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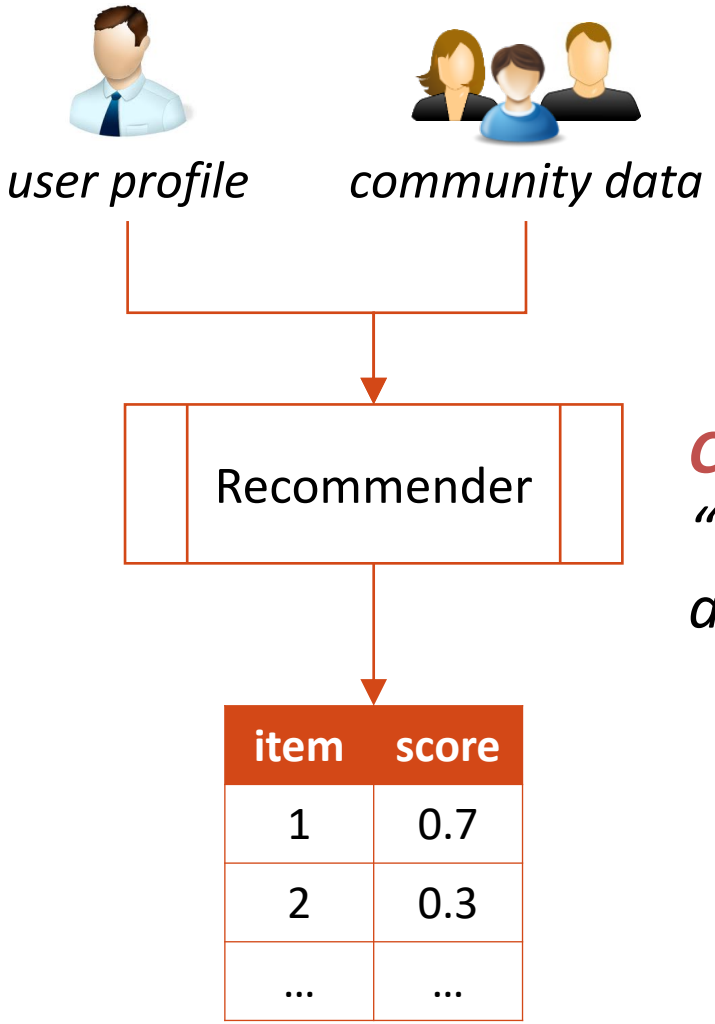
Recommender Systems

Constraint-based Recommendation

Rodrygo L. T. Santos
rodrygo@dcc.ufmg.br

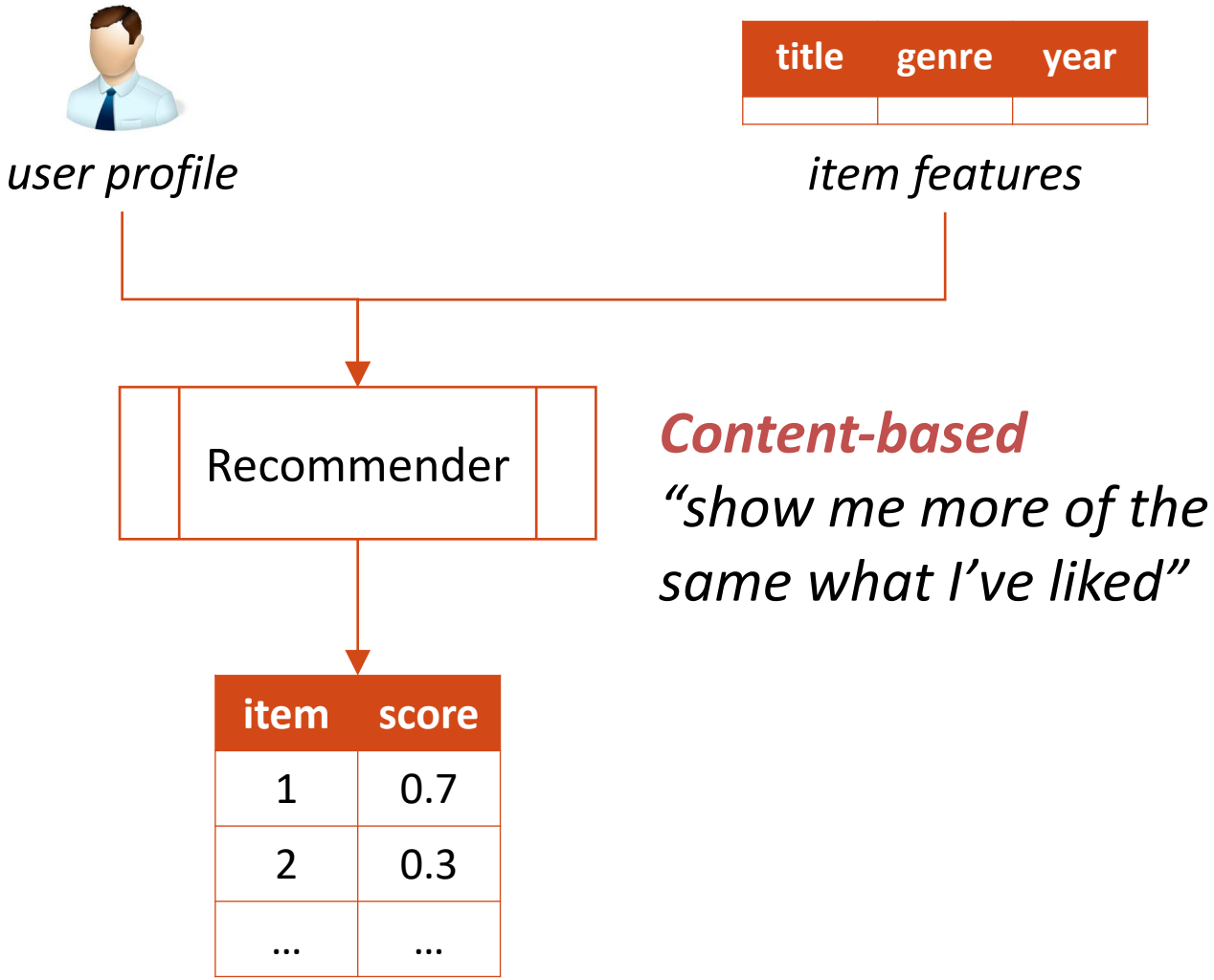
How to recommend?



