen coordinates, or view coordinates use the viewport window as the basis for the X, Y and Z axes, and remain the same no matter how our viewpoint on the 3D scene changes. This can be convenient for repositioning objects.

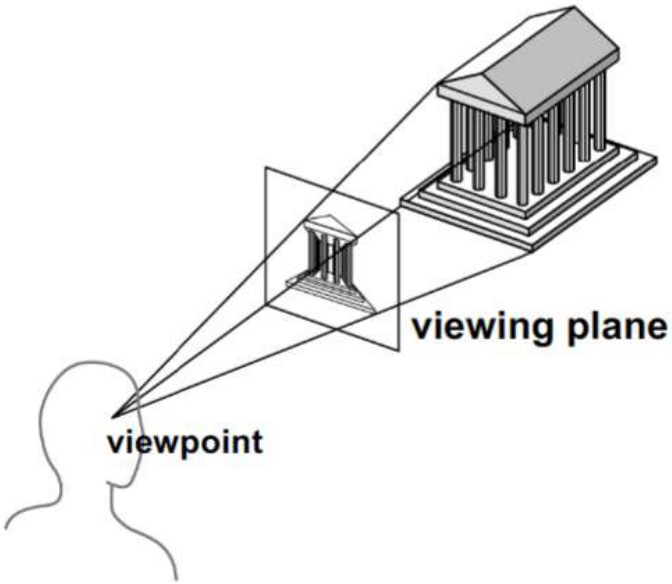


Screen coordinates are tied to the viewport window and remain the same regardless of how the viewpoint is changed.

Viewpoints

The ***viewpoint*** represents the current vantage point of the user. The ***viewing plane*** indicates the limits of the user's view, because only objects in front of that plane are visible.

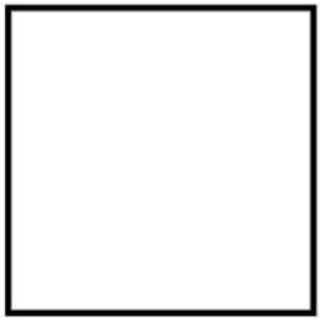




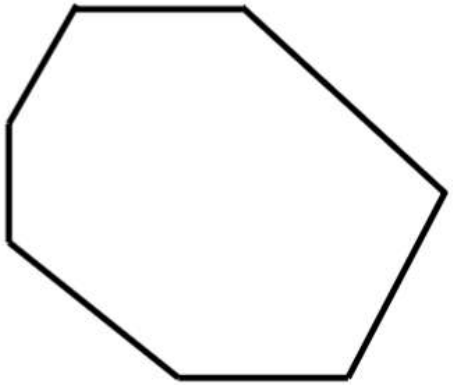
Lines, Polylines and Polygons

Drawing a *line* (a segment) means you play connect-the-dots with two points. A *polyline* is a continuous line that consists of multiple lines / segments. And a *polygon* is a closed shape made by polylines.

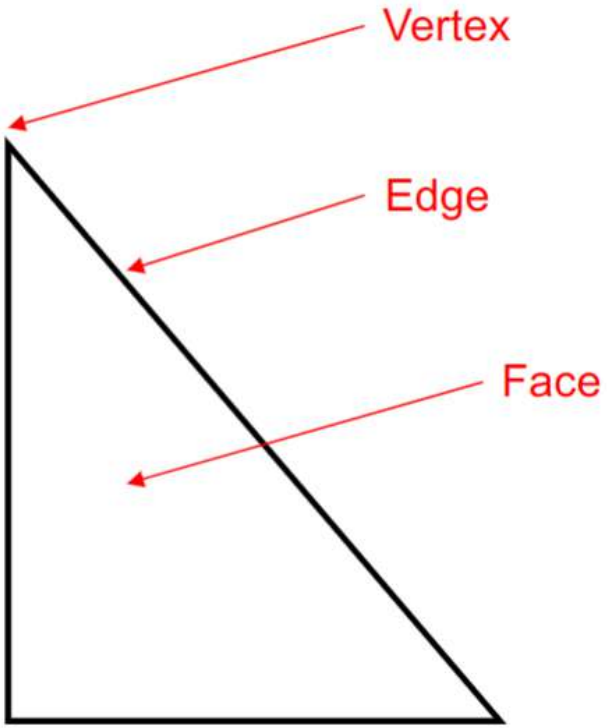
A *vertex* is a point where any number of lines come together and connect to each other. Each one of the lines you draw form a boundary, or *edge* of the polygon. And the area enclosed by the edges is called a *face*.



4-Side Polygon (Quad)



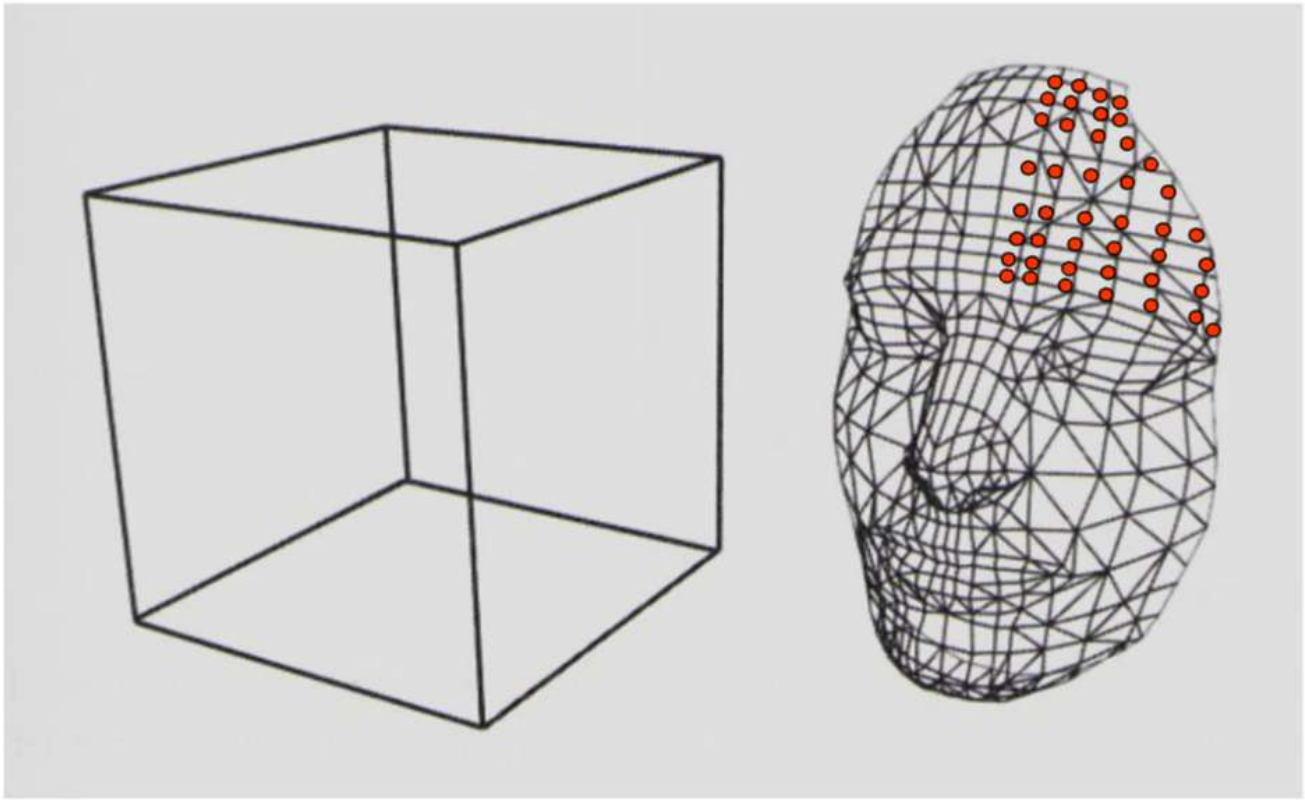
n-Side Polygon (Multigon)



3-Side Polygon (Triangle)

3D Objects

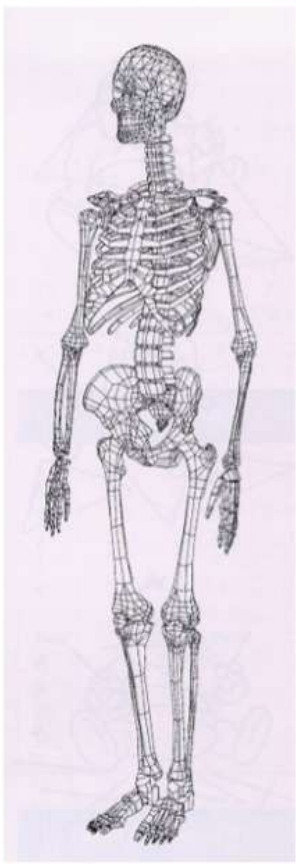
3D objects are made up of polygons, which are arranged into the form you desire.

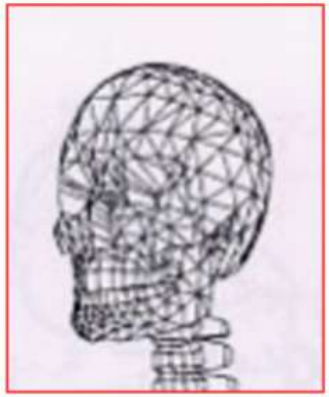


A simple cube has eight vertices that define the corners of the objects. Complex objects can have hundreds or thousands of vertices.

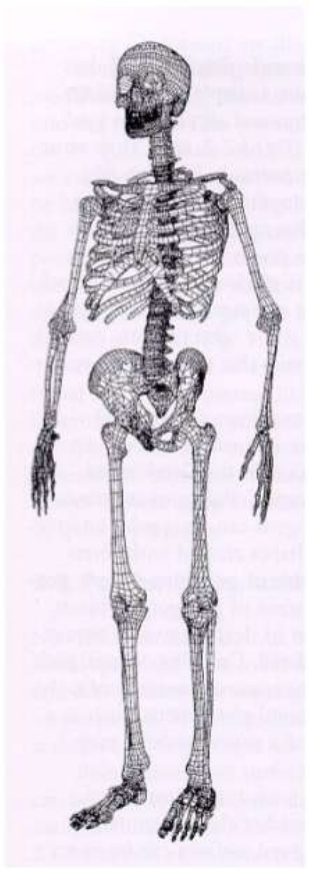
3D Objects

The higher density/number of polygons in areas of the surface, the more modeling details.

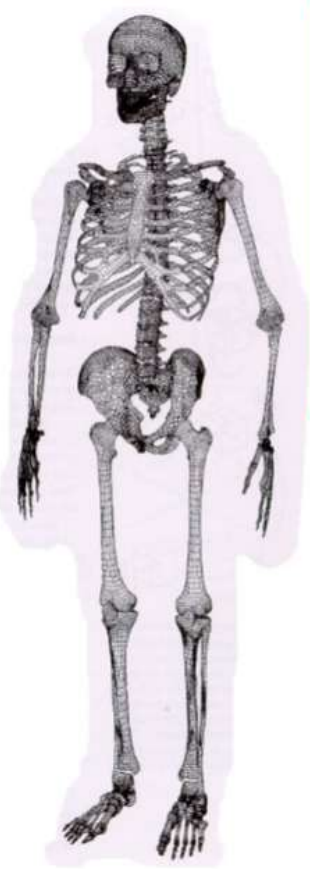




8,979 Polygons

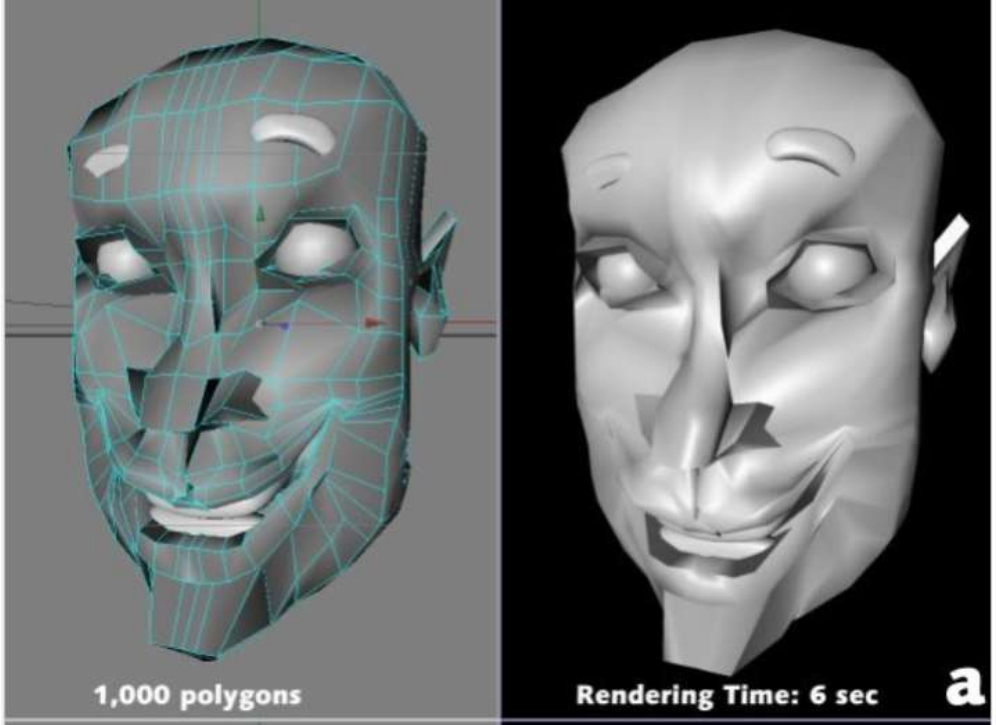


35,305 Polygons

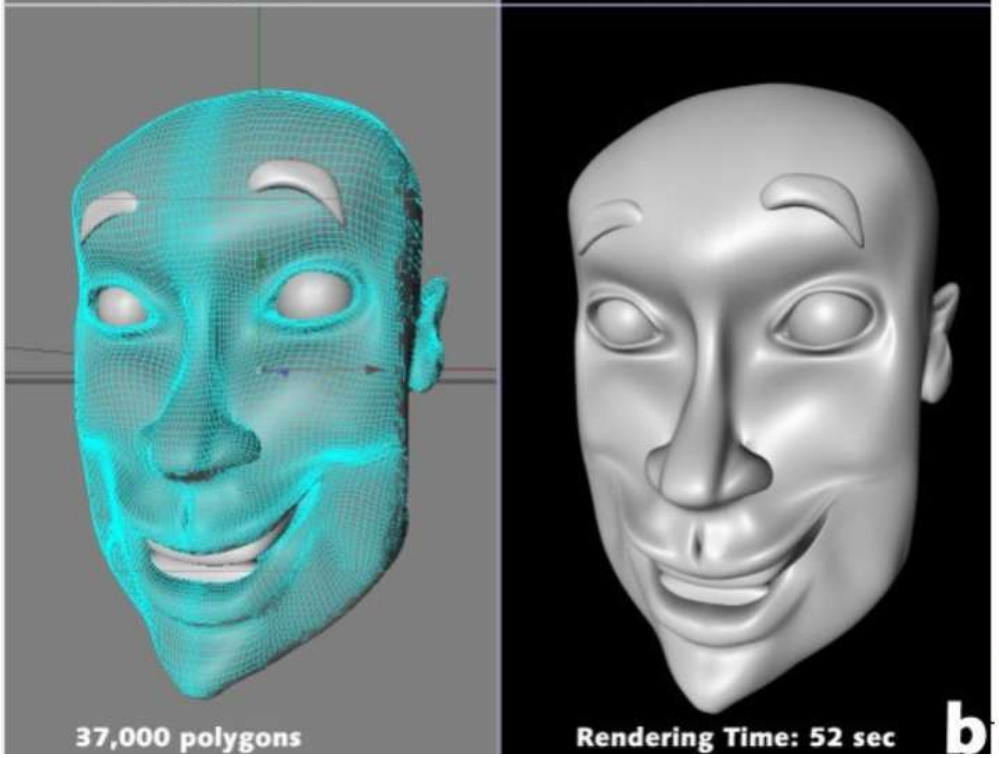


141,788 Polygons

3D Objects

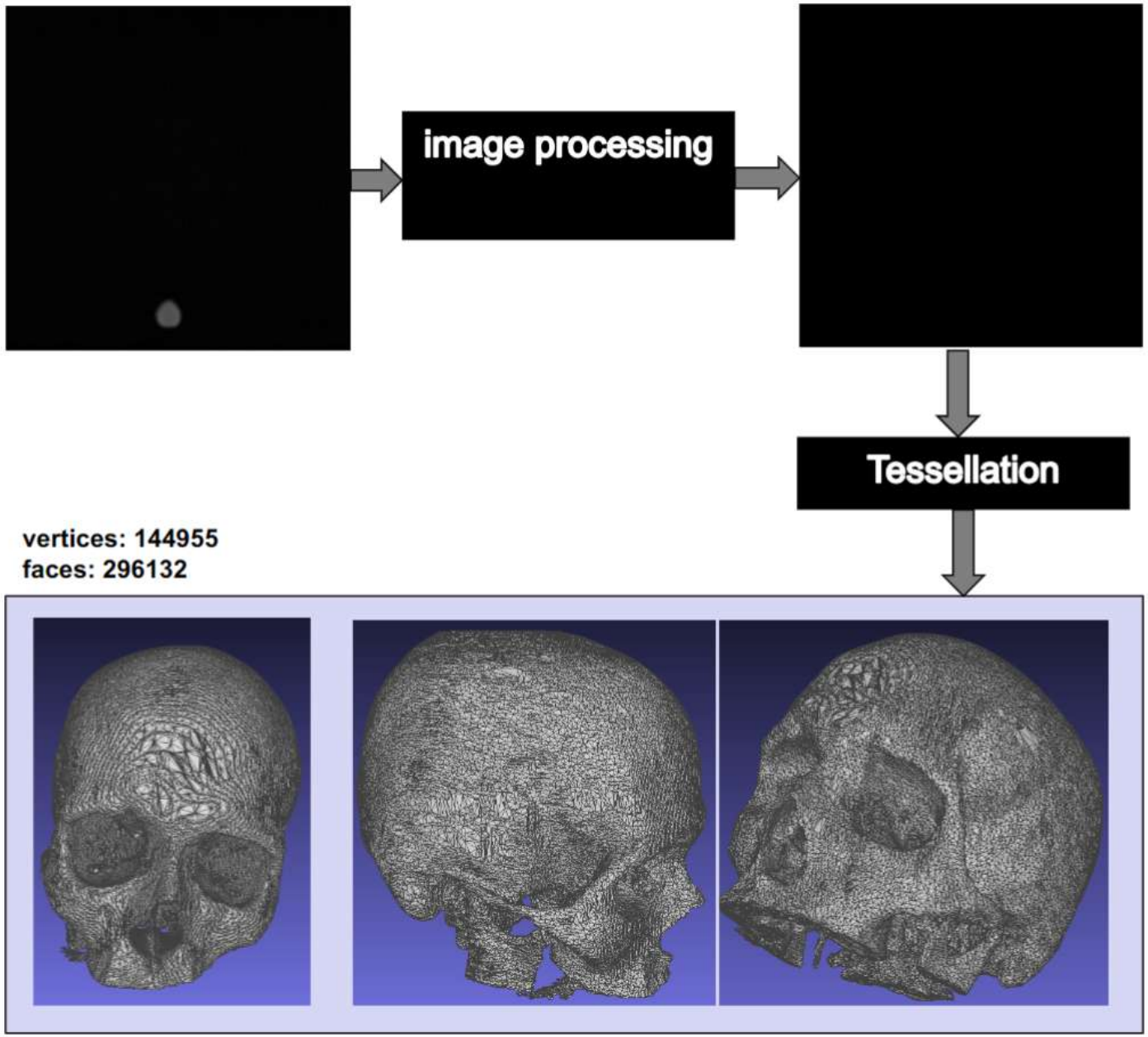


The image **a**, using about 1,000 polygons renders in less than 6 seconds.



The smooth (and consequently high poly-count) image **b**, although better looking, takes 52 seconds to render.

Construct 3D Models from Real Anatomical Medical Volume



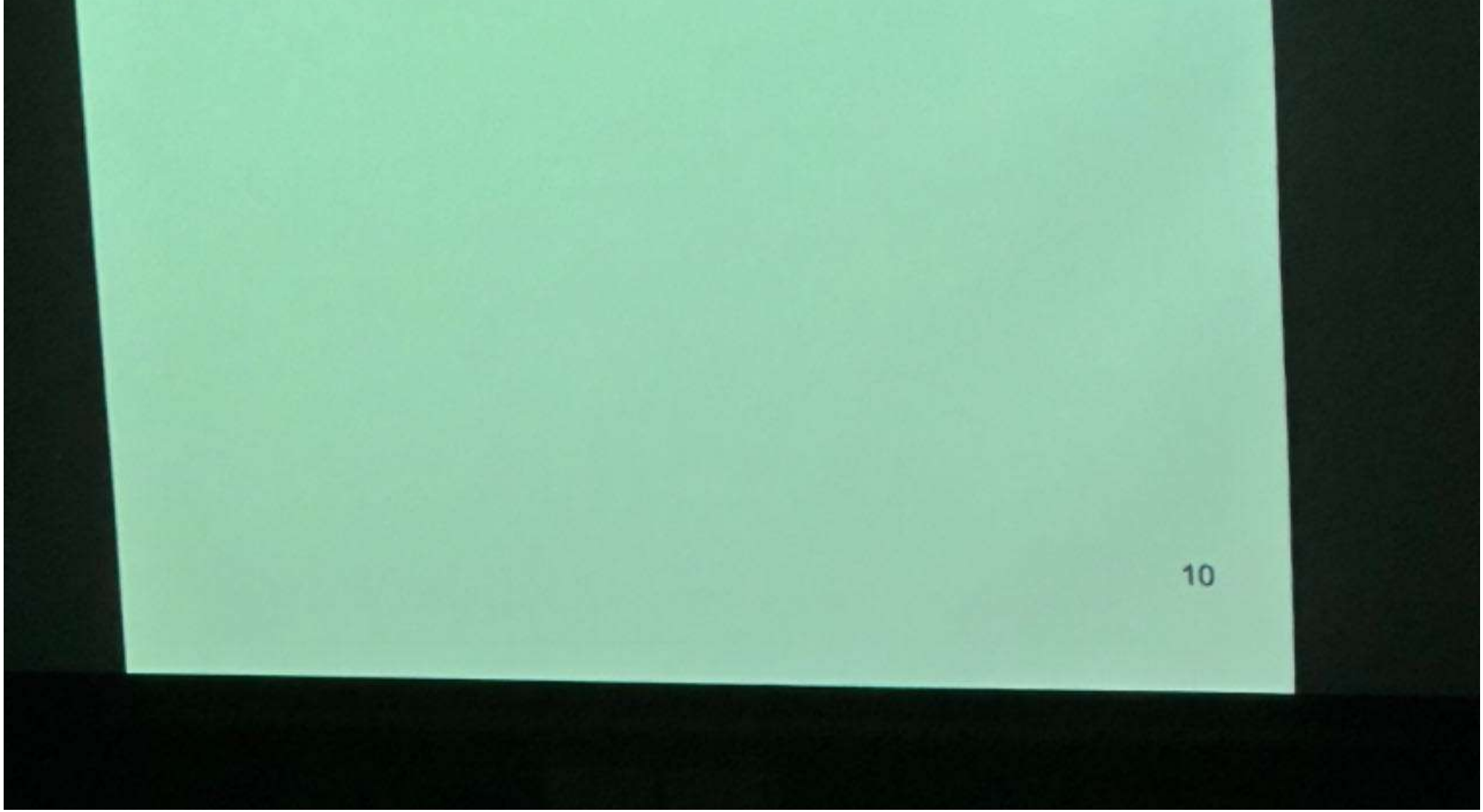
3D Computer Animation - Rendering

3D Computer Animation - Rendering

- 3D light sources and factors (*);
- Camera factors (#)

- Main rendering techniques (*)
  - Hidden-line (#)
  - Flat (*)
  - Gouraud/smooth (*)
  - Phong (*)
  - Ray casting (*)
  - Ray tracing (*)

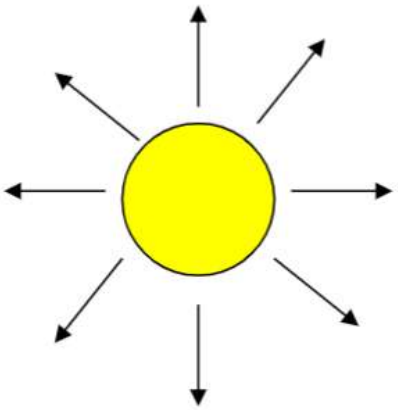
- Texture mapping techniques and mapping coordinates; (*)



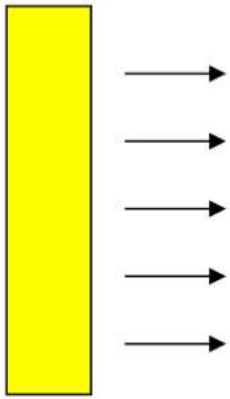
3D light sources and factors

由于能量守恒定律，omni light在某一个位置的最大光强和物体与光源距离的平方成反比（相当于是把能量分散在球壳上，根据球壳的表面积公式可得），这也是所有非平行光都有光衰的现象的原因，包括平行光
光强与物体表面（片元）和光线之间的夹角有关。

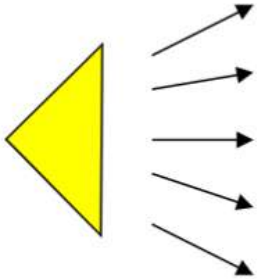
3D Light Sources



A **point light** (omni light)
casts light in all directions

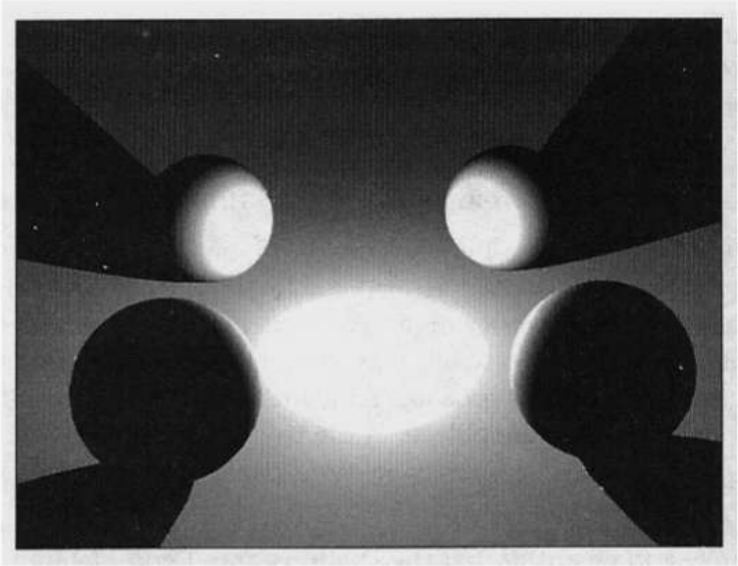


A **directional light**
casts parallel light along
a single axis



A **spotlight**
casts a cone or pyramid
of light

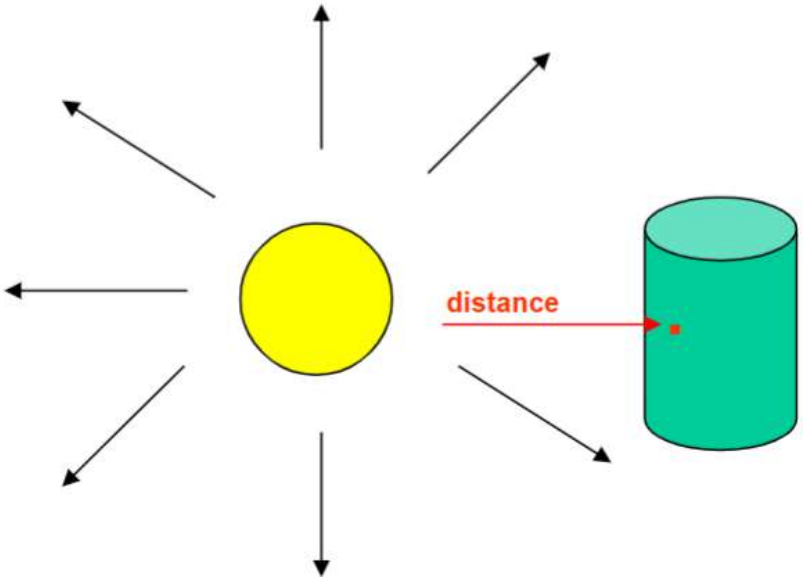
Point / Omni Light



Point / Omni light source characteristics:

(a) An omni light source positioned in the center of a scene ***casts light in all directions***.

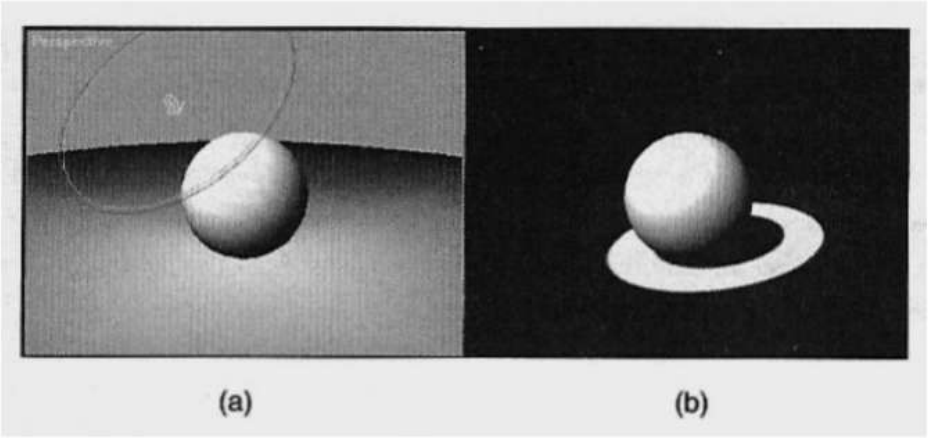
(b) It is generally ideal for simulating any kind of "***non-directional***" light source.



Factors when model the point light

a) **Intensity** of the light
b) **Position** of the light
c) **Distance** for attenuation: how much energy is lost as the object distances from the light source

Directional Light

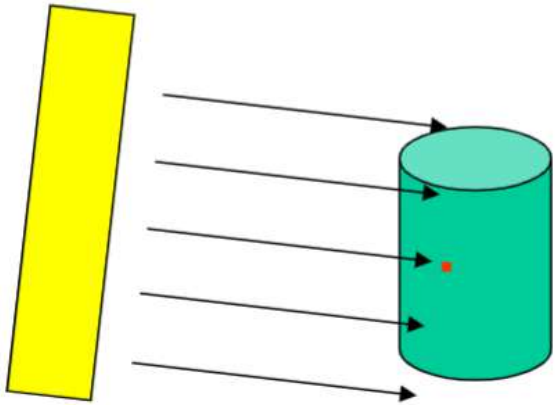


Directional light source characteristics:

(a) A directional light source, which *casts* ***parallel light rays***, aiming down a sphere.

(b) The resulting shadow from a directional light source.

* Directional lights are good for simulating ***light sources that are very far away***.

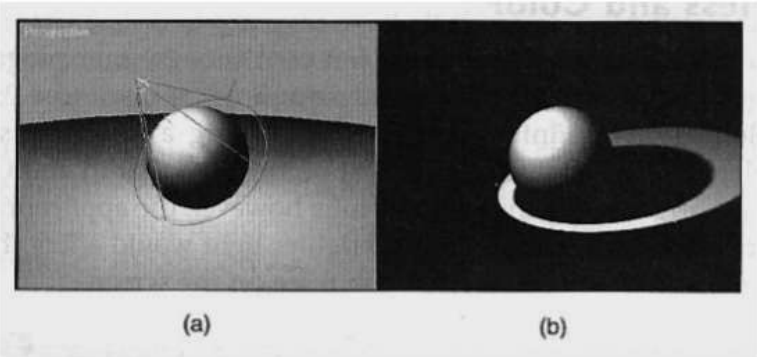


Factors when model the directional light

- **Intensity** of the light
- **Direction** of the light
- **NO** attenuation with distance

Lighting

Spotlight

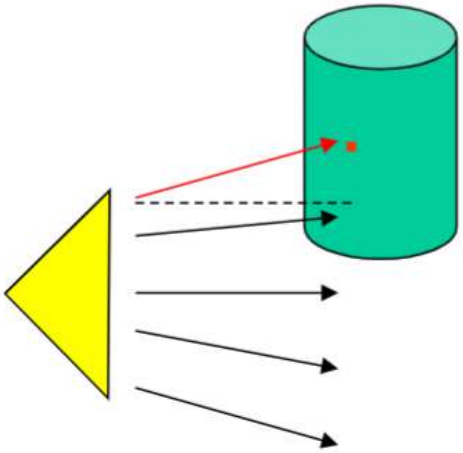


Spotlight light source characteristics:

(a) A spotlight source *projects* *a cone of light* at a sphere.

(b) Shadows created by a spotlight **radiate away from the source**.

* Spotlights can be used in any lighting situation, and also good for ***adding small highlights and accent lighting***.



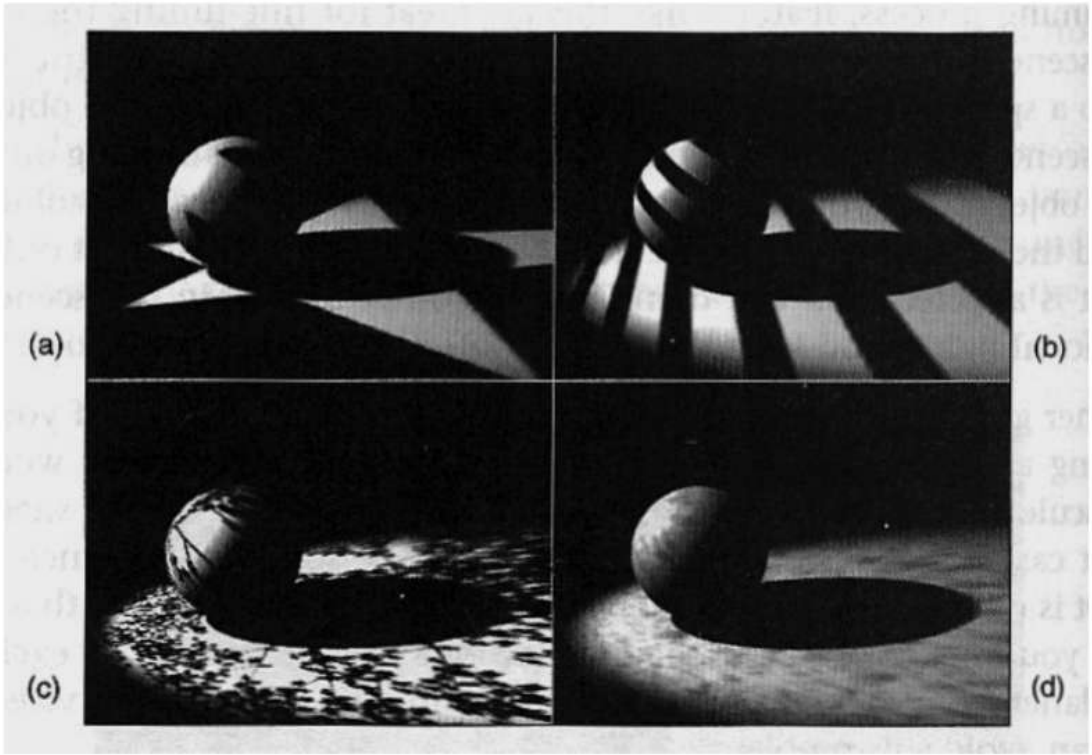
Factors when model the directional light

- **Intensity** of the light
- **Position** of the object with regard to the light
- **Direction** of the light
- Attenuation with **distance**

Lighting

Spotlight for Projection Mapping

Some 3D programs enable you to define a spotlight as a **projector**, meaning you can add a map to the light to change its shape or cause it to throw a pattern onto objects it illuminates.



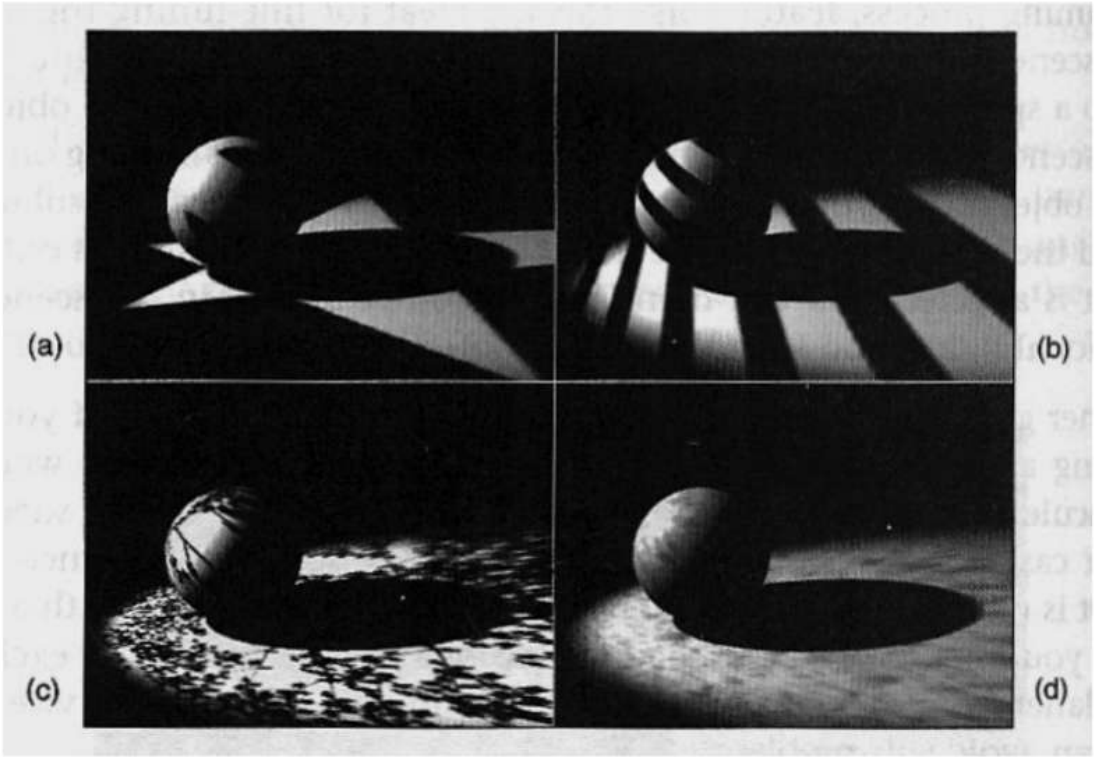
Projection map samples:

(a) Star-shaped gobo.
(b) Venetian blinds.
(c) Tree branches.
(d) Full-color or grayscale images can also be used.

Lighting

Spotlight for Projection Mapping

Some 3D programs enable you to define a spotlight as a **projector**, meaning you can add a map to the light to change its shape or cause it to throw a pattern onto objects it illuminates.



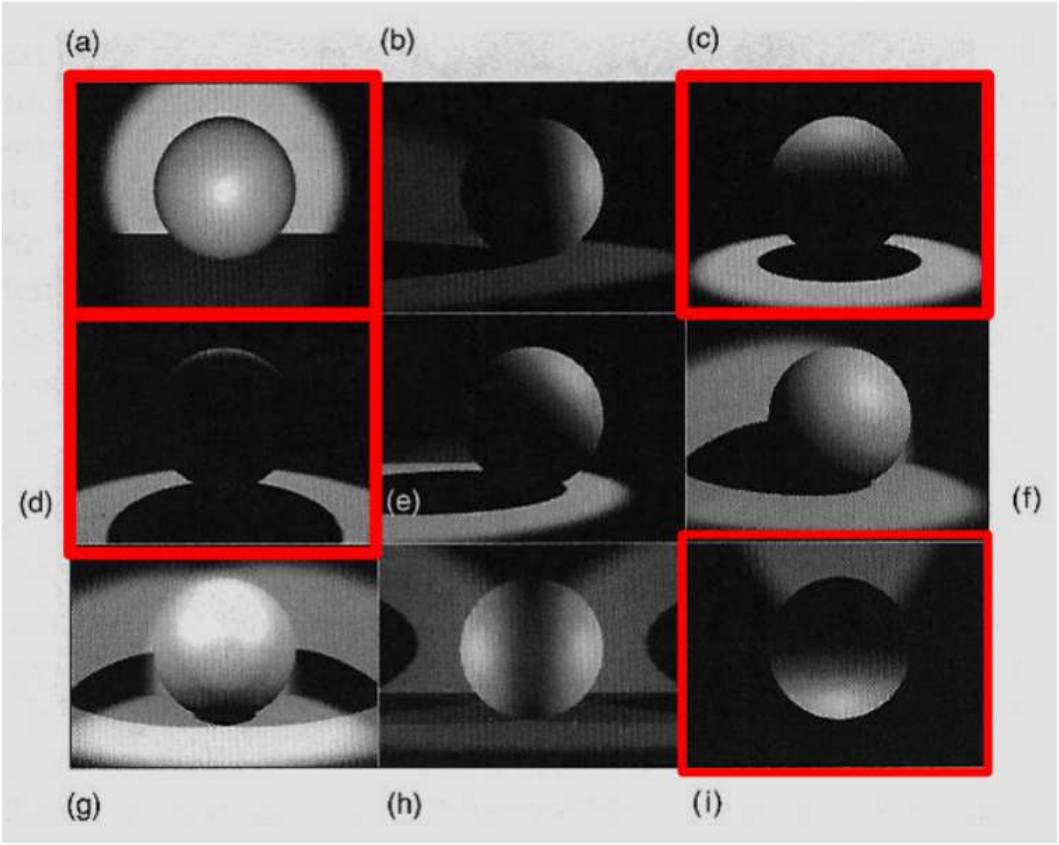
Projection map samples:

(a) Star-shaped gobo.
(b) Venetian blinds.
(c) Tree branches.
(d) Full-color or grayscale images can also be used.

Lighting

Lighting Arrangements

"It's no good guv, he won't talk."



Sample lighting patterns:
(a) Frontal. (b) 90° side. (c) Overhead. (d) Backlight.
(e) 45° side. (f) 45° side/front. (g) Twin 45° side/front.
(h) Twin 90° side. (i) Underlight.

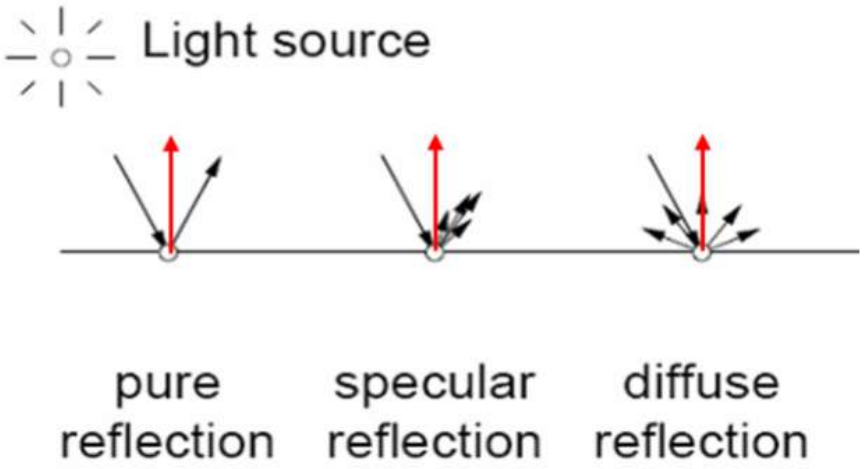
The quantity and angle of the light has a great deal of impact, and can aid in assigning characteristics to an object.

For example, *frontal lighting* in (a) gives the impression that the viewer is holding the source of light, such as flashlight, and the unfortunate sphere has just been caught doing something unsavory. The *overhead lighting* in (c) makes the sphere seem like a suspect under interrogation. *Backlighting* an object in (d), makes the object appear mysterious and potentially dangerous. *Under lighting* in (i), as the old horror movie standard, is always sinister.

Reflection

Reflection: to calculate how many photons can be reflected or scattered back into the atmosphere. The amount of photons reflected is highly relevant to the **characteristics of the object surface**.

- **Pure reflection**: if the surface is perfectly smooth (e.g. mirror), the reflection would satisfy the rule of "***angle of reflection equals to the angle of incidence***" and results in mirror-like or very shiny appearance.
- **Specular reflection**: less perfect reflection like unpolished metal and shiny plastics. Glossy materials look shiny and show specular highlights.
- **Diffusion**: the reflected light uniformly scatters in all directions.

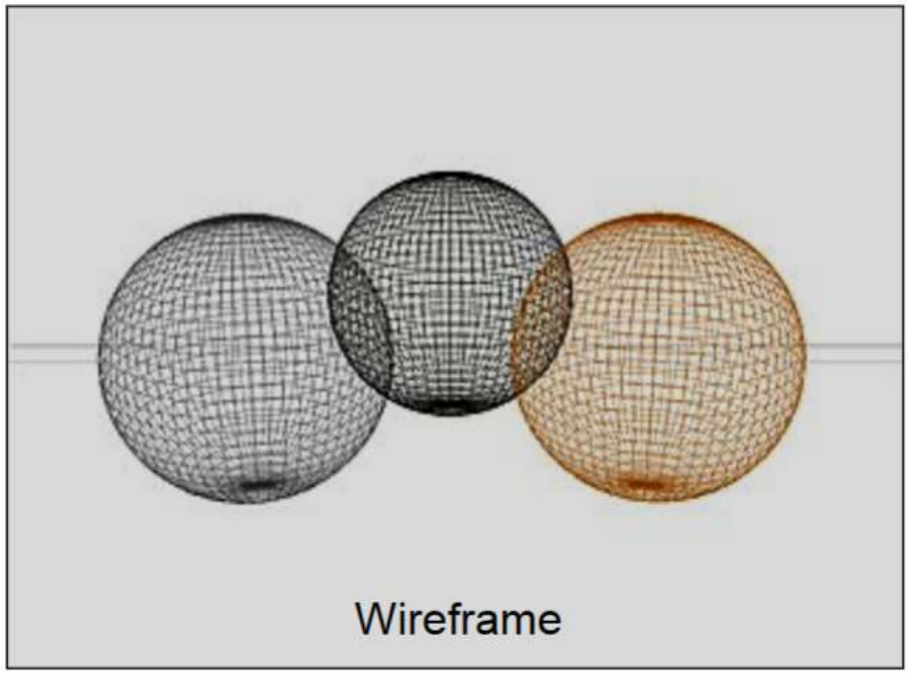


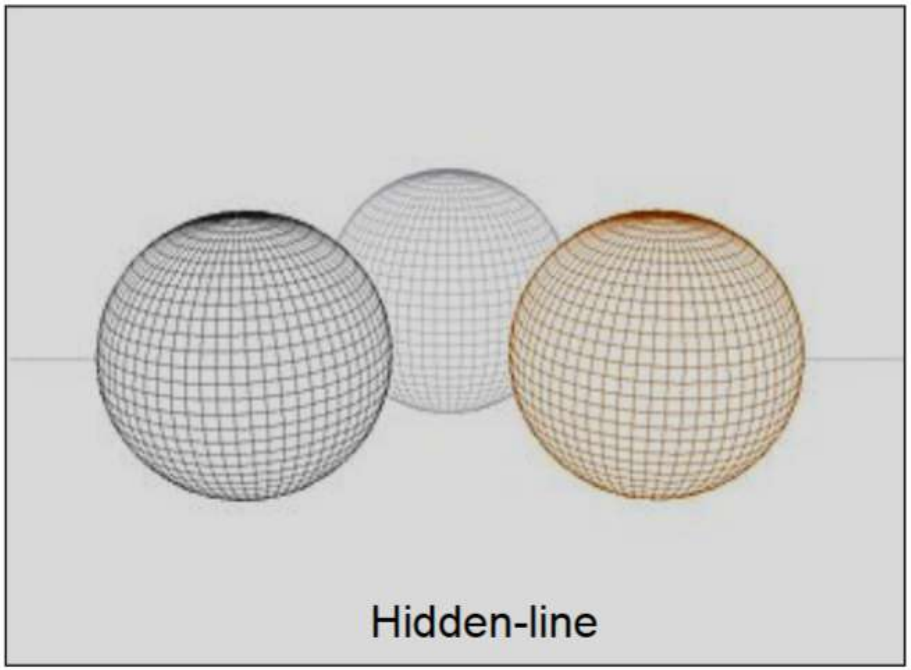
关于ambient reflection，specular，以及diffuse之间的关系基础光照这个网站讲的更加清晰

Main rendering technique

Wireframe and Hidden-line Rendering

The two most basic and fastest rendering methods are ***Wireframe*** and ***Hidden-line*** rendering. But they are rarely used except for animation tests or when a “computery” look is desired for the image.