Collaborative filtering

"tell me what's popular among my peers"

How to recommend?



Content-based

"show me more of the same what I've liked"

Credit: Eddy 1 CC BY 2.0

How to recommend this?

Collaborative filtering?

- Probably not that many ratings…

Content-based filtering?

- Hard to describe in words

In both cases, users' preferences may evolve

- Different family / financial situation

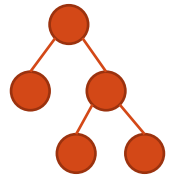
How to recommend this?

Users may have their own ***explicit requirements***

- 25m+ swimming pool
- 10+ bedrooms
- 8+ parking spaces

How to recommend?

user profile



knowledge models

Recommender

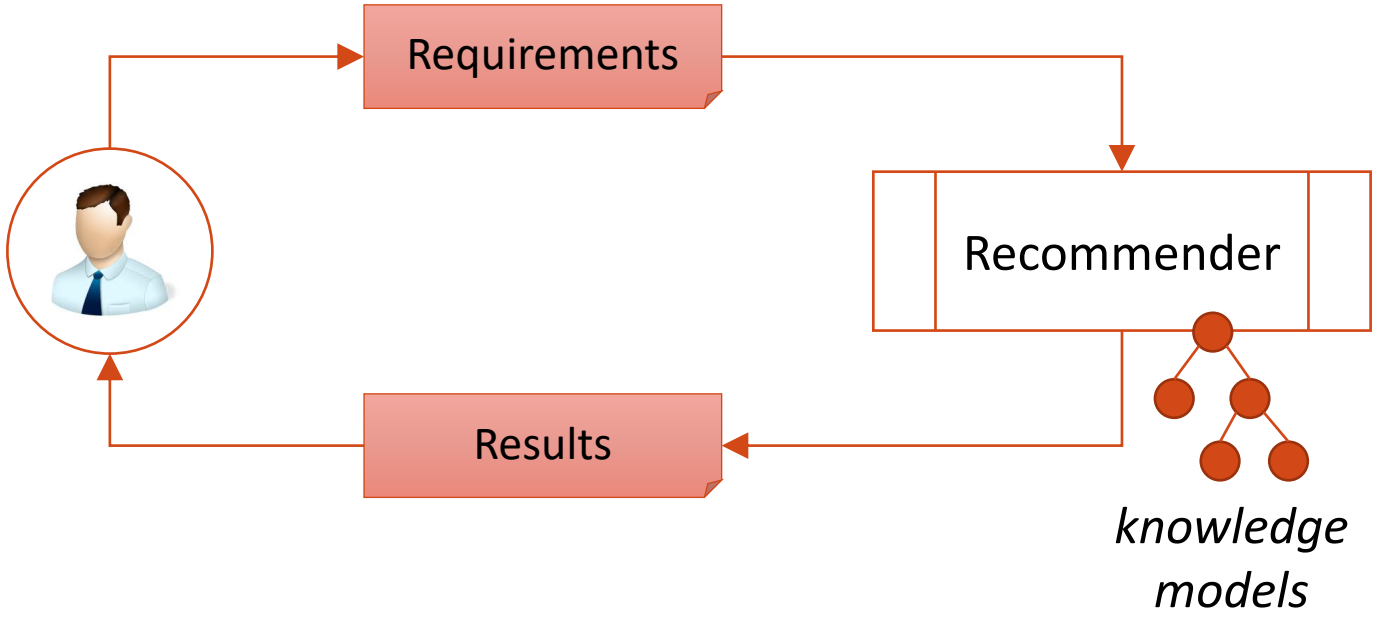
Knowledge-based

"tell me what fits based on my needs"