这里提一下，flat，gouraud，phong shading的显著效果差异会在面数少的情况下体现，面数多到一定程度的时候三者效果不会有明显差异。着

色中最为困难的不是风格化着色，而是模拟现实场景的着色，上面把现实光照的原理进行拆分和简化，下面是在模型上实现这些现实光照的方法。

Flat

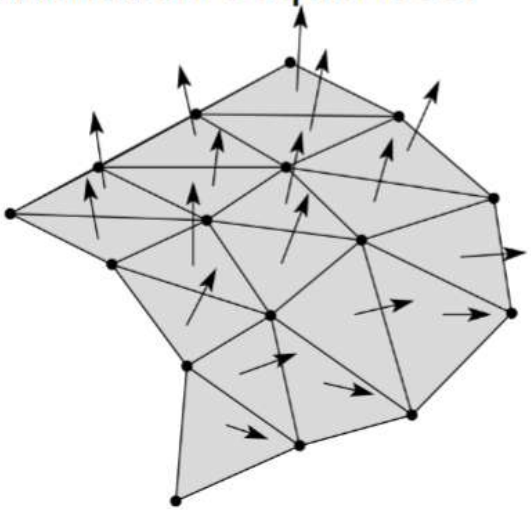
这种着色方式是片元级别的着色方式，根据每个面的法线方向，给每个面进行着色，同一个面的颜色一样，特点是非常快，但是不是特别平滑。高光效果很差。

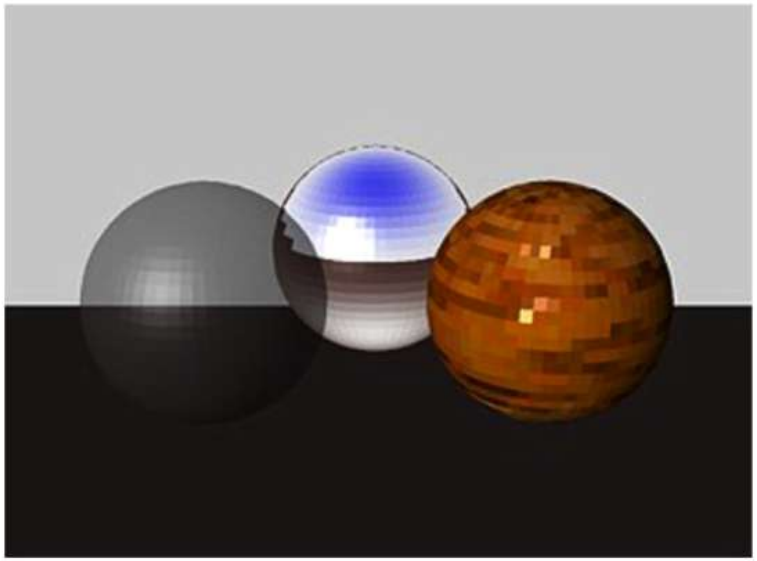
Main Shading Techniques

Flat Shading

For a ***flat shading***, the computer calculates the color and value of a polygon face based on **a single normal**; and therefore **one illumination value per polygon**.
The resulting image is a collection of sharply defined polygon surfaces, each with one solid color. Detailed information, e.g. texture information, is ignored, and image has a faceted appearance (Mach bands are prominent). Not good for smooth surfaces.

Flat shading is a very quick way to render a scene, and can be used for making test renders of animation sequences.





Gouraud/smooth

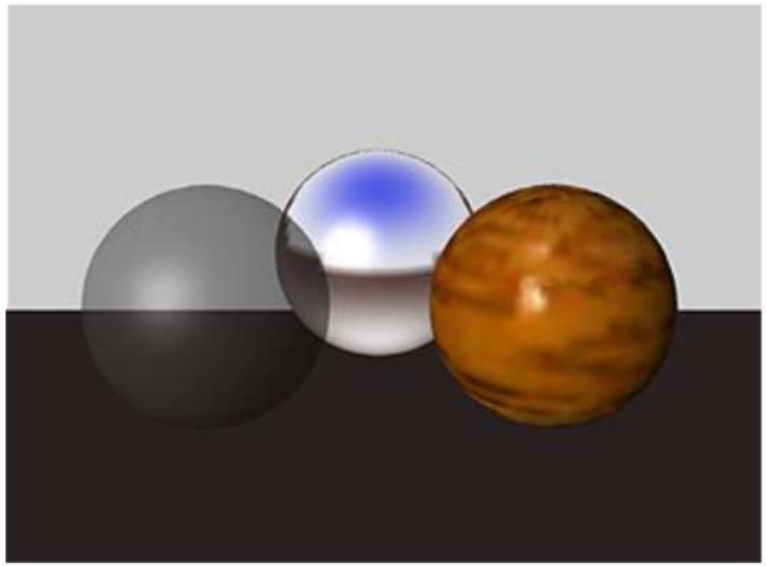
这种着色方式计算了每个顶点的法线，并根据法线的方向进行着色，着色时对片元内像素的颜色进行插值运算，得出像素的颜色。当然，计算顶点的法线的时候根据顶点临近面的比值去计算顶点的法线会优化最终效果。

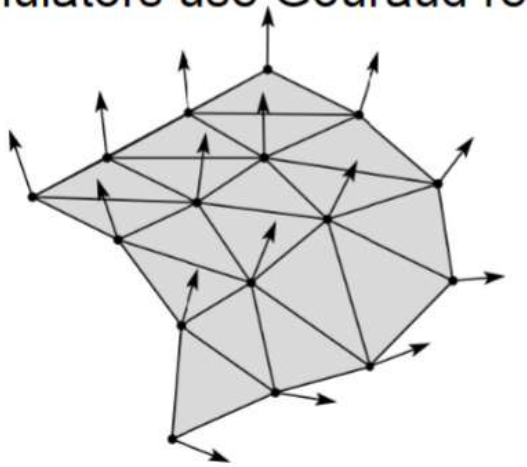
Main Shading Techniques

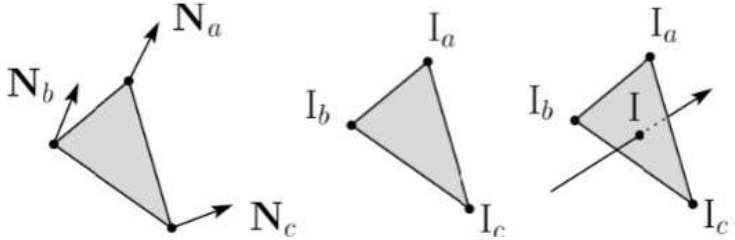
Gouraud (Smooth) Shading

For a ***Gouraud or smooth shading***, the computer calculates the color and value **at each vertex of the face** and then interpolates the colors across the polygon face. The effect is to smoothly blend object surfaces that are more realistic than a flat rendering's surface.
Smooth shading also incorporates textures that may have been applied to the objects. Creates soft shadows. Needs fine mesh/polygons to capture subtle lighting effects.

Many real-time 3D games and flight simulators use Gouraud rendering.





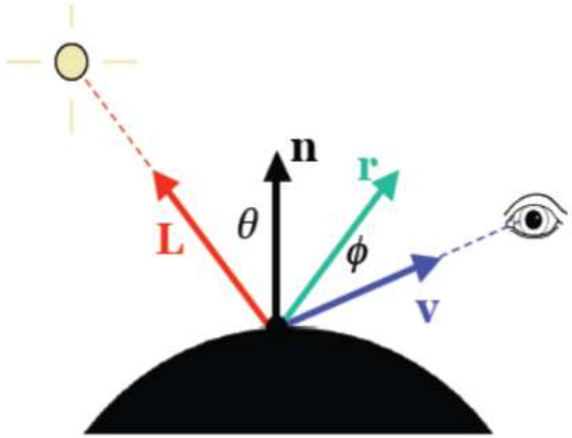


Phong

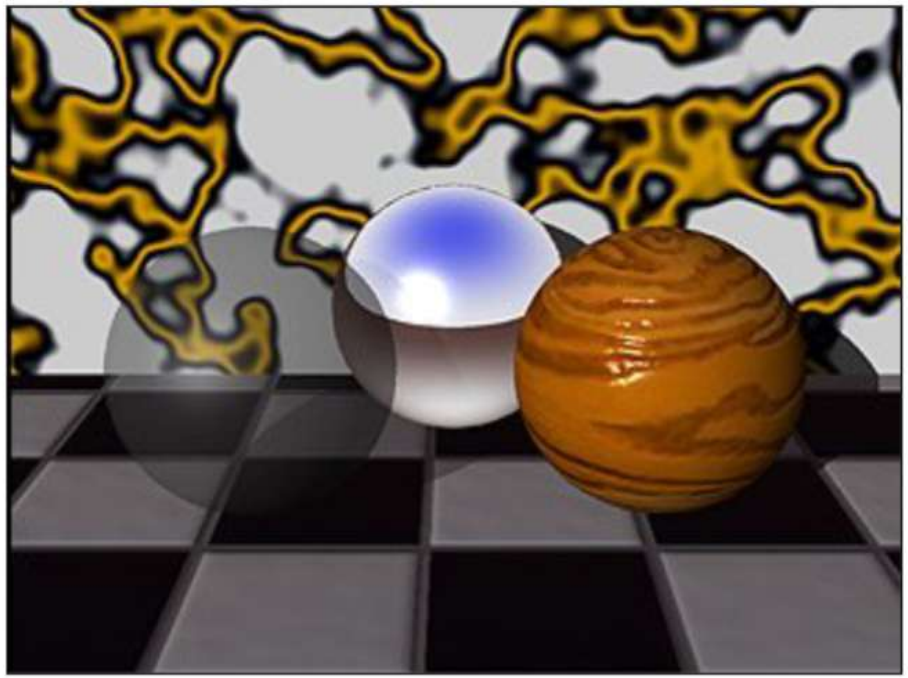
这种着色方式也是先计算每个顶点的法线，然后插值出每个像素的法线，再对每个像素着色。这种着色方式是三种方式中唯一一种像素级别运算的着色方式，高光的模拟效果最好。

Phong Shading

Phong shading retains the smoothness of Gouraud shading and adds specular highlights for even more realism. In Phong rendering, the computer calculates the surface normal for every pixel on the screen that represents an object.

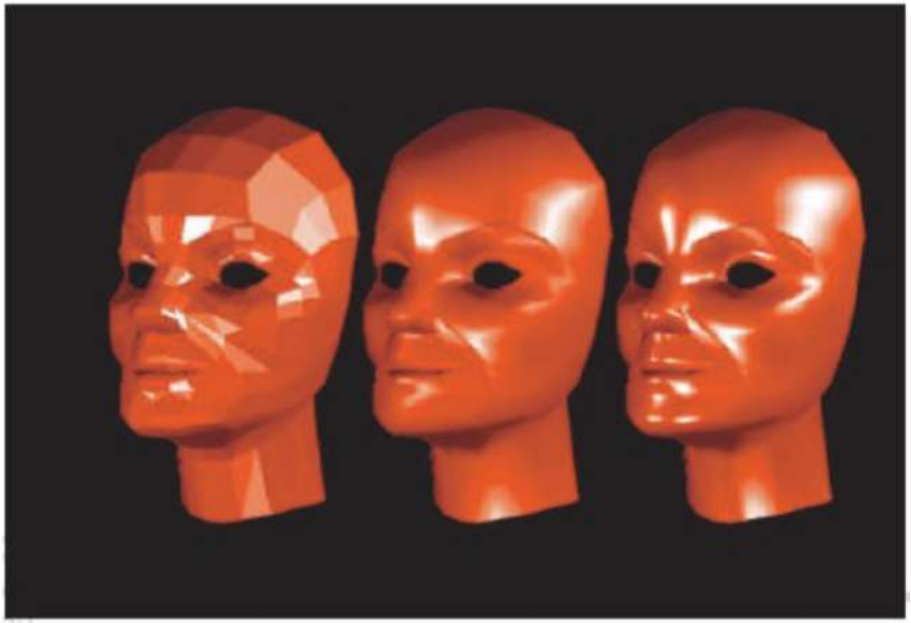


$$I = \sum_{\text{all lights } L} \overbrace{I_L k_d (\mathbf{n} \cdot \mathbf{L})}^{\text{diffuse reflection}} + \underbrace{I_L k_s (\mathbf{r} \cdot \mathbf{v})^n}_{\text{specular highlight}}$$



Phong Shading

Phong shading is one of the most common techniques used for finished images and animation.



Flat Gouraud Phong

- In 1975 Phong Bui-Tuong improved on Gouraud's method, and Phong shading became the *de facto* standard in mainstream 3D graphics.
- Despite the subsequent development of "global" techniques, such as ray tracing and radiosity, Phong shading has remained ubiquitous since it enables reality to be mimicked to an acceptable level at reasonable cost.

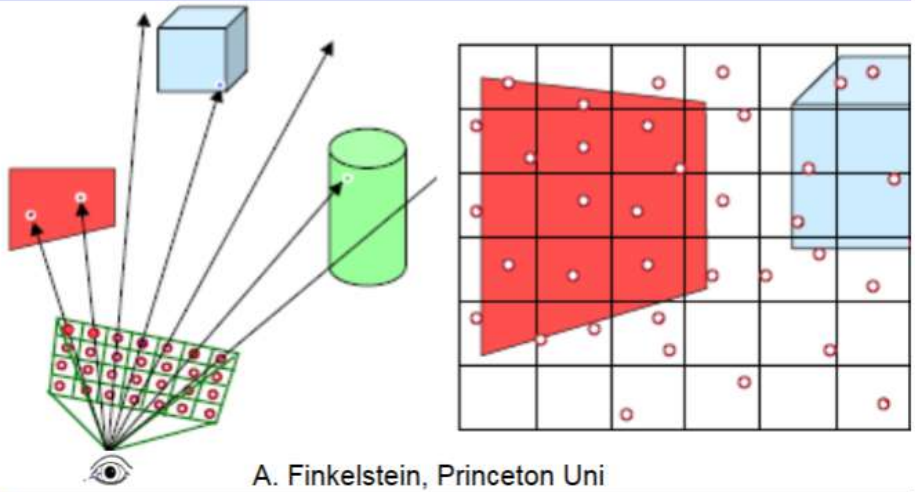
ray casting不如说是ray tracing的基础方法，其中有一个很重要的简化运算的思想是屏幕未显示的部分不参与运算，与其从光源开始追溯光线，不如从屏幕的每一个像素反过来追踪光线的传播路径，来确认哪一些光线被追踪或者是不被追踪。实际上，一个像素可以追踪到的光线数量很

多，引入了一个和空间以及步长相关的算法去控制哪些光线被追踪，哪些可以省略。

Main Shading Techniques

Ray Casting

- The color of each pixel on the view plane depends on the light reflection (radiance) from ***visible surfaces.***
- **Ray casting: an algorithm for hidden surface removal based on finding the first intersection of a ray cast from the eye through each pixel of an image back to the scene**
- Description of ray casting method - for each sample point on the viewport:
  - Construct ray from eye position through view plane
  - Find first surface intersected by ray through pixel
  - Compute color of a sample pixel on the view plane based on the illumination from the *unblocked light source*



A. Finkelstein, Princeton Uni

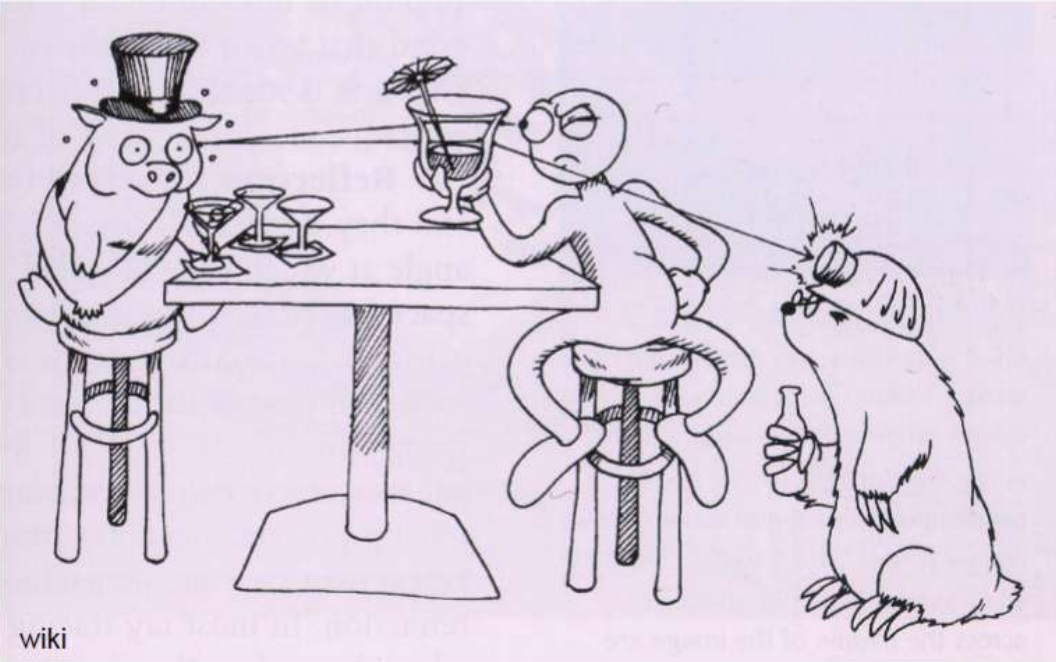
```
Image RayCast(Camera camera, Scene scene, int width, int height)
{
    Image image = new Image(width, height);
    for (int i = 0; i < width; i++) {
        for (int j = 0; j < height; j++) {
            Ray ray = ConstructRayThroughPixel(camera, i, j);
            Intersection hit = FindIntersection(ray, scene);
            image[i][j] = GetColor(hit);
        }
    }
    return image;
}
```

Ray tracing

优缺点都要了解，相较于phong shading，ray tracing的好处是可以计算光线的多次反射，使得场景更加的真实。（phong只计算了环境光，高光和光衰）。phong shading以及上面两种shading还有一个缺点是都无法计算阴影的生成，ray tracing计算之后会很自然的生成阴影。最后一点（我的想法）在shading之后有一个光栅化的过程，ray tracing在其中的表现也会更好。

Ray Tracing

One of the highest levels of rendering quality available from most 3D packages is called ray tracing. ***Ray tracing*** is a method where the color and value of each pixel on the screen is calculated by casting an imaginary ray backward from the viewer's perspective into the model, to determine **what light and surface factors influence it**.
The values are calculated as the ray of light bounces off (**reflection**) or travels through (**refraction**) different surfaces with a variety of characteristics.



wiki

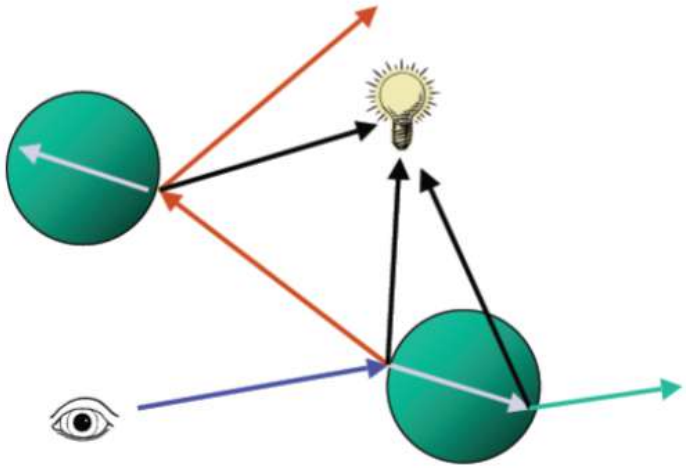
Ray Tracing

The difference between ray tracing and the other methods is that the ray can be bounced off surfaces and bent. The result is very realistic, with more accurate shadow, reflections, and even refraction.

Intensity calculation includes:

$$I = I_{local} + K_r * I_{reflected} + K_t * I_{transmitted}$$

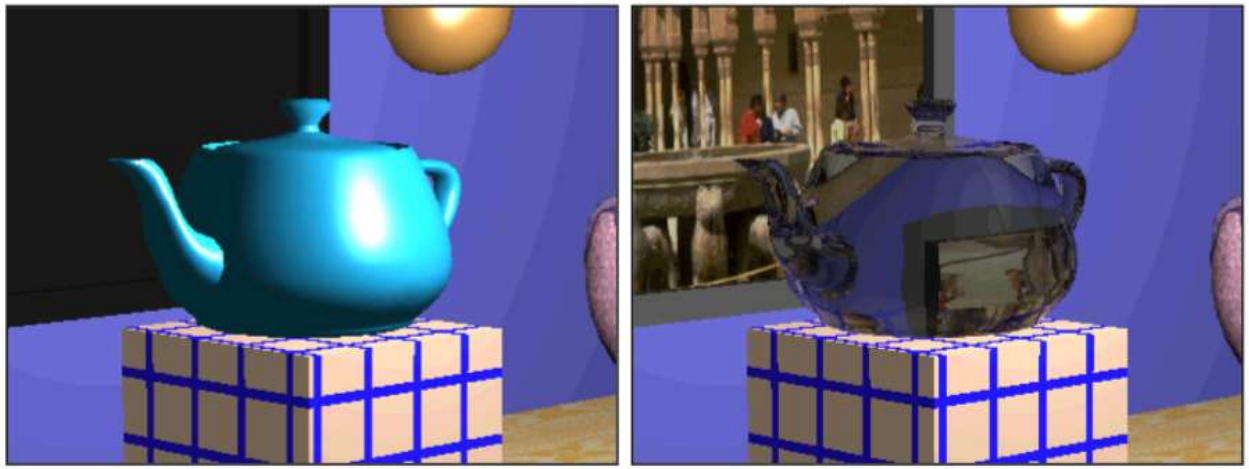
In addition to local light calculated by Phong mode (which takes care of diffusion reflection and specular reflection), the reflected light and transmitted light also need to be calculated recursively to get realistic image.



Ray Tracing

- The main strength of the ray tracing is that the image of a 3D scene is calculated in 3D space.

- When traveling in 3D space, the traced rays often bounce from object to object. These rays are able to deal with processes – such as images being reflected on a surface, or the light being bent by a transparent object – and therefore can best simulate 3D scene in a 3D space.



The object has been rendered using Phong and the object is rendered as glass using a ray tracer.

Texture mapping techniques and mapping coordinates

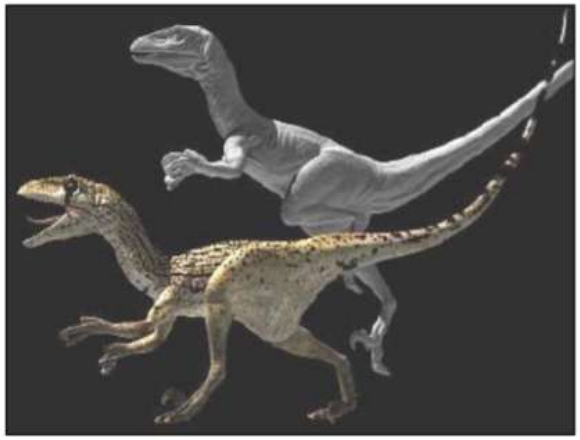
Texture mapping

Texture Mapping

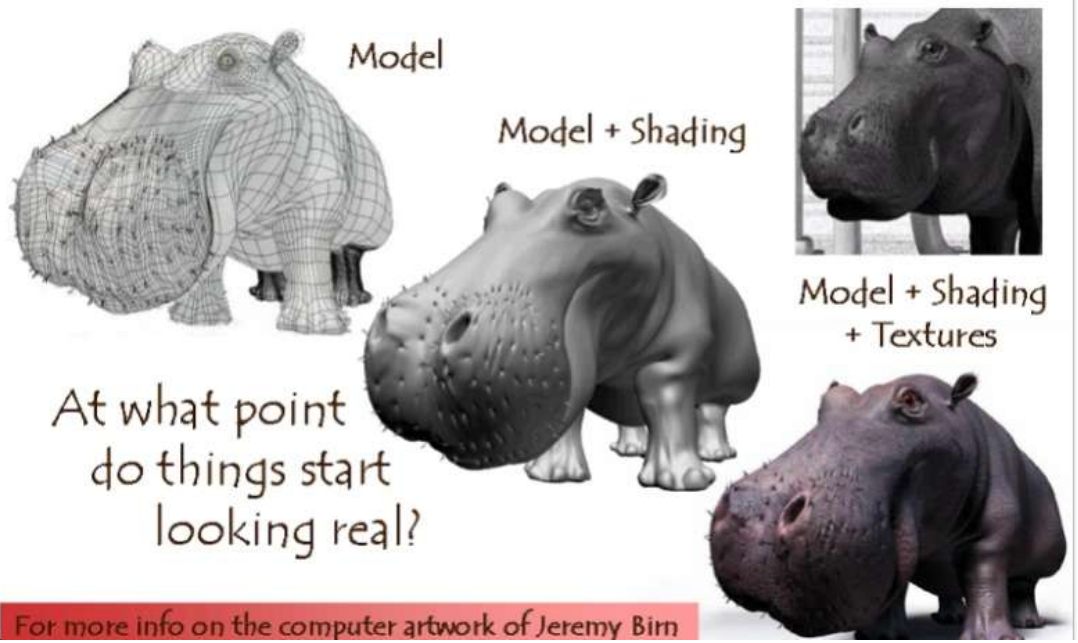
- ***Texture mapping*** is the process of developing and assigning **material attributes** to an object. Before textures are applied, all objects in a 3D package have a default plastic appearance, either gray or some range of colors.

- Texture mapping enables the user to give the object a specific color, to adjust whether it is shiny or matte, apply a pattern, and so forth.

- A scene's textures have a major impact on its final appearance.



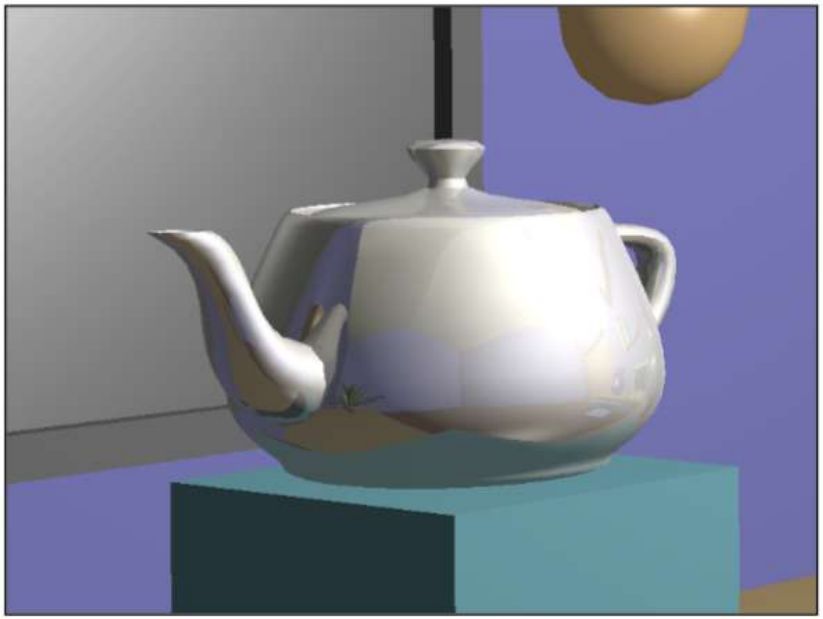
[Daren Horley]



环境贴图是立方体的原因：环境贴图直接展开会产生变形。（椭圆展开的世界地图的两侧会产生这种变形）

Texture Mapping – **Specular 'Color'**

This technique – known as **environment mapping** or **chrome mapping** – is a special case of ray tracing where we use texture map techniques to avoid the expense of full ray tracing. The map is designed so that it looks as if the (specular) object is reflecting the environment or background in which it is placed.



silver plate

polished gold

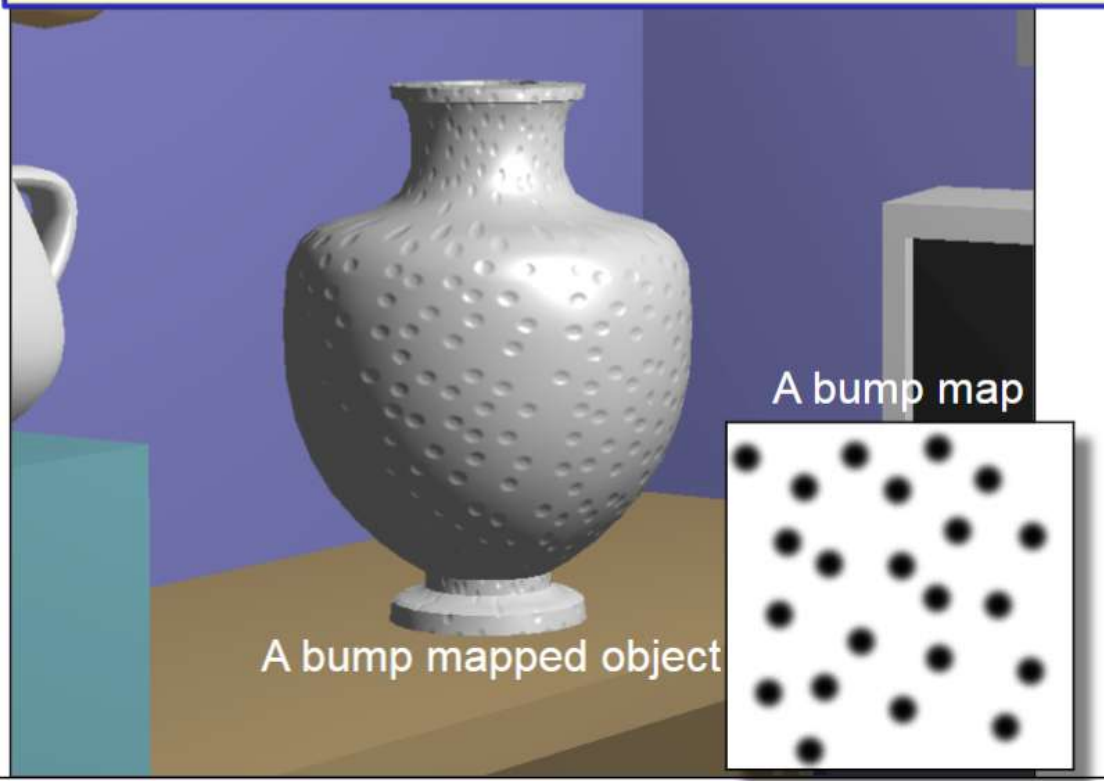
bump map实际上只改变了法线在运算光照时的方向，但是没有改变模型。

Bump Mapping

Bump mapping is a technique for simulating bumps and wrinkles on the surface of an object. This is achieved by ***perturbation of the surface normals*** of the object and using the perturbed normals during shading calculation.

The result is an apparently bumpy surface rather than a smooth surface although **the surface of the underlying object is not actually changed**.

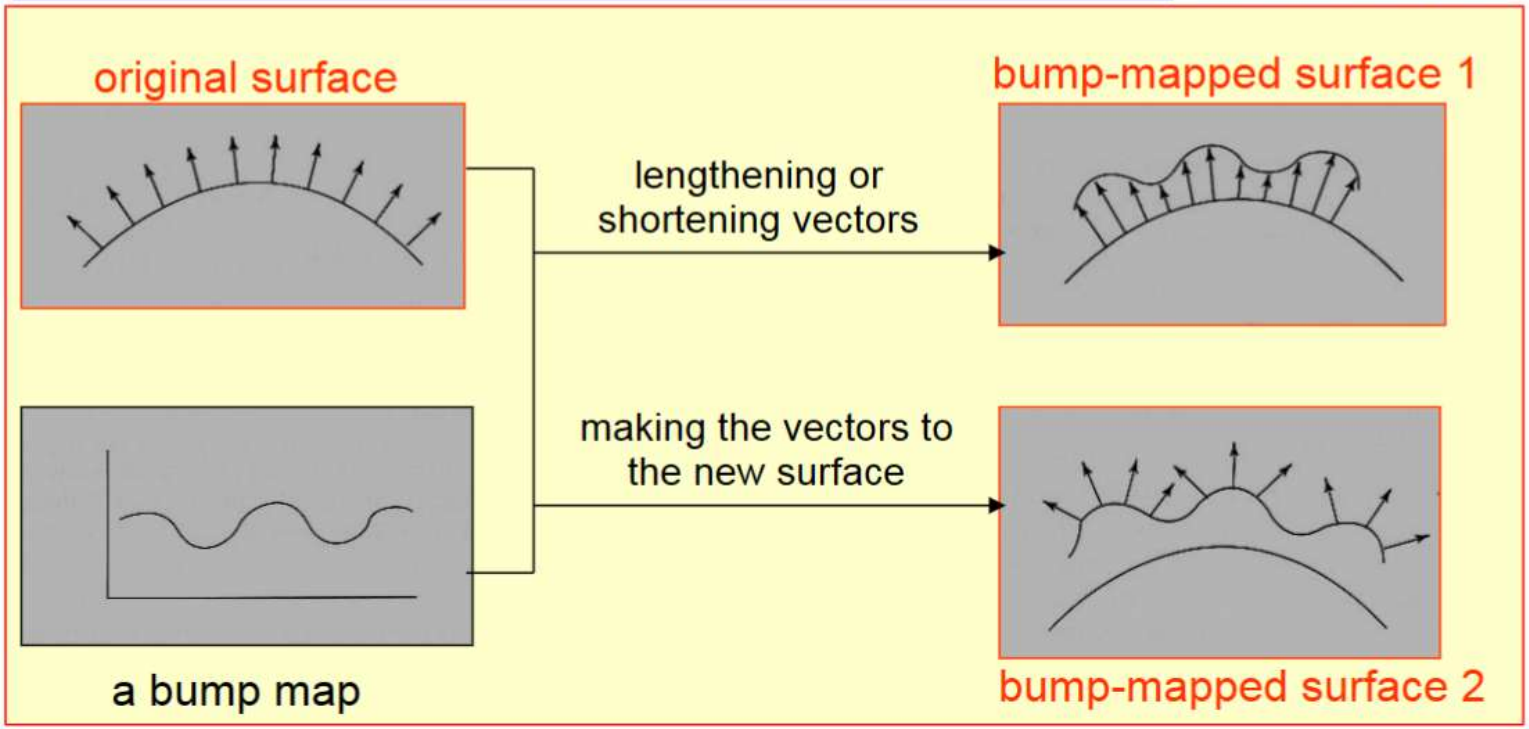
Bump mapping and was developed by a famous pioneer of 3D computer graphic techniques – J. Blinn.



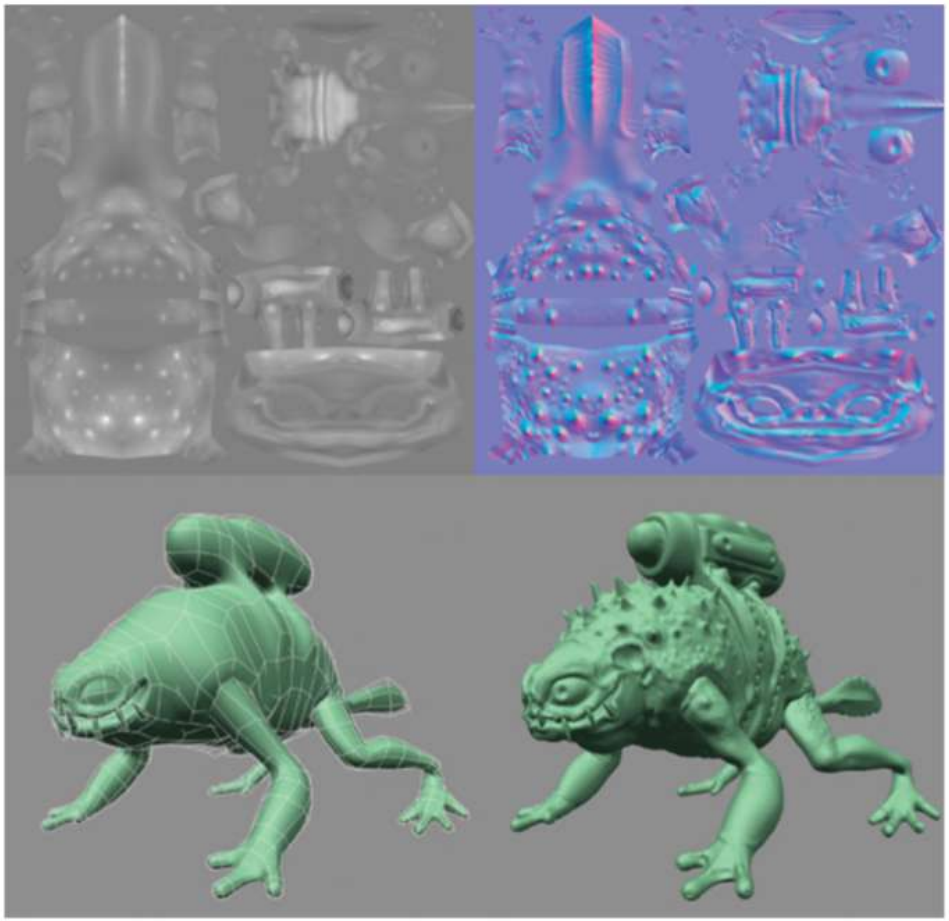
Bump Mapping – **Normal Vector Perturbation**

It enables a surface to appear as if it is wrinkled or dimpled **without the need to model these details geometrically.** Instead, the surface normal is angularly **perturbed according to information given in a 2D bump map and this "tricks" a local reflection model**, wherein intensity is a function mainly of the surface normal, **into producing (apparent) local geometric variations on a smooth surface.**

Acknowledgement - https://www.sidefx.com/docs/houdini/shade/normalmaps.html



Example:

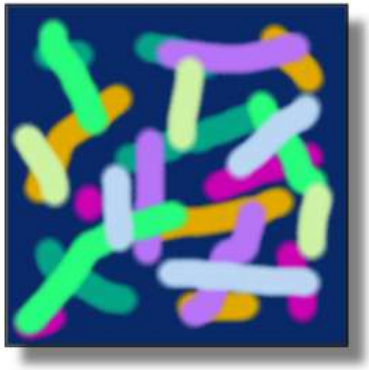


Normal mapping is done per pixel, so it generally allows more detailed shading than is possible with vertex normals.

Texture Mapping – **Normal Vector Perturbation**

combining bump and color mapping

A bump map



A color map

Texture Mapping – **Normal Vector Perturbation**

Bump mapping and texture mapping used on text

A bump map

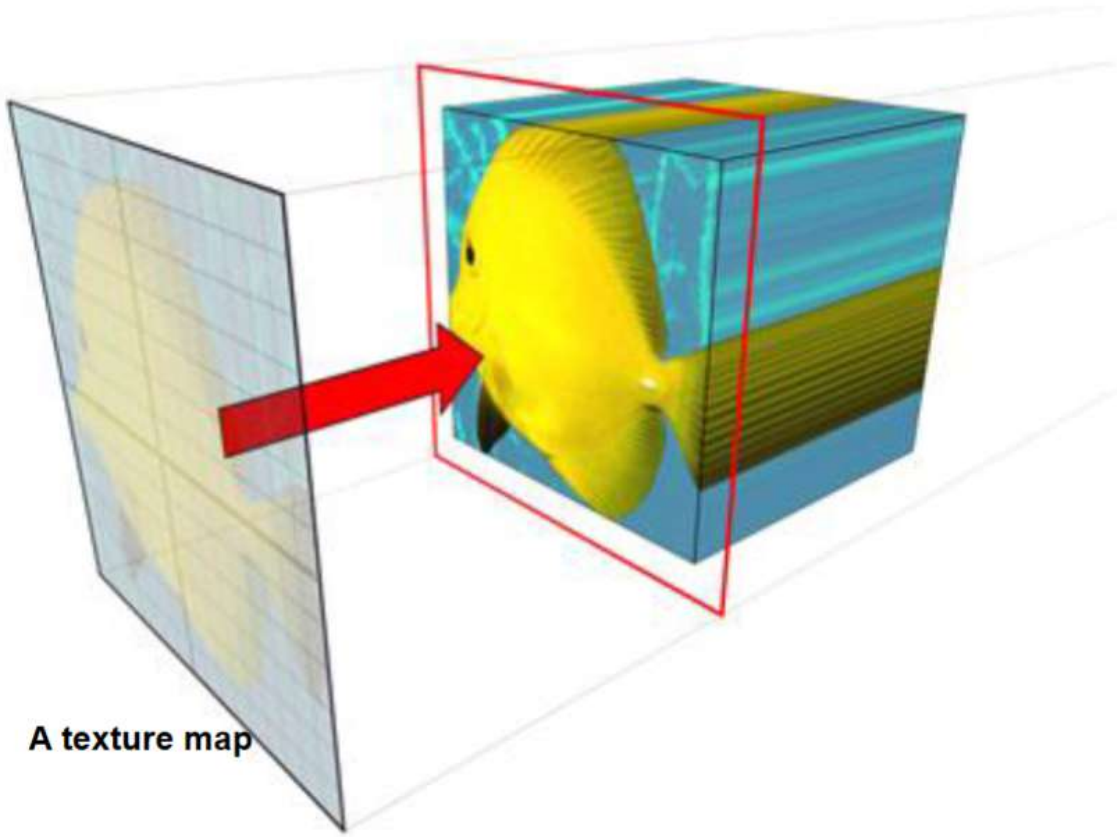
A texture map

Mapping Coordinates for Texture Mapping

To paint the texture in a 2D image onto your 3D object, we need mapping coordinates to indicate where to apply the textures.

Mapping coordinates are a set of coordinates that specify the location, orientation, and scale of any 2D textures applied to a 3D object.

- Texture Mapping for a Parametric Surface



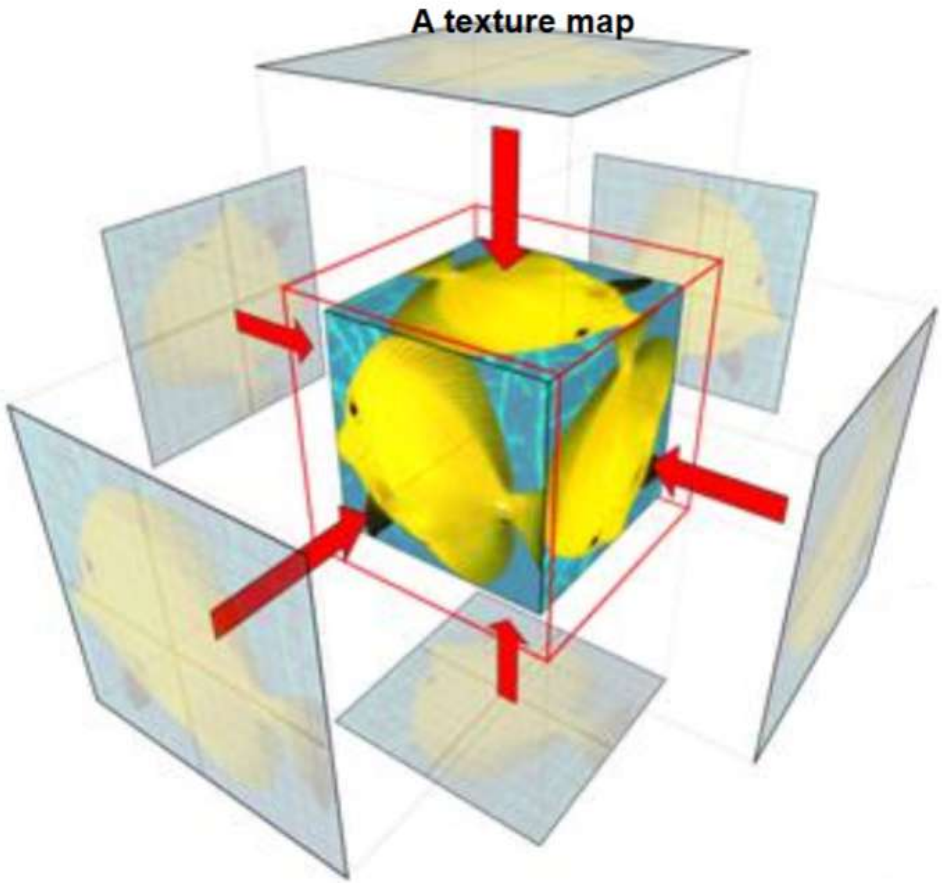
A texture map

Planar Coordinates

Planar coordinates are flat, like a sheet of paper. Planar maps act as though they're pushing the map through the mesh, which may cause streaks along the sides of the object.

Planar coordinates are useful for mapping flat objects, such as walls and doors.

- Texture Mapping for a Parametric Surface

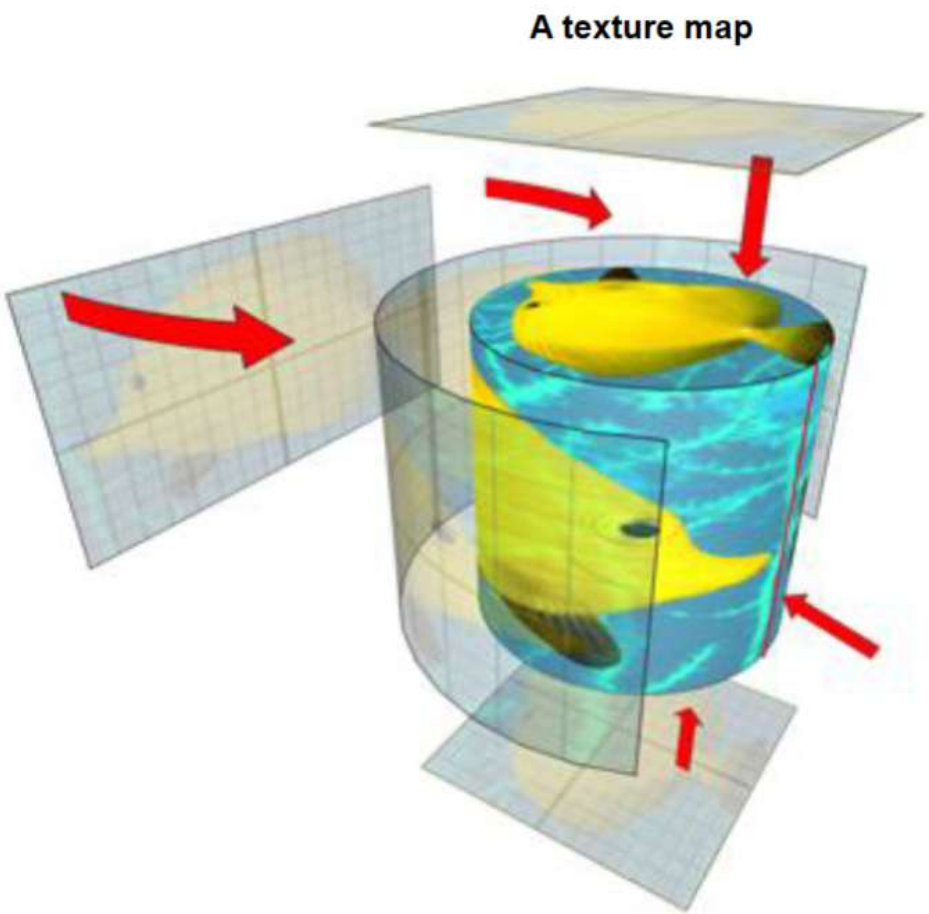


Cubic Coordinates

Cubic coordinates apply the image from six different directions, and are also known as box coordinates.

Obviously, they are ideal for mapping box-like objects, because they apply the image in planar form to each side of the object, preventing streaks.

- Texture Mapping for a Parametric Surface



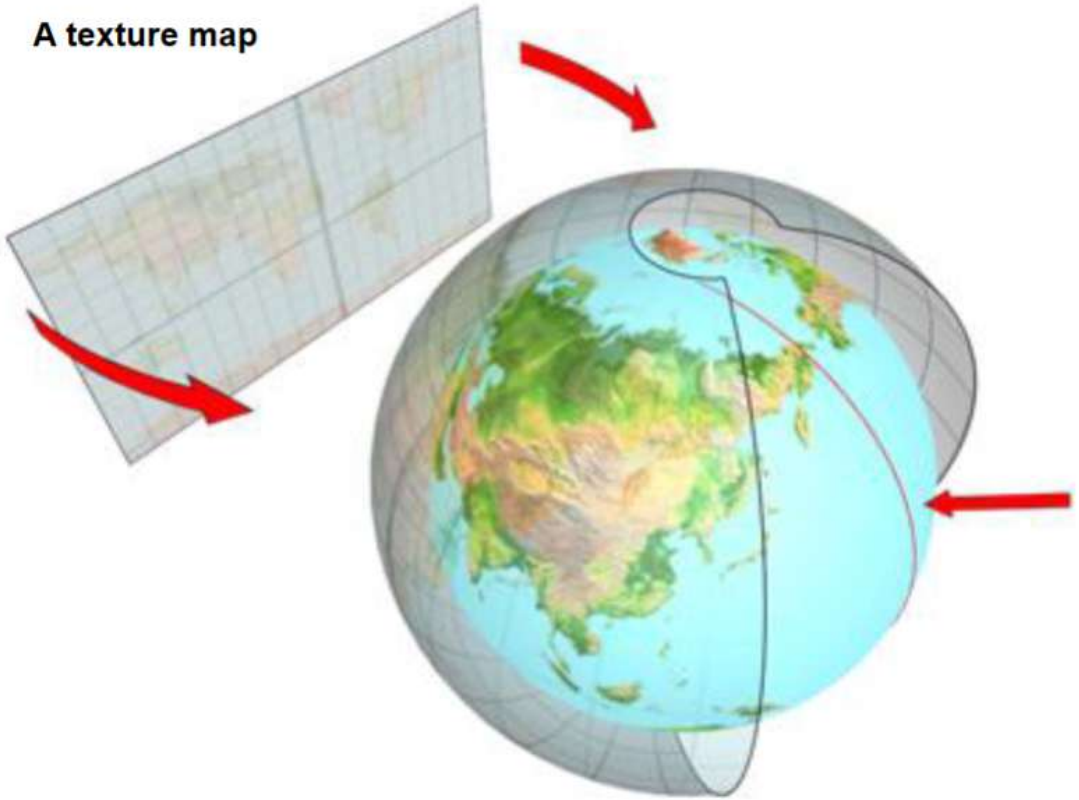
Cylindrical Coordinates

Cylindrical coordinates wrap the image around one of the object's axes until it meets itself.

Cylindrical coordinates are obviously ideal for roughly cylindrical object shapes, *such as applying a label to a 3D bottle, or to apply a wood texture to a post.*

Texture Mapping

- Texture Mapping for a Parametric Surface



Spherical Coordinates

Spherical coordinates wrap the image around a spherical object.

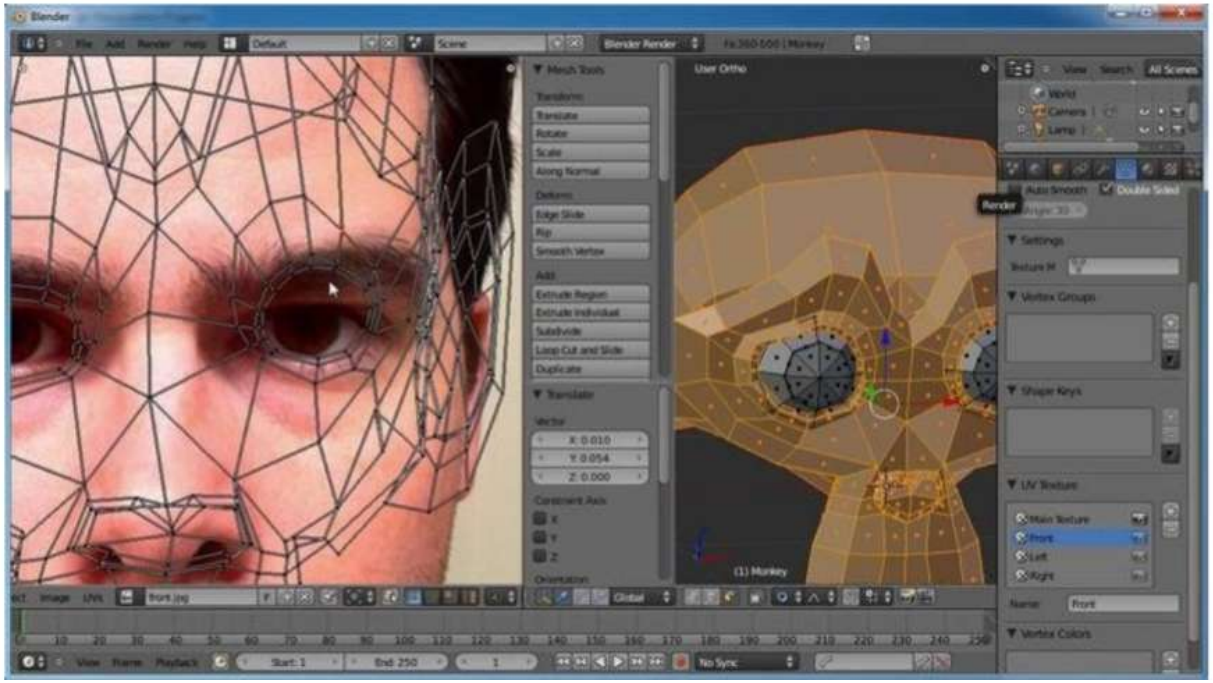
Texture Mapping

Mapping Coordinates

To paint the texture in a 2D image onto your 3D object, we need mapping coordinates to indicate where to apply the textures.

Mapping coordinates are a set of coordinates that specify the location, orientation, and scale of any 2D textures applied to a 3D object.

Mapping coordinates are used to define how a texture map is aligned to a 3D object. These coordinates are expressed using ***U, V dimensions*** **to differentiate the XYZ coordinates.**

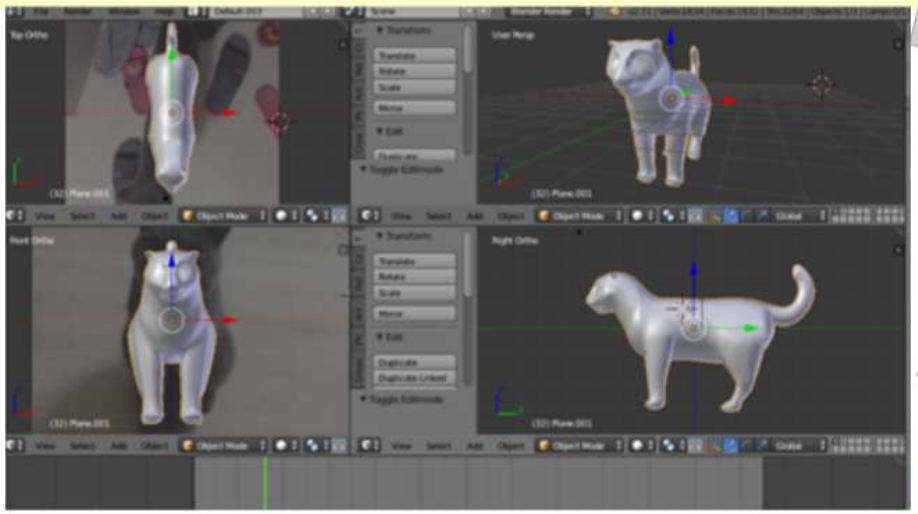


Acknowledgement: http://vimeo.com/15824758

Texture Mapping for a Mesh Model

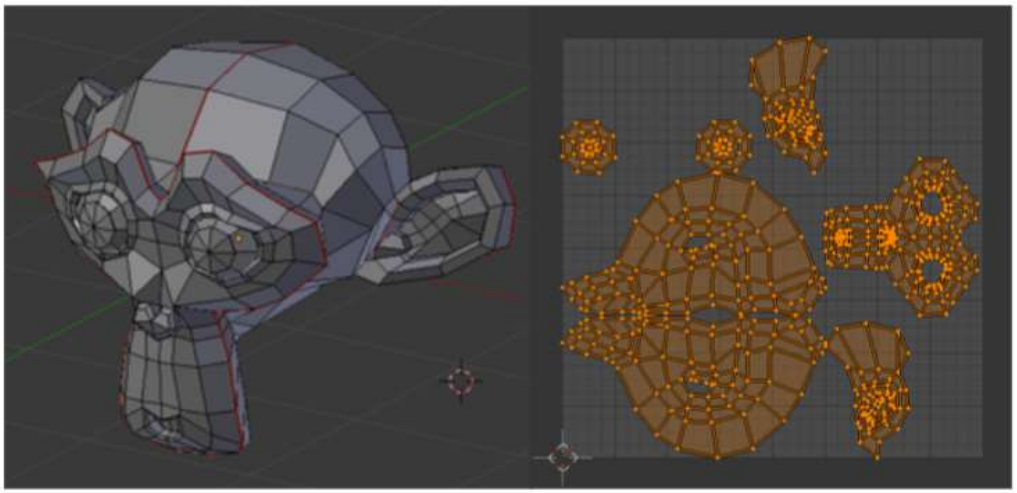
The texture coordinates UVs determine the corresponding 2D texture locations for the 3D vertices.

Every point in the UV map corresponds to a vertex in the mesh. The lines joining the UVs correspond to edges in the mesh. Each face in the UV map corresponds to a mesh face.



Texture Mapping for a Mesh Model

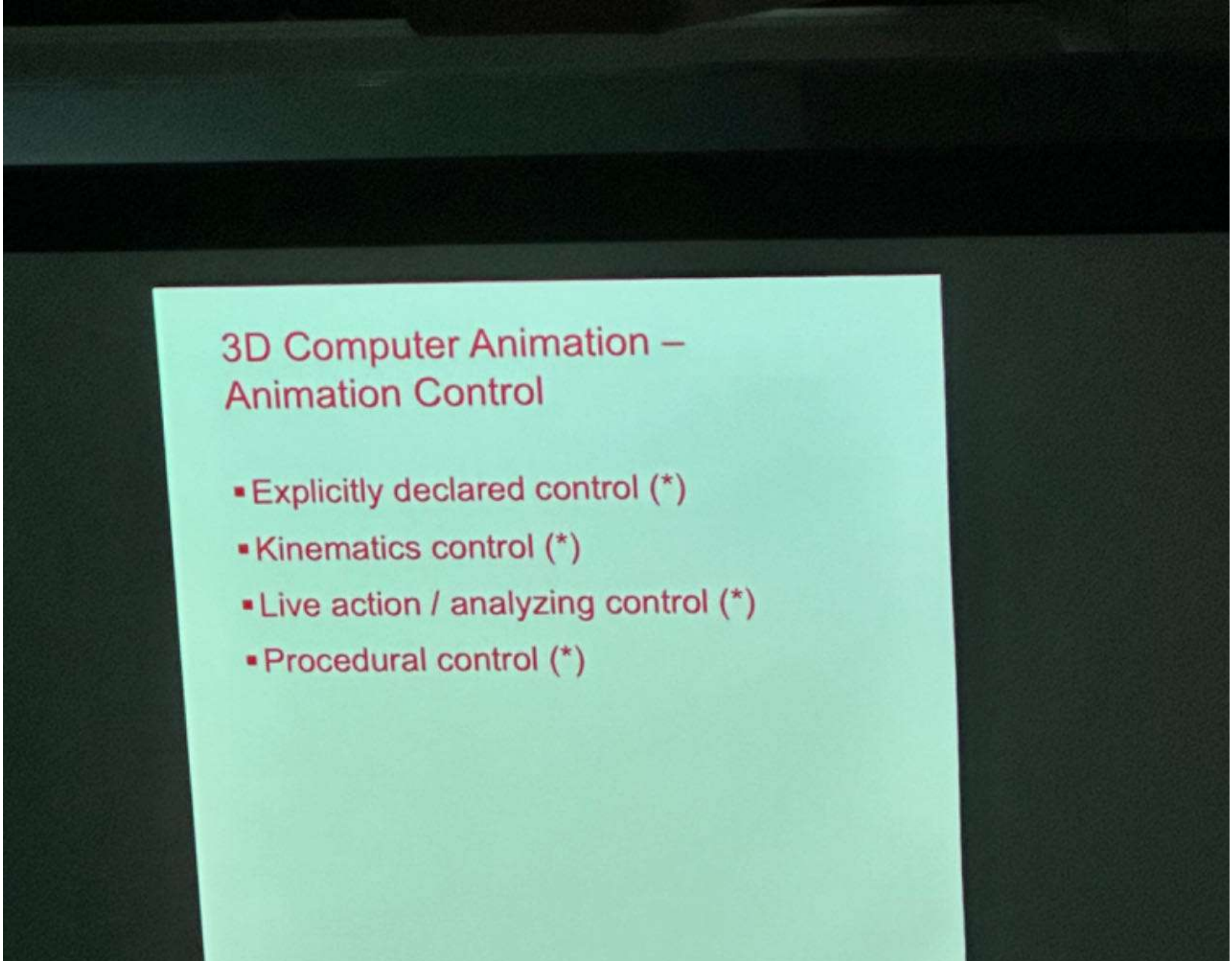
Each vertex in the 3D mesh model stores 2D texture coordinates (u,v). These coordinates can be provided manually but very time-consuming and tedious. *Alternatively, we can "flatten" 3D object onto 2D UV coordinates. For instance, define "seams" and cut the 3D object along the seams to flatten the object onto 2D UV coordinates.*

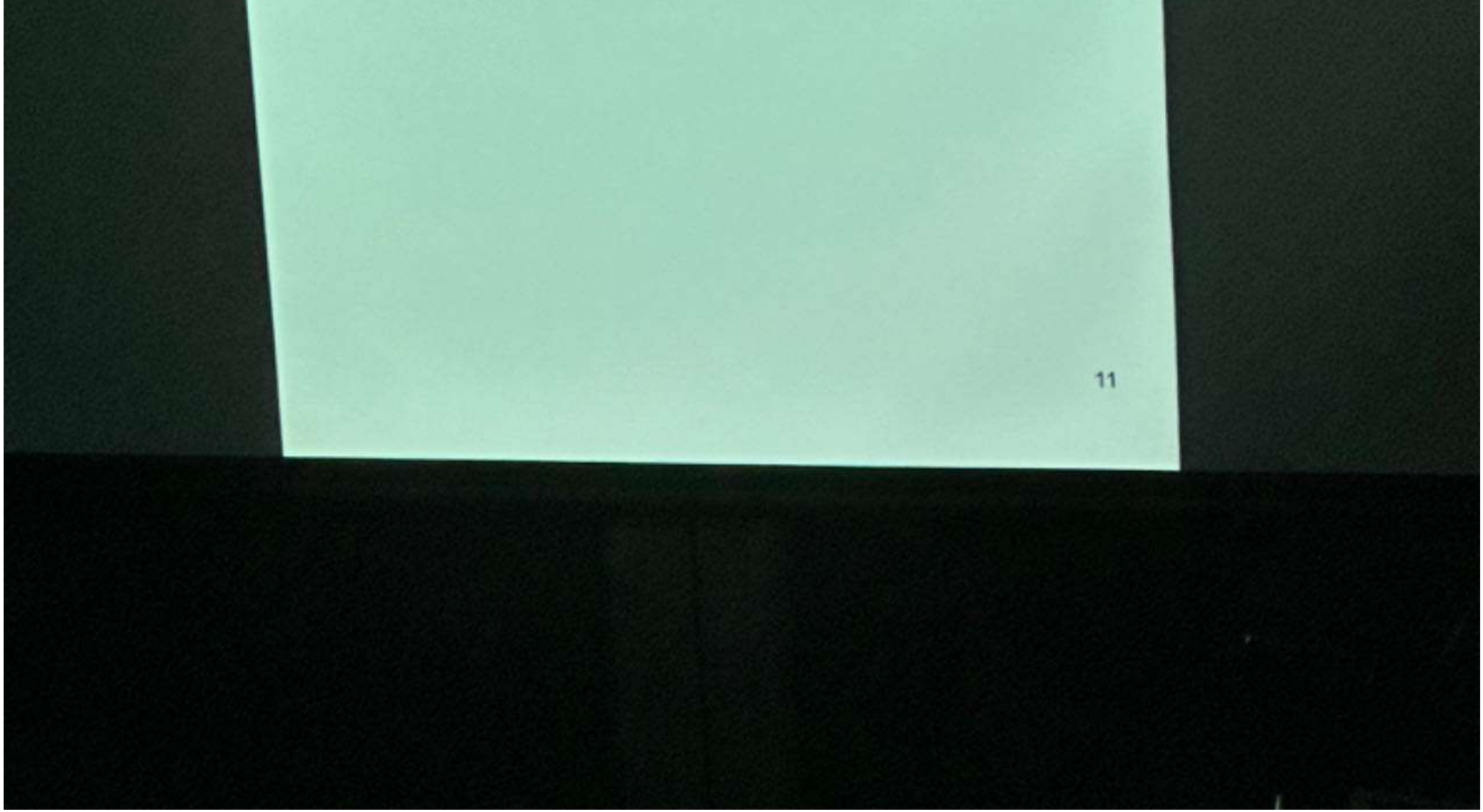


Cut along seams to flatten 3D object onto 2D UV texture map

Acknowledgement: http://vimeo.com/15824758

3D Computer Animation - Animation Control


3D Computer Animation –
Animation Control
Explicitly declared control (*)
Kinematics control (*)
Live action / analyzing control (*)
Procedural control (*)



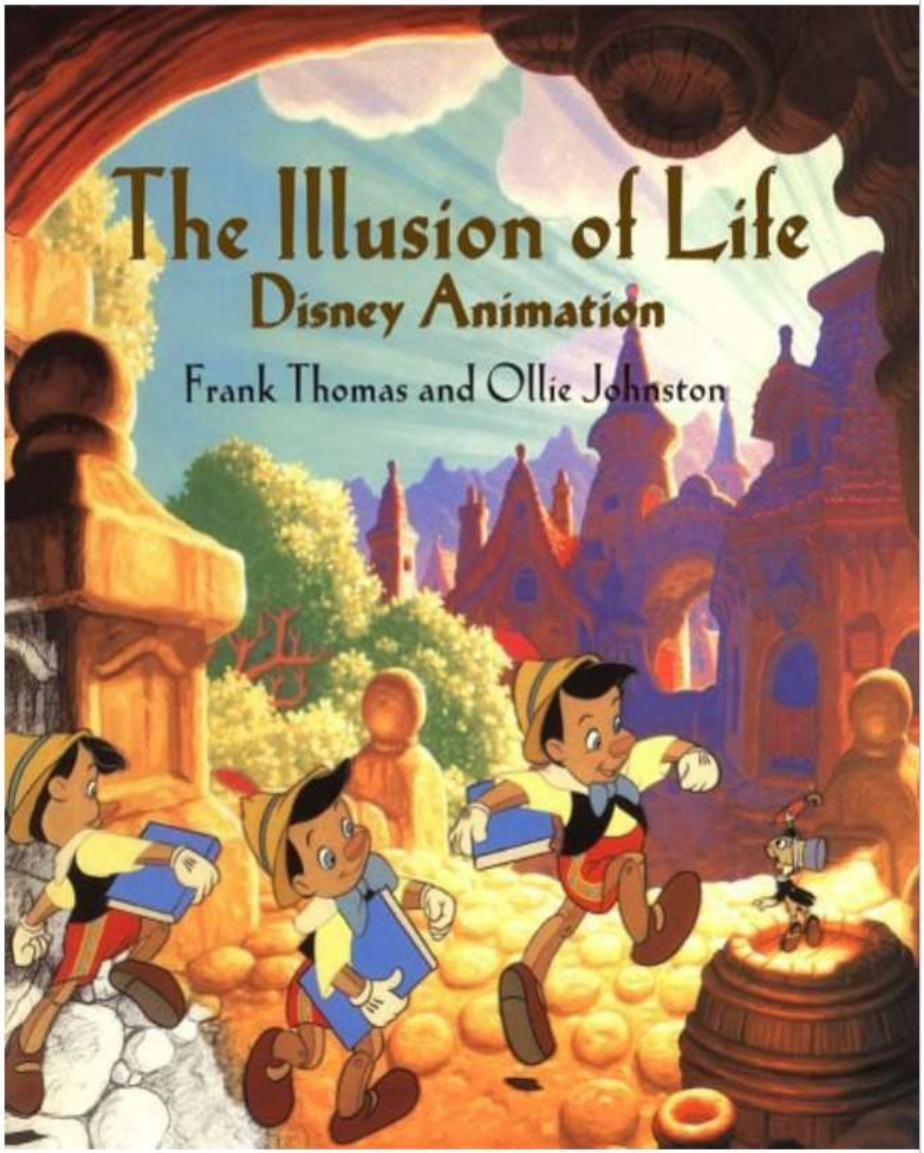
Explicitly declared control

Explicitly Declared Control

- In explicitly declared control, **the animator provides a description of all events that may occur in an animation.** This can be done by specifying

1) simple transformations – such as scaling, translation, and rotation or
2) ***key frames*** and *methods* for interpolating the movements between the key frames.

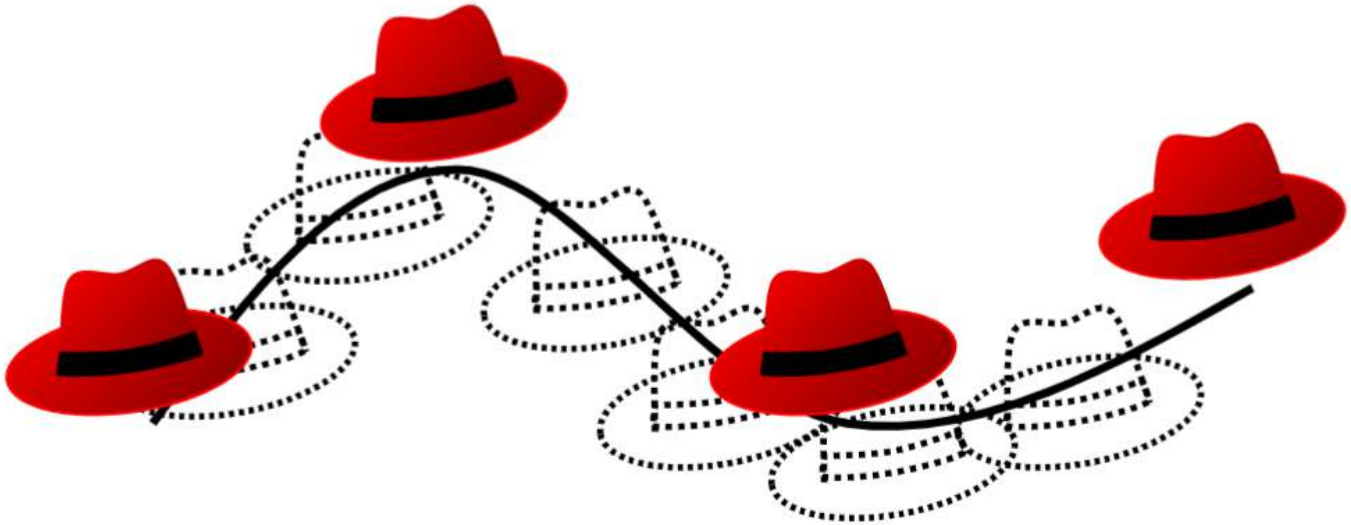
- Motions can be specified either explicitly or, in an interactive system, through direct manipulation with a mouse, joystick, data glove, or other input device.
- Many 3D animation systems provide rich interfaces giving the animator complete control over movements.

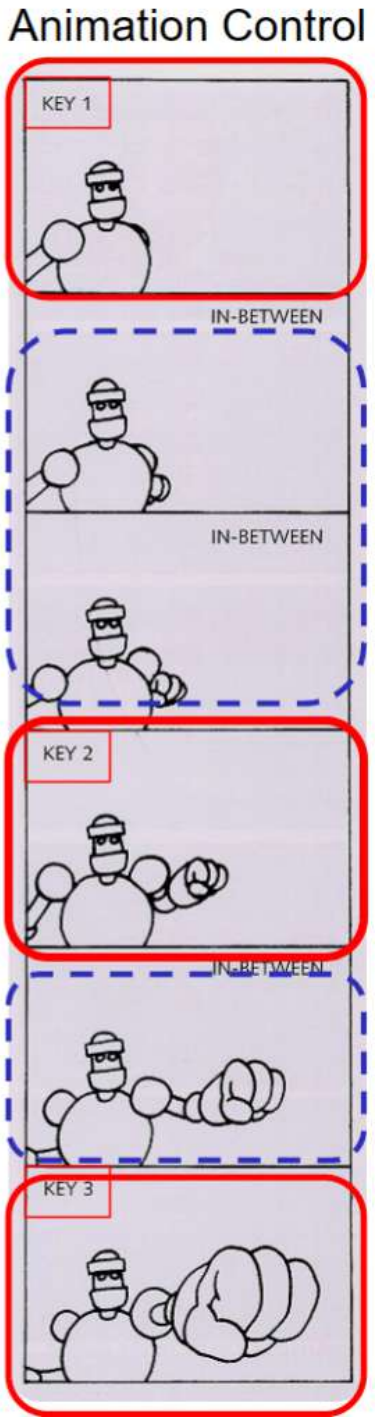


Explicitly Declared Control

- **A key-frame is a frame where you define the key/important changes in the animation.**

- The **keyframe interpolation technique** is used in computer animation to create sequences of still frames. Interpolation *technique* calculates and creates the ***in-between frames*** based on the information and key changes contained in the key-frames.





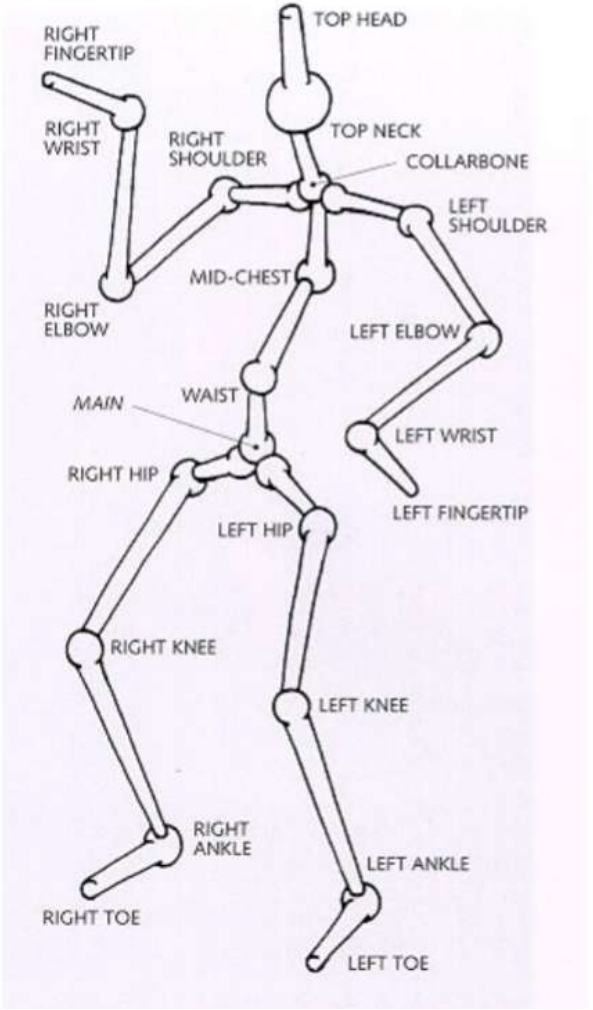
Kinematics Control

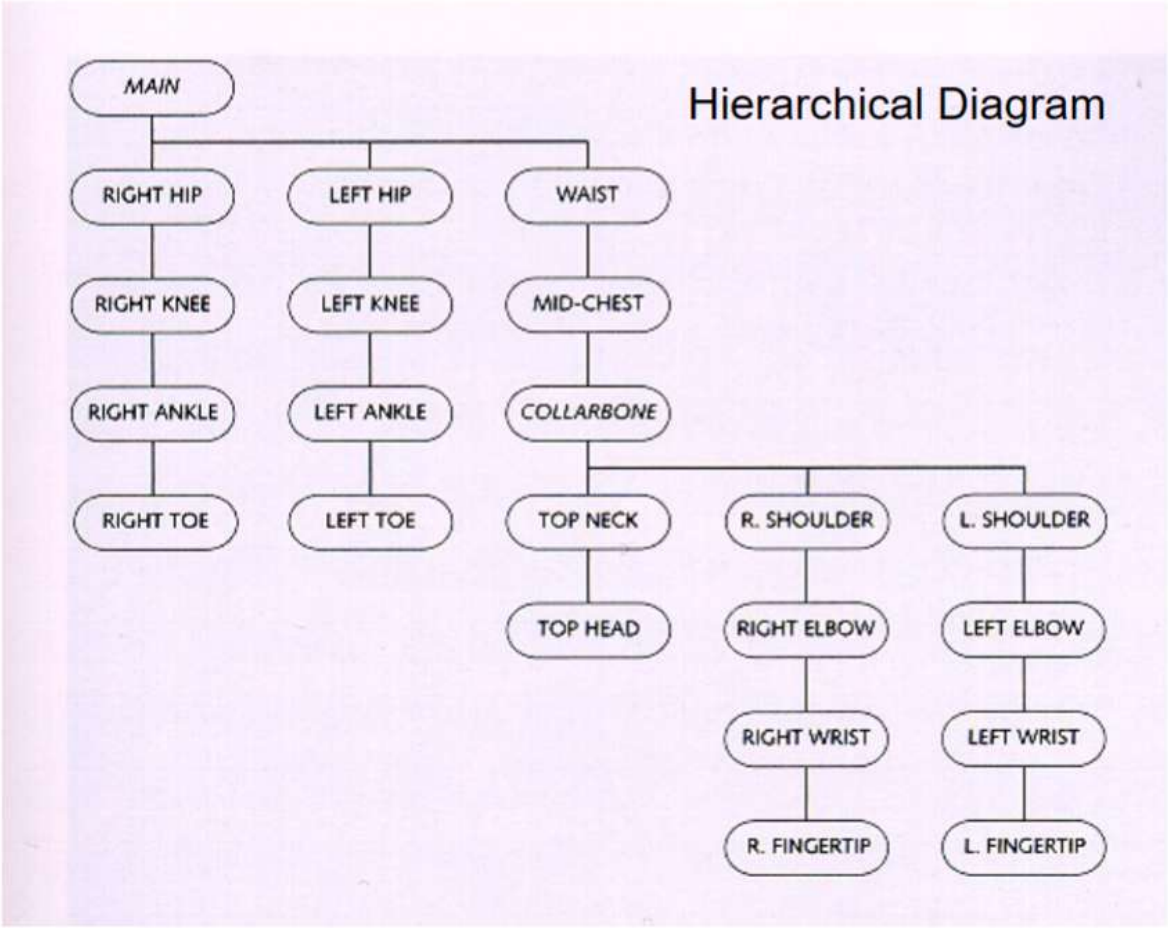
- Kinematics is particularly useful in controlling the objects with jointed structures, such as the limbs of human or animal figures. Because they are jointed together, the various parts of the arm, for example, can only move in certain ways.

- To produce realistic movement, a 3D model of an arm must obey the same kinematics constraints as a real arm – for example, if the upper arm is raised, the lower arm and hand must move along with it.

Kinematics Control

Rig - a digital articulated skeleton bound to the 3D mesh. Similar as a real skeleton, a rig is made up of joints and bones/links, each of which acts as a "handle" that animators can use to adjust the character into a desired pose.

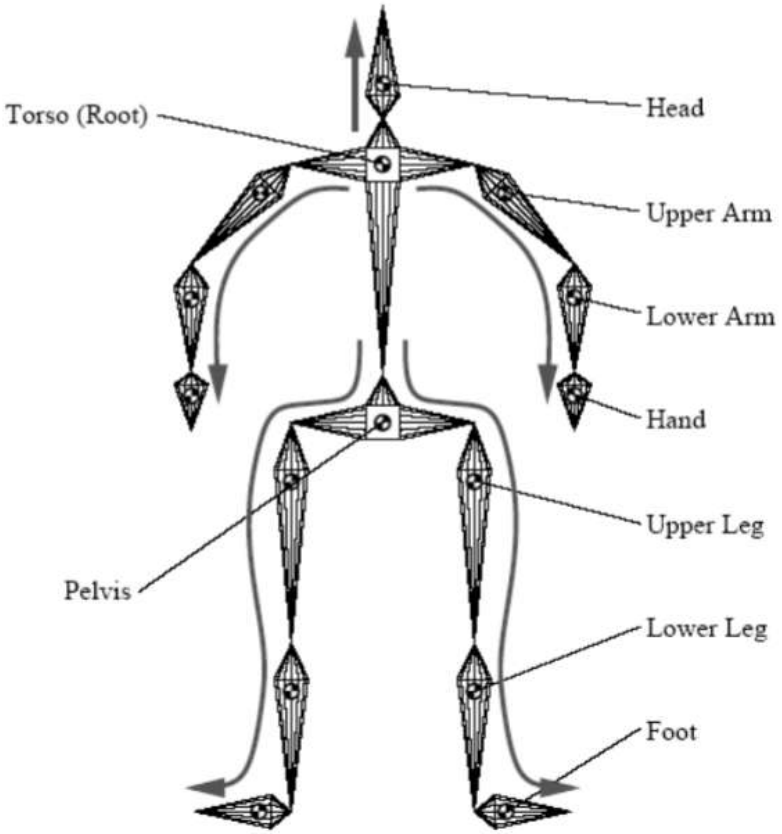


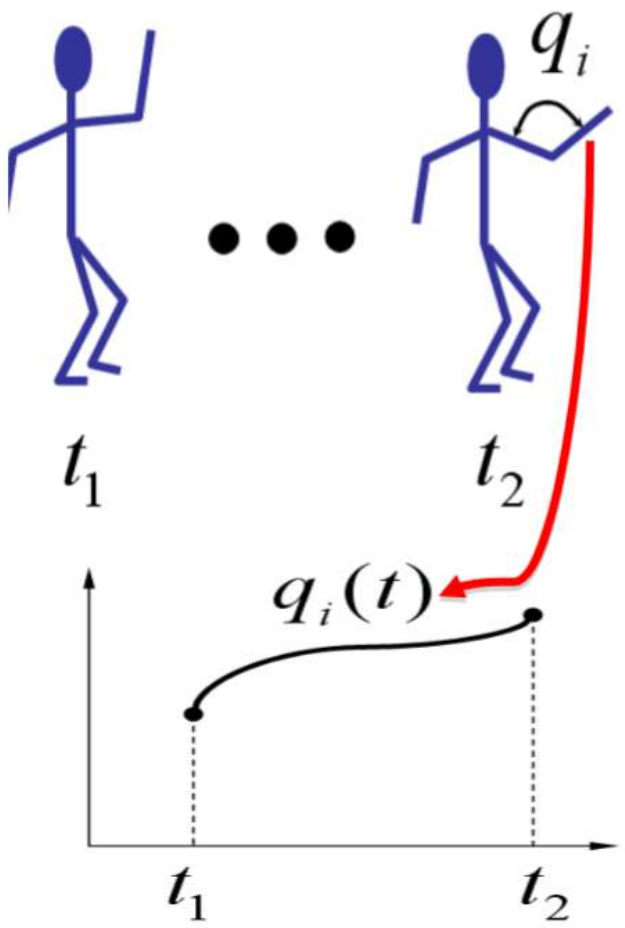


Kinematics Control

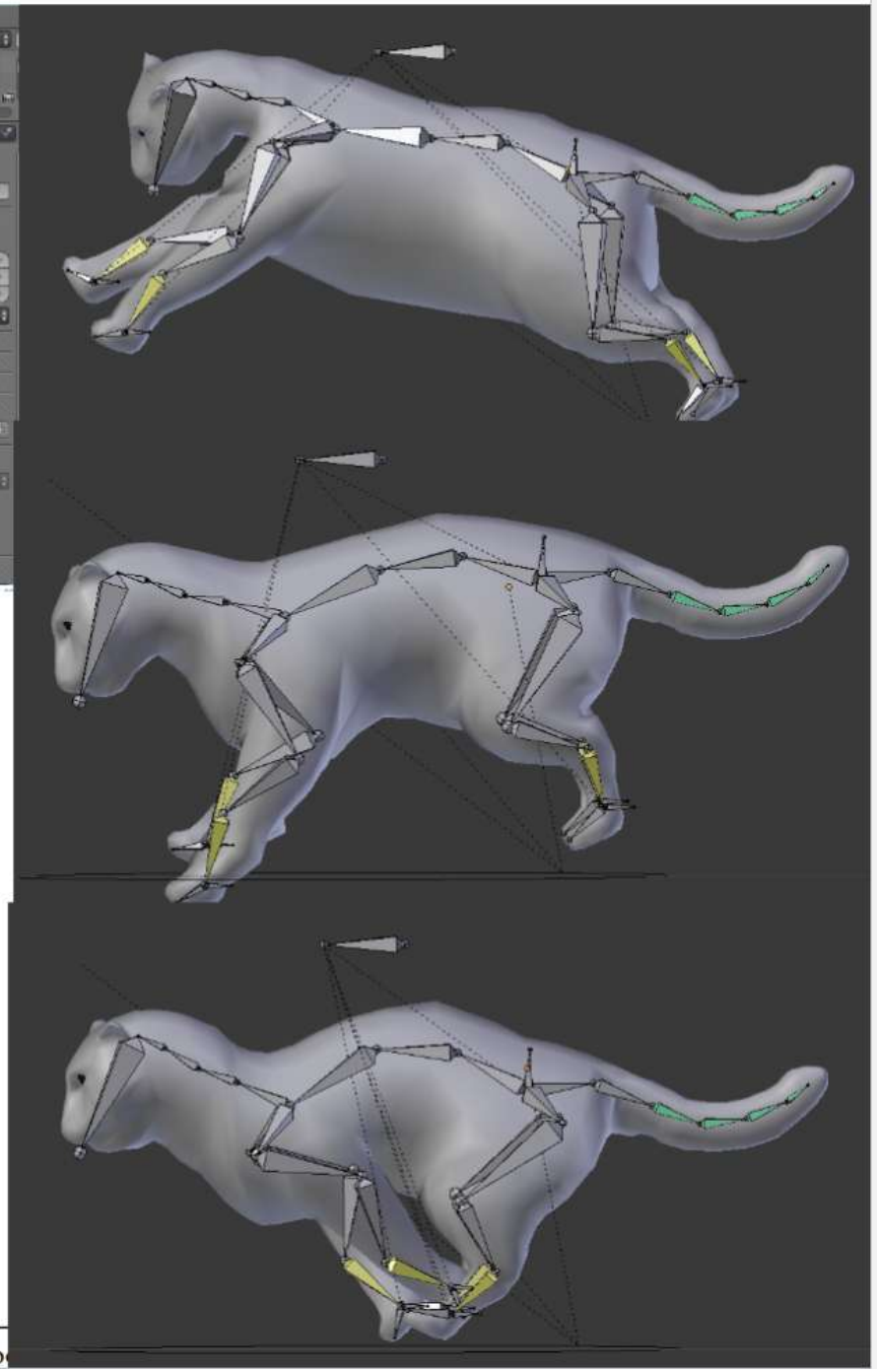
Articulated Model

Rigid parts connected by the joints, and can be animated by specifying the *joint angles as a function of time* to generate the movements in the animation.





Kinematics Control – Example from our previous student

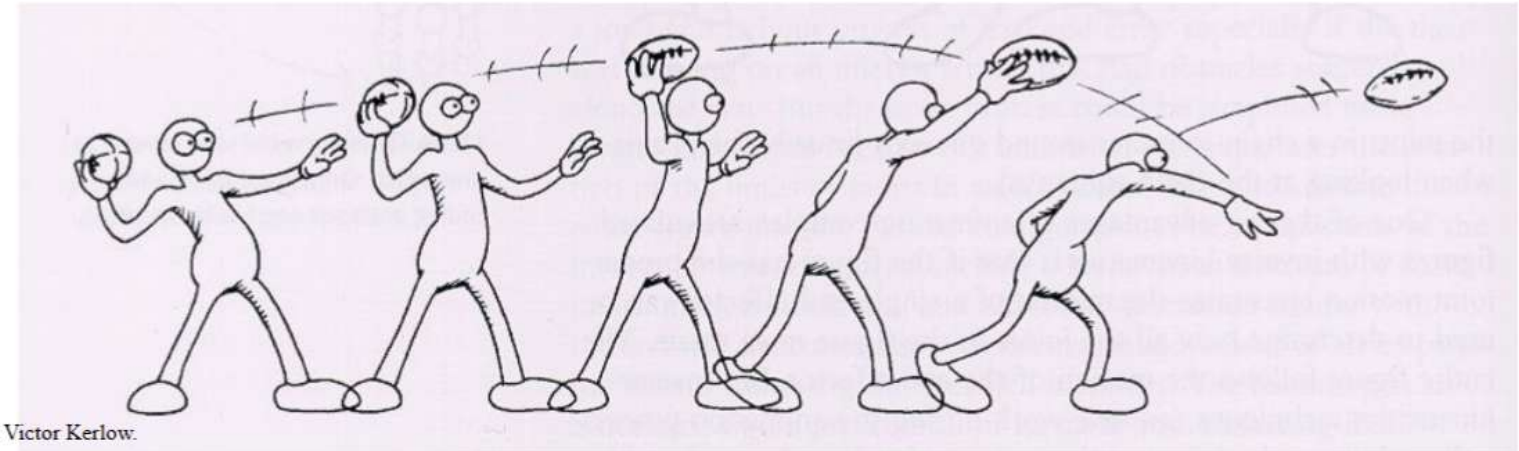


Forward Kinematics (FK) Control

- The forward kinematics (FK) technique consists of determining the angles of its joints. This can be accomplished by typing the numerical values for each joint angle directly into the appropriate fields or dialog boxes provided by the software, or by using an input peripheral.

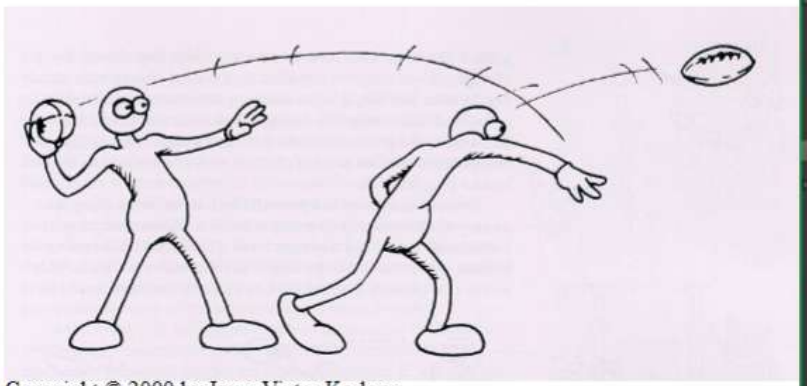
- Forward kinematics is a simple technique but that requires a great deal of manual work.

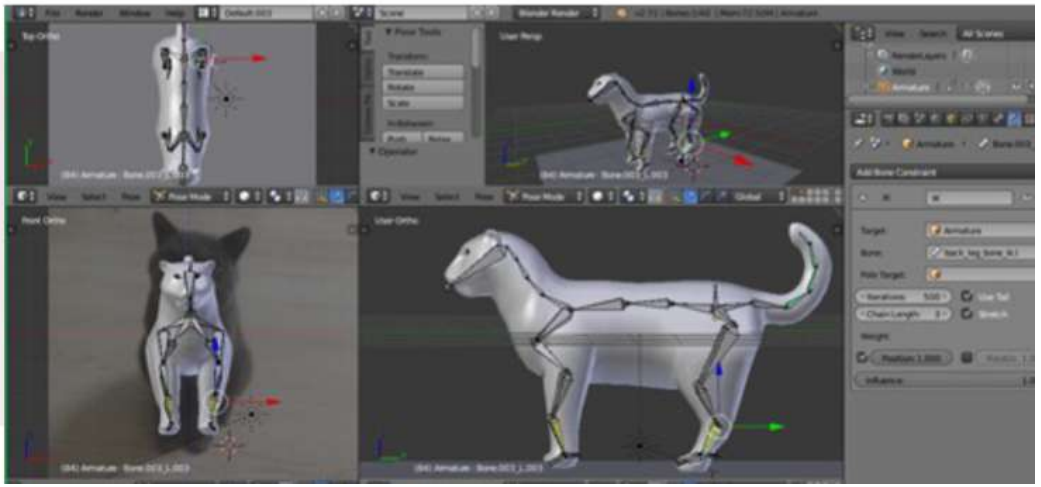
- FK can be used very creatively in situations when all the joint angles are known in advance and are repeated many times. For example, an interactive game – the positions of the characters are finite, repeated many times, and known in advance.



Inverse Kinematics (IK) Control

- The **inverse kinematics (IK)** technique is useful for animating complex models with a large number of joints. It determines **the motion of entire hierarchy based on the final angles of some of the key joints** that define the motion.
- The IK animation techniques require that the 3D models to be animated are built as hierarchical structures. Inverse kinematics techniques are most commonly applied to articulated figures that are defined as hierarchical skeletons constructed with links that are connected by joints, each with different motion constrains.
- *Inverse kinematics techniques can greatly simplify the animation of models with multiple joints that have to move in a complex and somewhat realistic way.*





Live action / analyzing control

Live Action / Analyzing Control

- *By examining the motions of objects in the real world, one can simulate the same movements to create the corresponding sequences of an animated object.*

- Example – we can attach indicators to key points on the body of a human actor. The coordinates of the corresponding key points in an animated model can be calculated by observing the position of these indicators.

Animation Control

Live Action / Analyzing Control

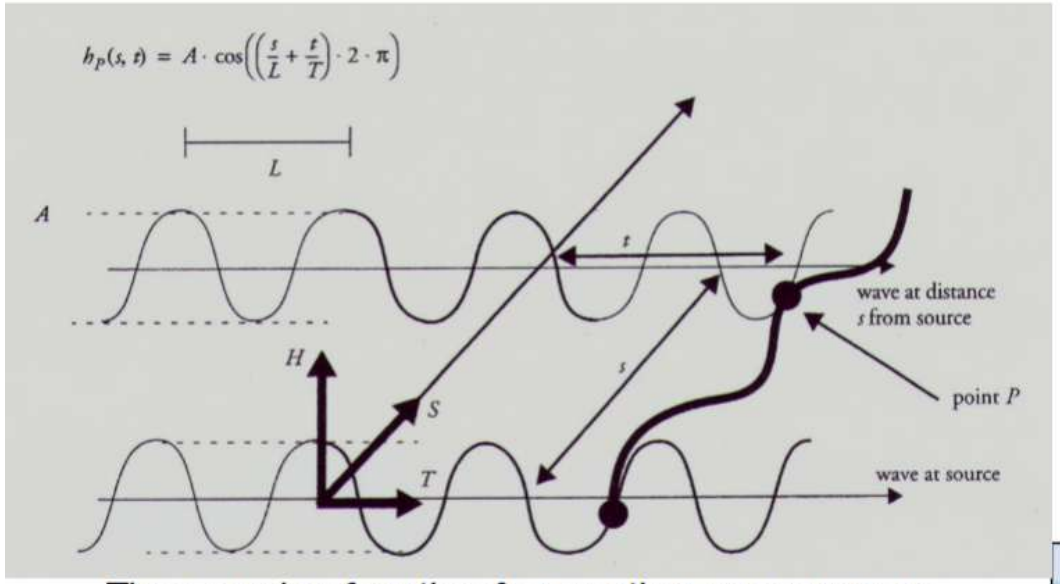
- The live data capture is especially important in visual effects projects that rely heavily on getting material from the live action set, whether it is a remote location or a sound stage. Most live data capture requires specialized equipment and software in motion capture.

Photo credit: The Return of the King

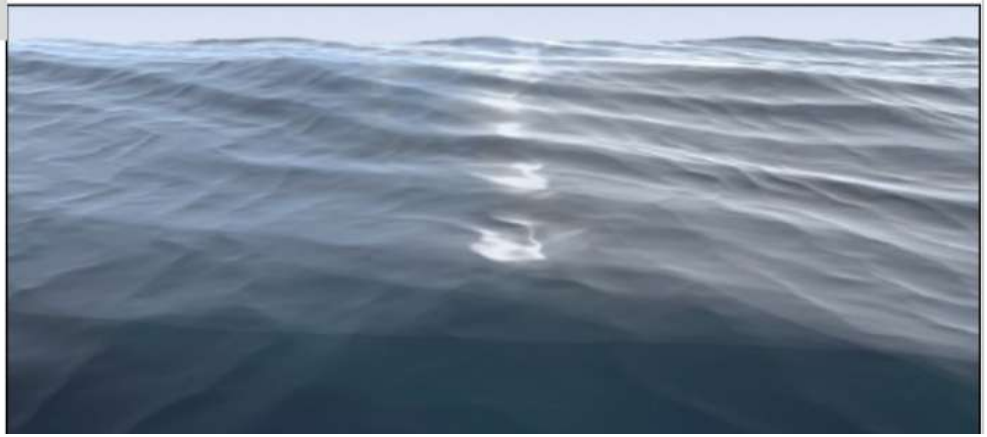
Procedural control

Procedural Control

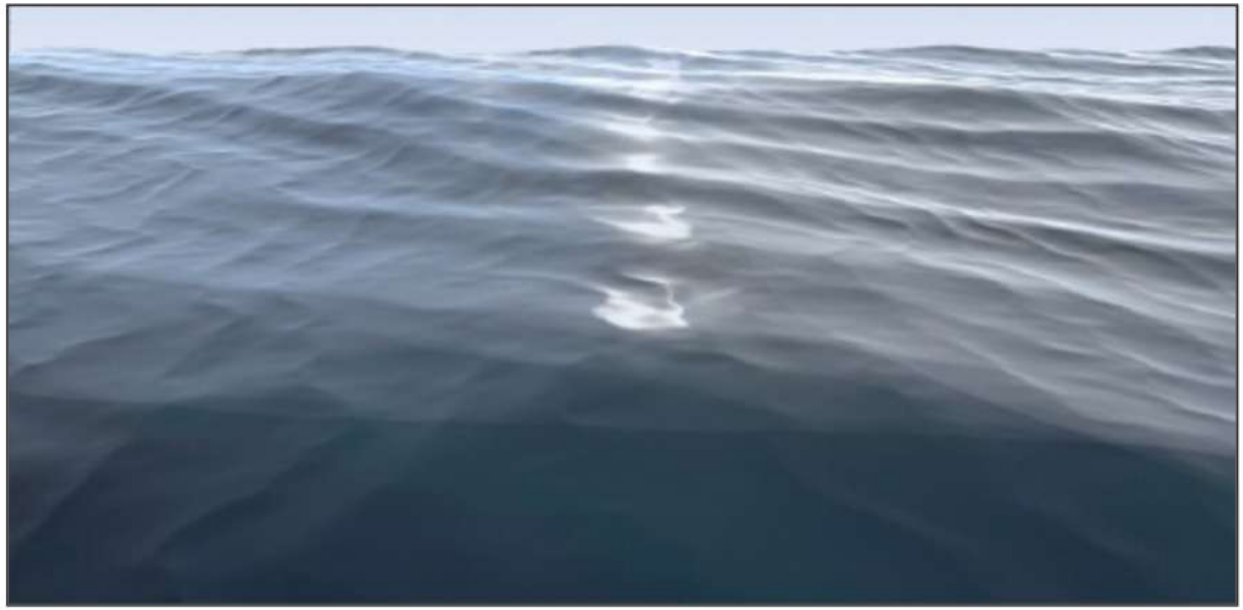
Procedural control enables to simulate many natural effects, such as water, fire, sparks, or bubbles, set by formulas and parameters.



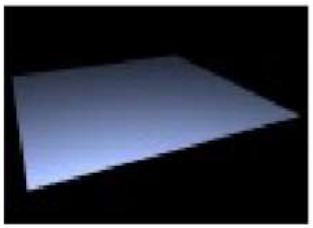
Time-varying function for creating ocean waves

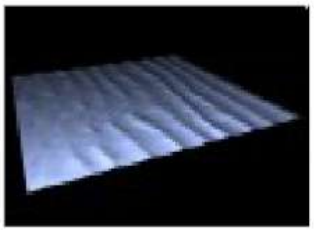
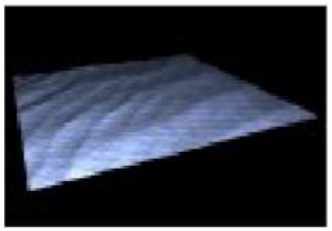


Procedural Control



The surface of the sea created by a procedural texture / shader management tool called Slim in RenderMan® package from PIXAR.

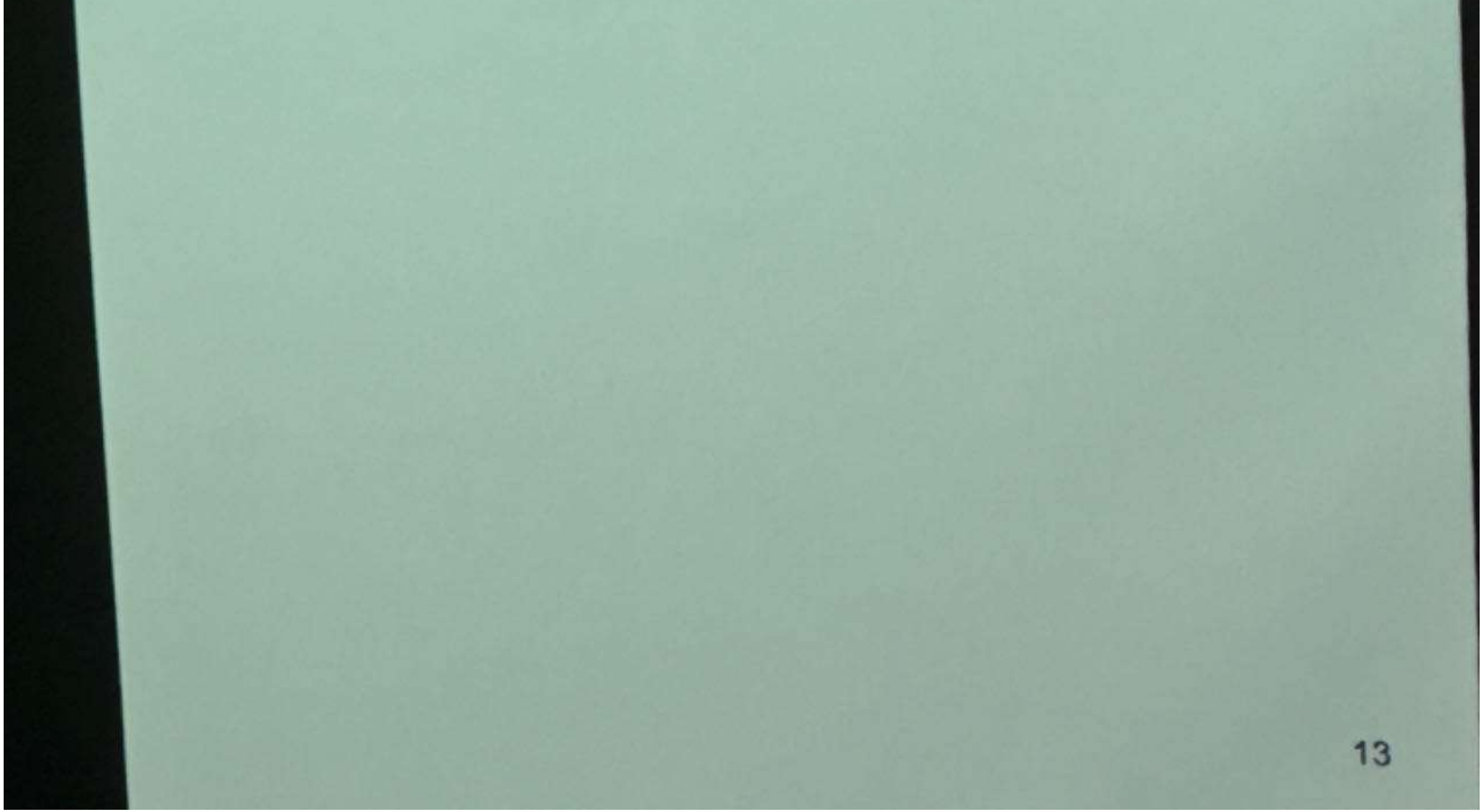



Post-processing(后处理)

Post-processing

- Compositing and re-touching (*)
- Basic image compositing techniques/ operations, e.g., addition, over operations etc (*)
- Compositing with pre-multiplied images (*)
- Bluescreen and Greenscreen (*)
- Matte creation/extraction methods (*)
    - Chroma-keying (*)
    - Luma-keying (*)
    - Difference matting (*)
    - Color difference (*)



Post-Processing

Once the video/images recorded, the resulting quality can be further enhanced with digital manipulation / processing, such as retouching and compositing.

These post-processing techniques are used to modify the color, contrast, and brightness of images, as well as the contents.

- increase the overall brightness of an image / frame;
- enhance the contrast between light and dark tones;
- *remove mistakes*;
- *add missed details*;
- *combine areas of different sources into a single image / frame*.

In particular, post-processing facilitates *the blending of computer-generated images with photographic or painted images*. These capabilities open up new creative avenues that were not possible with traditional tools.

Compositing and re-touching

Image Retouching

- There is a wide variety of tools for retouching the rendered and live action images. Retouching tools are typically used to touch up mistakes in the rendered file or to add details that were missing.

Lens Flares

A lens flare is the pattern of bright circles and rays that is seen when you point a camera lens toward the sun or other bright light source.

Lens flares add realism to scenes with bright lights, helping to create the illusion that a real camera was used for the shot.

It is often desirable to introduce some sort of lens flare when creating a scene with bright light sources that were not present in the original shots.

Lens flares are caused by bright sources of light interacting with camera lens elements. Their appearance varies significantly, depending on the lens type and brightness of the light source.

Motion Blur

- When recording reality with a video or a film camera, we observe that objects that move too fast in front of the camera appear blurred. This phenomenon is called **motion blur**, and it occurs naturally in film or video recordings where the shutter speed is too slow to freeze an object in motion.

- Motion blur can add a touch of realism to computer animation because it reminds viewers of the blurring effect that occurs when we record fast-moving real objects directly with a camera. But motion blur does not occur naturally in computer animation, it must be added.

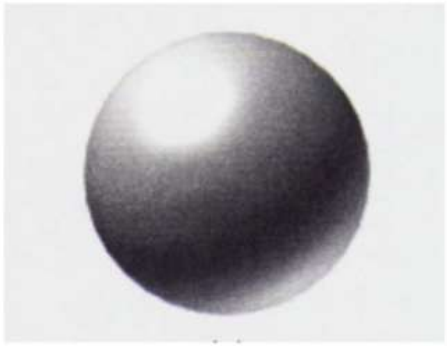
wikipedia.org

Image Retouching

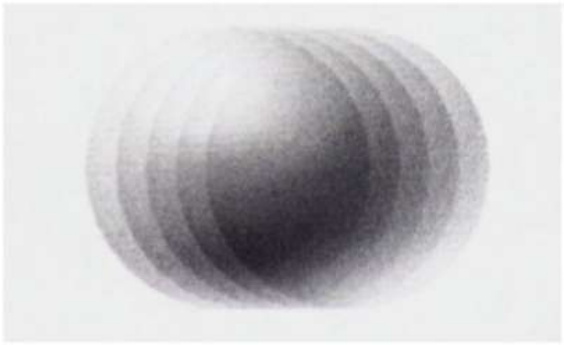
Motion Blur

One of the techniques to create motion blur is rendering the scene a number of times while advancing the animation slightly. The multiple images are then composed together into a single, motion-blurred image. However, this means a 4-5 fold increase in rendering time.

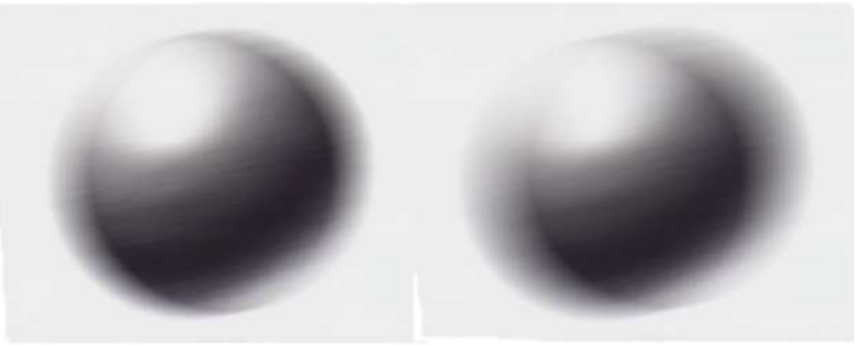
Another way to create the effect is by applying a directional blurring filter in post-production using either a plug-in or paint program. This type of blur is generally more realistic, and renders faster as well.



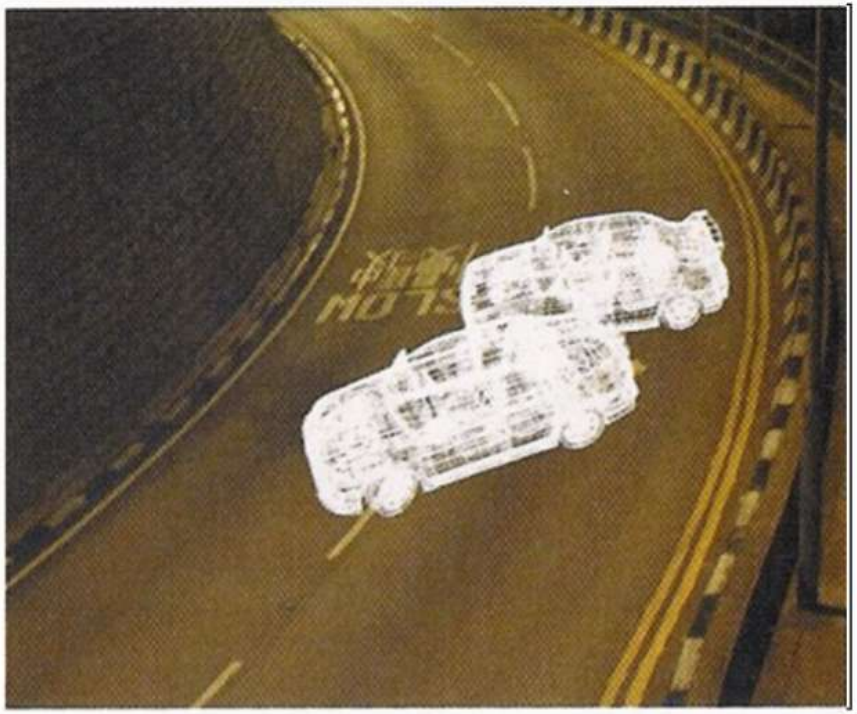
Unaffected object



5-step motion blur created by 3D rendering



20/35-pixel Motion Blur applied with software



Motion Blur

The cars in *Legend of Speed* are comupter-generated props rendered with motion blur and volumetric lights.

Basic image compositing techniques/operations,e.g.,addition,over operations etc

Image Compositing

- **Image compositing** combines two or more different images into one in such a way that an illusion of time and space is created. It seems that all the image events were recorded together at the same time and place.

- The main purposes of image compositing include to save expensive production costs or to create the scene that is physically impossible in our reality.

- In the film industry, image compositing is also known as ***matting*** because of the masks, or mattes, used in the compositing process.

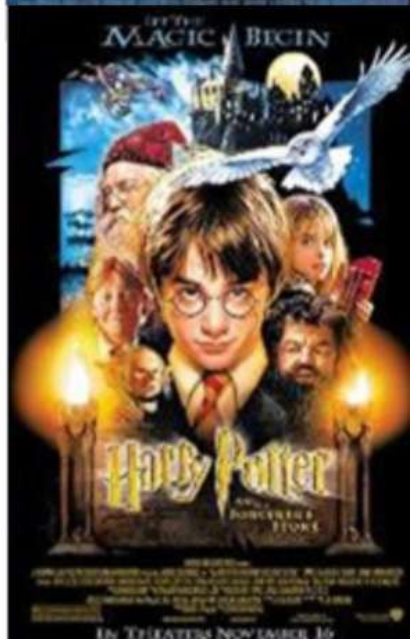
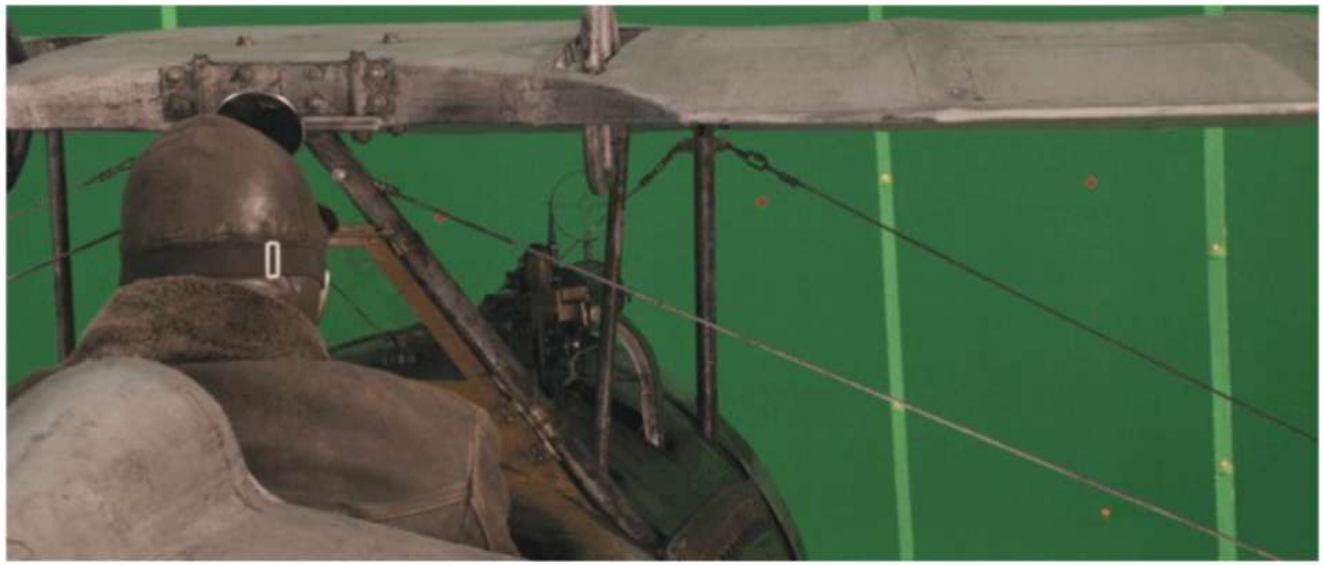


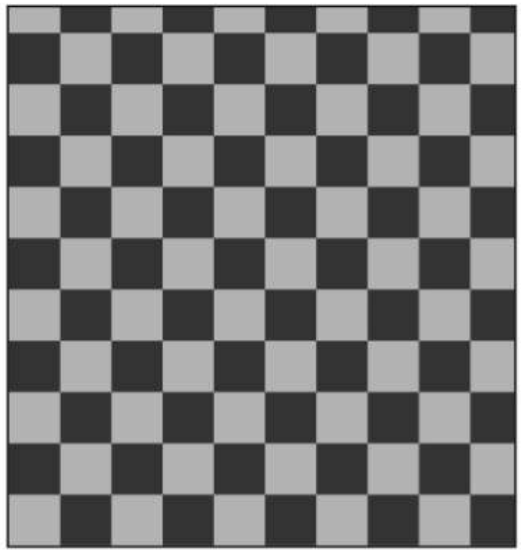
Image Compositing



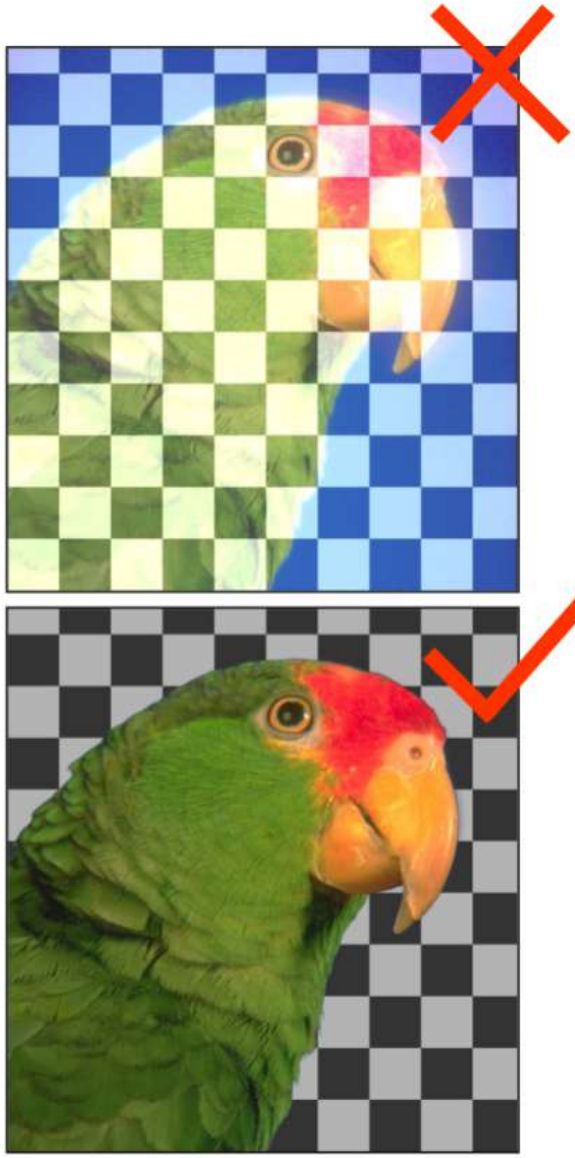
Low-budget production – save expensive production costs

Basic Image Compositing

(a) Foreground image



(b) Background image



Example – **multisource operator ("ADD").** While this effect is useful in a variety of situations, it does not give us the impression that any sort of layering has occurred. There is no sense that certain portions of one image are actually occluding the second image. To accomplish this, we need to introduce the concept of a ***matte***.

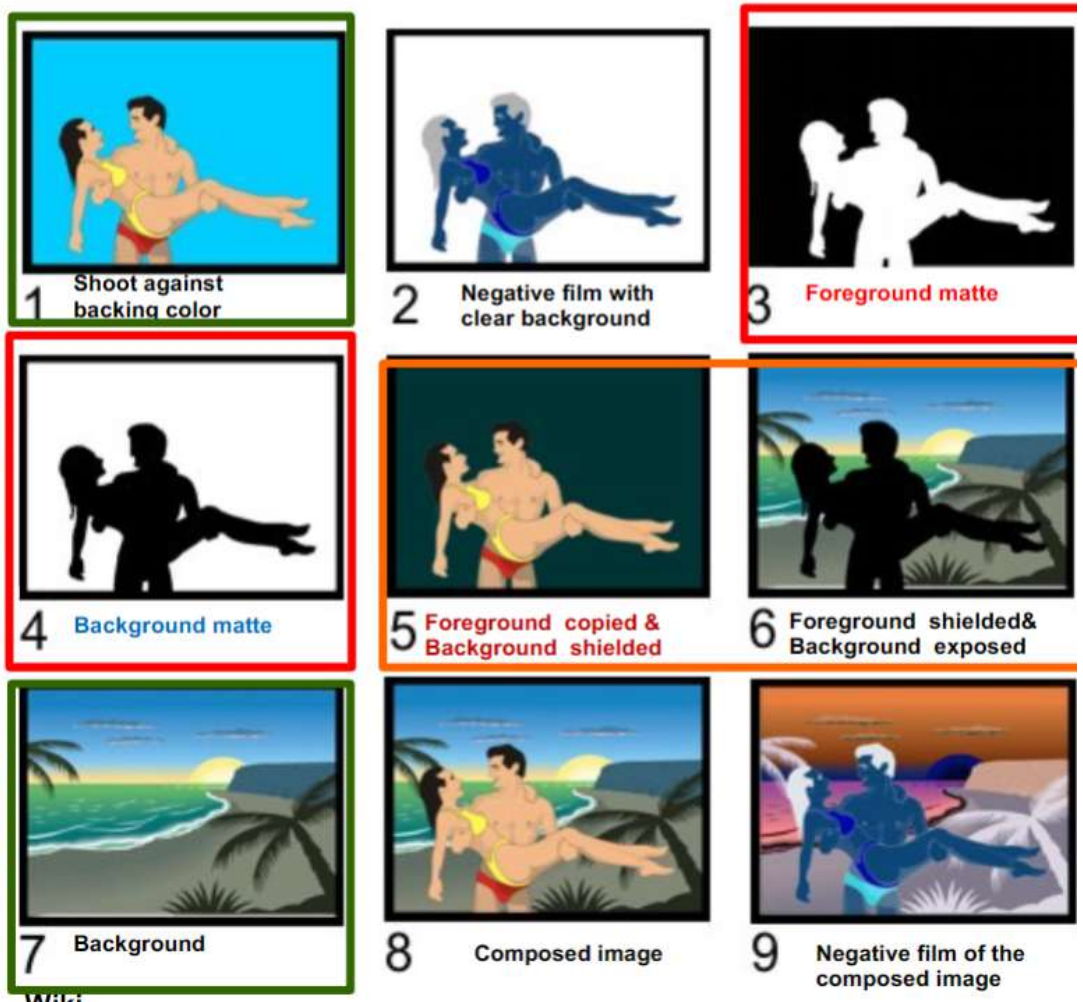
Image Compositing

Matte represents transparency information about the original image.
Originally, a matte was a strip of monochrome film that was overlayed with the color film strip so that only parts of the movie were visible.

First, a print from the original negative is made on high-contrast film, which records the backing as opaque and the foreground subject as clear (fig. 3). A second high-contrast copy is then made from the first, rendering the backing clear and the foreground opaque (fig. 4).

Next, a three-layer sandwich of film is run through an optical printer. On the bottom is the unexposed copy film. Above it is the first matte, whose opaque backing color masks the background. On top is the negative of the foreground action. On this pass, the foreground is copied while the background is shielded from exposure by the matte (fig. 5)

Then the process is repeated; but this time, the copy film is masked by the reverse matte, which excludes light from the foreground area already exposed (fig. 6). The top layer contains the background scene (fig. 7), which is now exposed only in the areas protected during the previous pass. The result is a positive print of the combined background and foreground (fig. 8). A copy of this composite print yields a "dupe negative" (fig. 9) that will replace the original foreground shot in the film's edited negatives



Wiki

Digital Image Compositing

1996: Academy scientific and engineering achievement award (Oscar Ceremony) "For their pioneering inventions in digital image compositing" This is essentially for the invention of the **alpha channel (**which defines the transparency of a region).

"Digital Light: A Biography of the Pixel" presented by Dr Alvy Ray Smith, computer scientist and co-founder of Pixar.
https://www.youtube.com/watch?v=NUp2W3b2dLM

Smith Duff Catmull Porter

The Matte Image

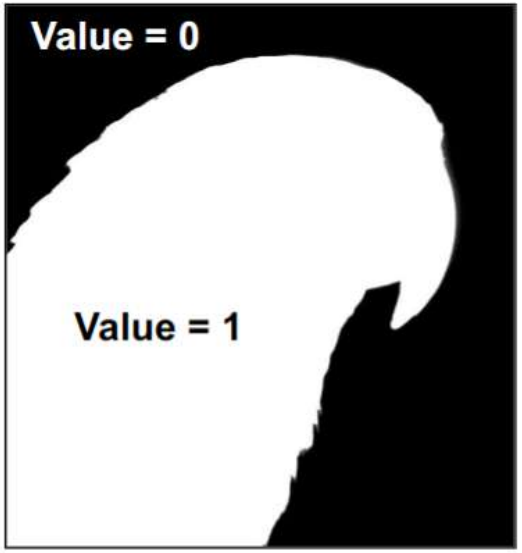
- **Mattes** are used during compositing when only a portion of a certain image to be included in the compositing result.

- Mattes are generally considered to be **single-channel, grayscale images,** since the transparency for any given pixel can be described by a single numerical value in the range of 0 to 1.

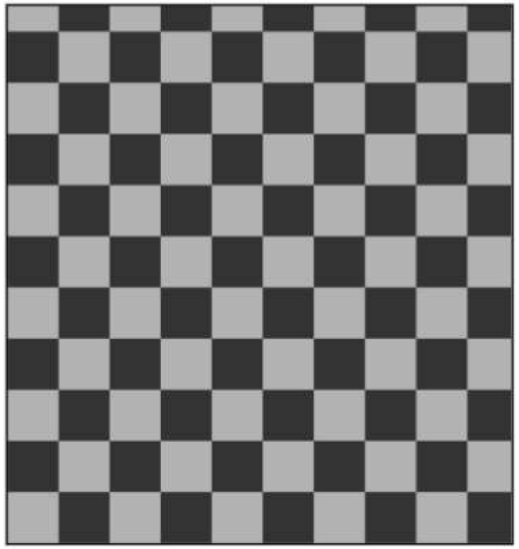
- A matte can also be bundled along with a three-channel color image as a discrete fourth channel. When the matte image is part of a four-channel image, it is known as the ***matte channel*** or the ***alpha channel***.

The Matte Image

(a) Foreground image



(c) Matte image



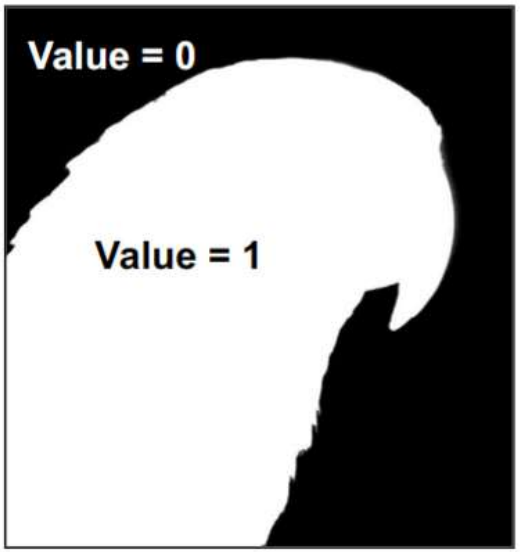
(b) Background image

Image resulting from (a), (b) and (c)

The areas that are white in the matte channel are used to specify that the corresponding area of the foreground image is kept at full transparence. Conversely, the black areas of the matte are used to specify that the corresponding pixels in the foreground image will be opaque, or effectively removed, when it is placed over the background.

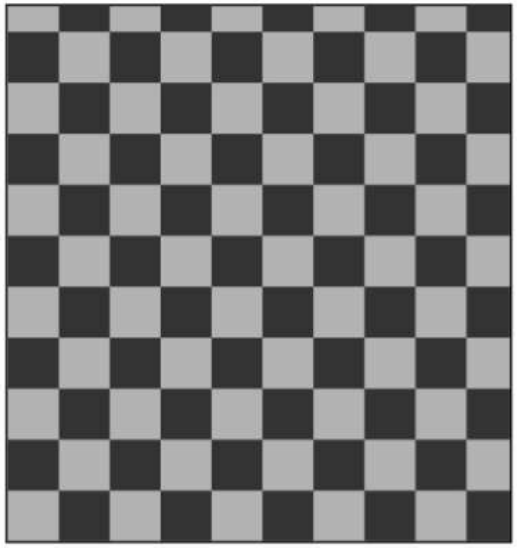
Multisource Operator – OVER

× (a) Foreground image **A**

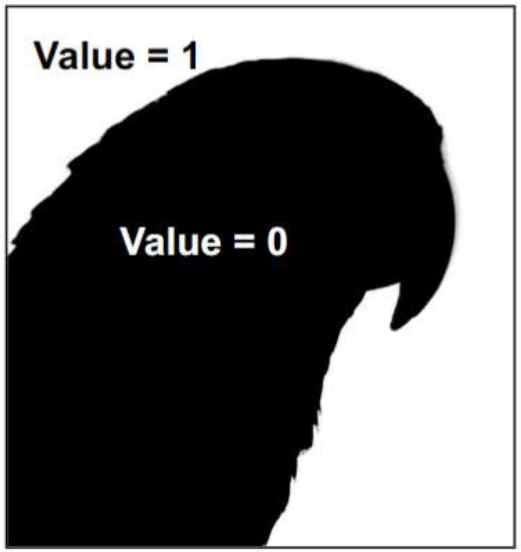


(c) Matte image **M**

+



× (b) Background image **B**



(d) Inverted matte image **(1 – M)**

O = (A × M) + [(1 – M) × B]

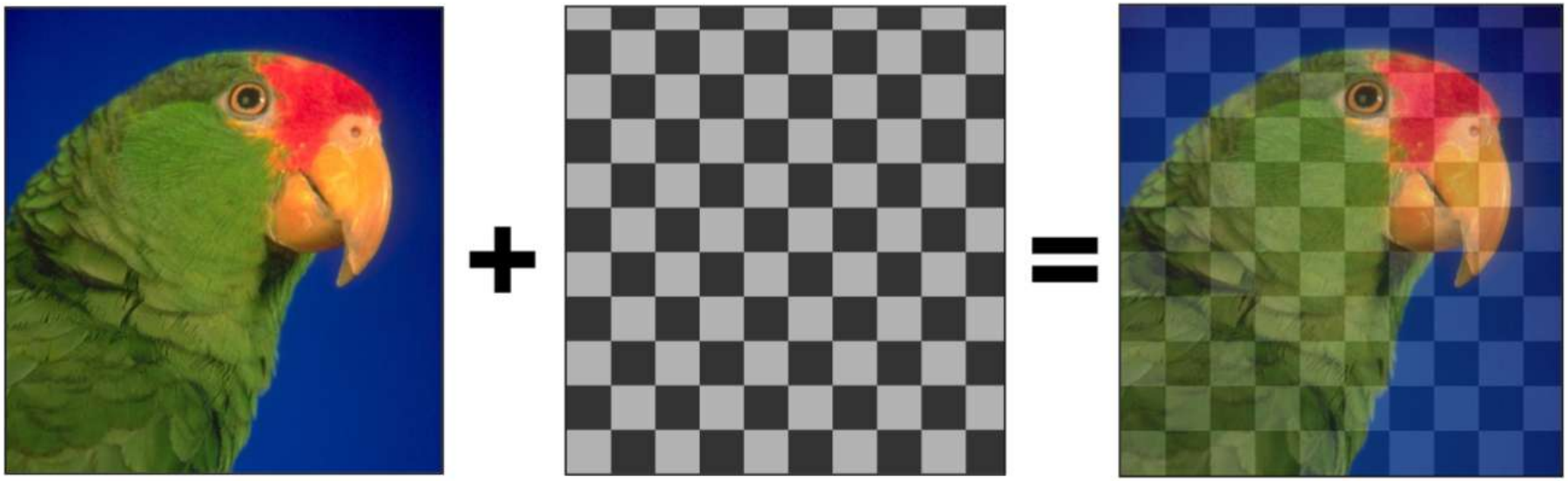
=

Image **O** resulting from placing (a) over (b) using the matte image in (c).

Multisource Operators - MIX

$$O = (MV \times A) + [(1 - MV) \times B]$$

A **mix** is the weighted, normalized addition of two images. In other words, the two images are averaged together, often with one of the images contributing a larger percentage to the output.



(a) Foreground image **A** × **75%**

(b) Background image **B** × **25%**

Image **O** resulting from mixing 75% of (a) with 25% of (b).

$$O = (MV \times A) + [(1 - MV) \times B]$$

*** MV = 75%**

Compositing with pre-multiplied images

The Premultiplied Image

Usually, when a fourth (Alpha) channel is added to an RGB image, the color channels are modified as well, to include some of the information from the matte channel.

The standard definition of a four-channel (RGBA) image assumes that the red, green, and blue channels have already been multiplied by the integrated matte channel. Such an image is referred to as a ***premultiplied image***.

Compositing with Premultiplied Images

It is extremely important to understand exactly what type of image (premultiplied or not) your system's compositing operators expect.

Some systems assume that they will always be dealing with premultiplied images; others may require the image and matte to be brought in separately so that they can be recombined during the operation.

If you do not use the proper type of image, you run the risk of introducing a wide variety of unacceptable artifacts.

Compositing with Premultiplied Images

(a) Foreground image of a dog

×

(b) A soft-edged matte for the dog

=

Foreground (a) premultiplied by the matte (b).

Compositing with Premultiplied Images

Background image – It features the same wall (shot from an identical camera position), only with a cat standing in front of the wall

×

background image premultiplied by the inverse matte

Compositing with Premultiplied Images

Normal Result

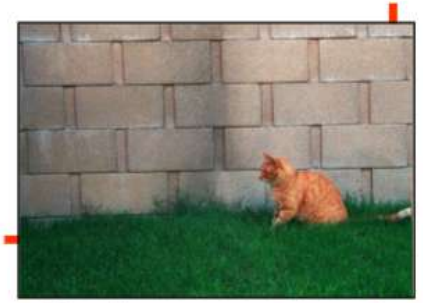
Premultiplied image placed over the background image in a system that assumes all images are premultiplied.

The soft edges blend well with the background and there are no noticeable artifacts.

Compositing with Premultiplied Images

Abnormal Result

However, if we combine them without premultiplying the color channels, we have an image that will not be handled properly if our Over operator is expecting a premultiplied image.



Note that the foreground element, in areas where its matte is supposed to be 0, is still contributing to the result. It is exactly as if we had simply added the two images together.

Bluescreen and GreenScreen

Chroma-keying里面有提到这俩，还有Animation里面的time freeze里面也有提到一嘴，其他地方都没有。

Matte creation/extraction methods

Static Matte and Traveling Matte

When handling matte extraction, if the object does not move, the required matte is called a **static matte**.

However, when compositing sequences of images, situations involving static mattes are fairly rare. More often we need to create a matte for an object that is moving within or through the frames. We require the use of a **moving matte**, or **traveling matte**.

Since hand-drawing a matte for every frame of a sequence is time-consuming and error prone. Ultimately, we will need to rely on more procedural techniques – semi-automated processes in which some initial parameters are determined that are capable of extracting a matte, and then the software is allowed to apply these same parameters over a sequence of images.

There are many different methods used to generate mattes for compositing. The process of generating a matte, particularly when automated, is referred to "**Matte Extraction**", "**Pulling a Matte**", or "**Keying**".

Procedural Matte Extraction

The methods of extracting a matte for a subject rely on the fact that we usually know in advance that we are planning to place the object into a different scene. Consequently, we can choose to photograph this subject in a manner that greatly simplifies its matte extraction.

Typically, this involves the use of **a special background** that is placed behind the subject we wish to isolate. This background should have a uniform color, ideally a color that is not significantly present in the subject itself. The exact choice of what color to use will be determined by the extraction technique that will be employed, but by far the most common color that is employed is **BLUE**. Thus, the process of shooting in front of any colored background is generically known as **bluescreen photography**.

Chroma-keying

Keying Based on Chrominance (Chroma-Keying)

In the case of a simple **chroma-keying**, the process **is to pick a certain range of colors or hues and to define only the pixels that fall within this range as being part of the background**. **A good chroma-key algorithm can be used to pull a matte from a bluescreen or a greenscreen video shooting**.

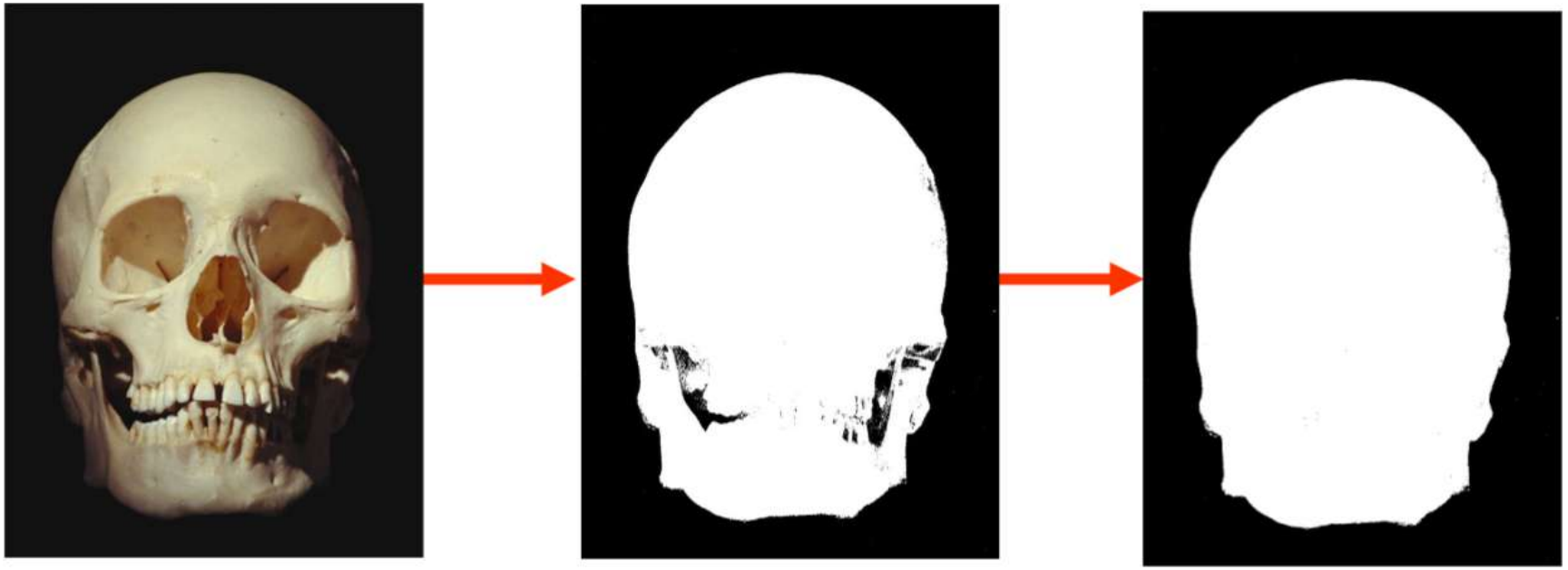
While the chroma-keying utilizes the color (**H**ue) information of an image, it ignores the luminance (**I**ntensity) and saturation (**S**) values. Due to the natural limitation of lighting technique, even professional studio hardly produces pure solid background color over the whole image.

Keying Based on Luminance (Luma-Keying)

One of the most common methods used to extract a matte for a given item is based on manipulating the luminance values in a scene. This is usually known as **luma-keying** and involves the application of some basic image processing **to choose the luminance values to be included or excluded from the matte**.

This technique is generally most useful when the feature you wish to extract from the scene is significantly brighter or darker than the background from which you wish to separate it. The ideal case would be a bright object shot over a black background. You will find that there are often situations in which the brightness difference between foreground and background is enough to extract a decent matte.

Keying Based on Luminance (Luma-Keying)



Skull image
on a dark background

Matte extracted by
luminance-based keying

A bit of manipulation can quickly produce the matte image. We now have something that could easily be used as a crude matte, and additional digital manipulations could continue to refine the result. This situation would also benefit greatly from the use of an interior garbage matte (a loose-fitting shape).

Difference matting

Difference Matting

In theory, if an image contains the subject you wish to isolate, and another identically framed image does not contain the subject, then subtracting one from the other will produce an image with the subject. This process is known as **difference matting**.

In practice, slight lighting discrepancies, shadows, and grain make the difference between the two images unpredictable and the results less than perfect. Difference matting is thus usually not considered a complete solution, but rather as a very useful first-pass method that can then be cleaned up using other methods.

Since a difference matte requires two separate images with the same lighting and camera setups, it is a limited tool. Using it to produce a traveling matte from a sequence of images would require either an unmoving camera or some method of perfectly synchronizing the camera movements.

In spite of these limitations, **difference matting is an very useful tool because it can be used to extract a matte from just about any background**.

Difference Matting

(a) Image of a dog

(b) A clean plate of the background

The difference matte that is created by subtracting (b) from (a).

While this is by no means a perfect matte, it is not a bad starting point and can be digitally manipulated to produce something that is more acceptable.

Color Difference Method

The Color Difference Method

By far the most popular and effective method for procedurally generating **traveling mattes** is known as the **color difference method**.

This method was developed and patented by Petro Vlahos (awarded Oscars) in 1964 as an optical matte extraction process. **The core idea of the color difference algorithm is to calculate the transparency value based on the difference between the R, G and B color channels.**

The method was originally invented for creating mattes from film material (and not digital images), this approach was later implemented in hardware for analogue video signals and since 1995 also in software distributed by Vlahos founded company ***Ultimatte***. This is the reason why *Ultimatte is the only company that offers professional keying solutions based on the color difference approach*.

The Color Difference Method

The matting or keying makes use of the important differences between the three color channels of the target and the special background e.g. bluescreen.

That means the blue background has much higher blue values than the target; in comparison, the target has higher red and green values than the background. Therefore, if a pixel has higher blue value than red and green, then it will be considered as a background pixel.

Bluescreen

Red channel

Green channel

Blue channel

The Color Difference Method

The method is a combination of steps that includes **matte extraction, color correction, and image combination**.

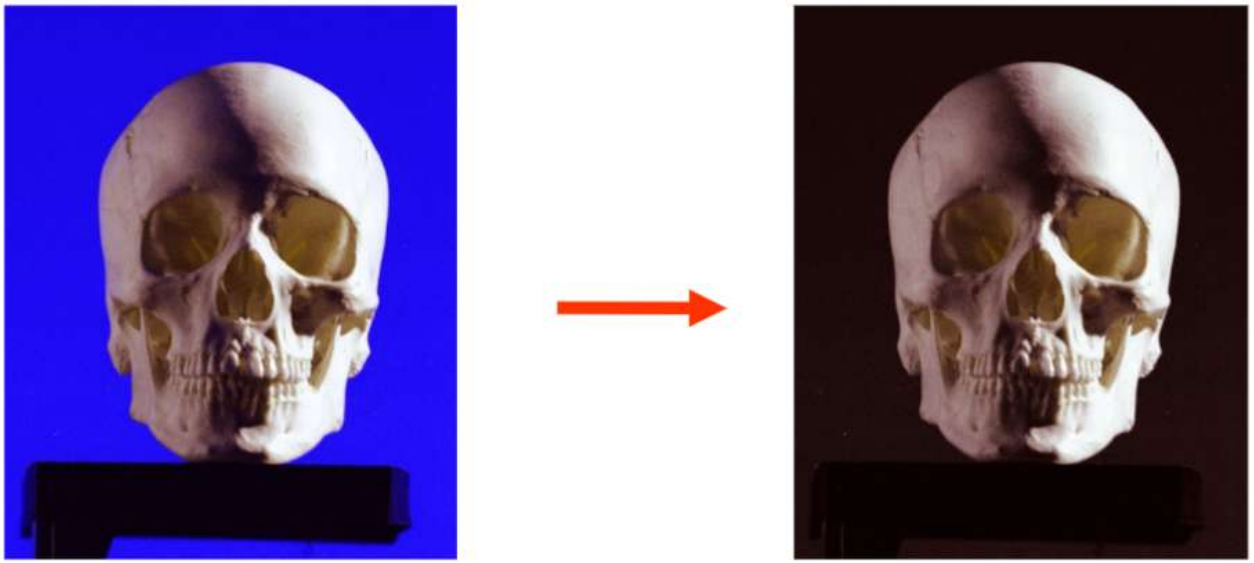
Assume we are working with an image shot against a blue background.

Step 1 in the color difference method involves the creation of a new image in which this **blue backing is suppressed to black**.

This is done by selectively substituting the blue channel by the green channel in every pixel in which the existing blue component has a greater value than the green component:

```
for each pixel
  If Blue > Green
  then replace Blue with Green
```

The Color Difference Method



(a) Original bluescreen image

(b) The image from (a) after applying spill suppression

Since the green channel should have a value of 0 in areas of pure blue backing, the primary result of this substitution is an image in which the blue background has gone to black.

Additionally, anything in the foreground that has a heavy blue component (i.e. blue or magenta areas) will be modified.

Although this effect is a problem if there is any blue coloration in the foreground that we wish to keep, it is a benefit in that it will ***neutralize*** *any* ***blue spill – blue lighting from the backing that has inadvertently fallen onto the foreground.*** This first step is also known as "**Spill suppression**".

The Color Difference Method

Step 2 in the color difference method involves **the creation of the (inverted) matte** itself. This is simply a matter of **subtracting the maximum of the red or the green component from the blue component**. To restate the step mathematically:

```
Matte = Blue - Maximum(Green, Red)
```

This operation will actually produce what we would normally think of as an inverted matte – the foreground area is black and the background area is white.

We then simply multiply this inverted matte with our intended background – a step that results in a background with a black hole in the shape of our foreground to this intermediate background, producing an integrated result.

Reverse matte extraction

The final steps of this process are identical to the way that the Over operator works for the premultiplied images.