item	score
1	0.7
2	0.3
…	…

Knowledge-based recommendation

Conversational recommendation process



Knowledge about items

Example for digital cameras

id	price	mpixel	zoom	LCD	video	sound	wproof
i_1	148	8.0	4×	2.5	no	no	yes
i_2	182	8.0	5×	2.7	yes	yes	no
i_3	189	8.0	10×	2.5	yes	yes	no
i_4	196	10.0	12×	2.7	yes	no	yes
i_5	151	7.1	3×	3.0	yes	yes	no
i_6	199	9.0	3×	3.0	yes	yes	no
i_7	259	10.0	3×	3.0	yes	yes	no
i_8	278	9.1	10×	3.0	yes	yes	yes

Knowledge about users

Absolute requirements

- *Price lower than US$ 300*
- *Suited for sports*

Relative requirements

- *Price lower than the current*
- *More sporty than the current*

Constraint-based recommendation

Case-based recommendation

Constraint-based recommenders

id	price	mpixel	zoom	LCD	video	sound	wproof
i_1	148	8.0	4×	2.5	no	no	yes
i_2	182	8.0	5×	2.7	yes	yes	no
i_3	189	8.0	10×	2.5	yes	yes	no
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i_7	259	10.0	3×	3.0	yes	yes	no
i_8	278	9.1	10×	3.0	yes	yes	yes

Example requirements

- Price lower than 200
- Suited for sports photography (*video* = yes, *wproof* = yes)

Constraint satisfaction

Given a tuple ($V_u \cup V_i$, D, $C_u \cup C_i \cup C_r$)

- V_u: user variables (requirements)
  - *maxprice* (0:1000), *usage* (digital, large-print)
- V_i: item variables (properties)
  - *price* (0:1000), *mpixel* (3.0:12.0), *wproof* (true, false)
- D: domain of each variable

Constraint satisfaction

Given a tuple ($V_u \cup V_i$, D, $C_u \cup C_i \cup C_r$)

- C_u: restrictions on user requirements
  - *usage*=large-print → *maxprice*>200
- C_i: available item properties
  - (*price*=100 ∧ *mpixel*=3.0) ∨ (*price*=700 ∧ *mpixel*=8.0)
- C_r: restrictions on user-item relationships
  - *usage*=large-print → *mpixel*>5.0

Constraint satisfaction

Given a tuple $(V_u \cup V_i, D, C_u \cup C_i \cup C_r)$

Solution

- θ: $\forall x \in V_i, (x = v) \wedge v \in dom(x)$
- s.t. $C_u \cup C_i \cup C_r$ is satisfiable

Classical problem in operations research

- Many solvers available

Conjunctive querying

Instead of finding solutions to a CSP

- Run a query against the item database

Conjunctive query

- A set of selection criteria connected conjunctively

$\sigma_{[criteria]}I$ I: available items

Conjunctive querying

id	price	mpixel	zoom	LCD	video	sound	wproof
i_1	148	8.0	4×	2.5	no	no	yes
i_2	182	8.0	5×	2.7	yes	yes	no
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$$\sigma_{[mpixel \geq 10 \wedge price < 300]}(I) = \{i_4, i_7\}$$

Interacting with constraints

User specifies initial constraints

- All at once or interactively, in a wizard-style

System presents matching items

- With potential explanations for each item

User might revise initial constraints

- Broaden or narrow down requirements

Defaults

What if there are too many variables?

- Provide users with reasonable defaults

Type of defaults

- Static: *usage* = large-print
- Dependent: (*usage* | *maxprice* = 200) = small-print
- Derived: (*usage* | *usage logs*) = digital

Unsatisfied requirements

What if no solution is found?

- We may suggest some alternatives

Constraint relaxation

- Eliminate constraints until a solution is found
- Suggest adaptations to current constraints

Conflict sets

id	price	mpixel	zoom	LCD	video	sound	wproof
i_1	148	8.0	4×	2.5	no	no	yes
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i_8	278	9.1	10×	3.0	yes	yes	yes

r_1: *price* <= 150

r_2: *zoom* = 5×

r_3: *sound* = yes

r_4: *wproof* = yes

CS_1: $\{r_1, r_2\}$ ✗

Conflict sets

id	price	mpixel	zoom	LCD	video	sound	wproof
i_1	148	8.0	4×	2.5	no	no	yes
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r_4: *wproof* = yes

CS_1: $\{r_1, r_2\}$ ✗
CS_2: $\{r_1, r_3\}$ ✗

Conflict sets

id	price	mpixel	zoom	LCD	video	sound	wproof
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r_1: *price* <= 150
r_2: *zoom* = 5×
r_3: *sound* = yes
r_4: *wproof* = yes

CS_1: $\{r_1, r_2\}$ ✗
CS_2: $\{r_1, r_3\}$ ✗
CS_3: $\{r_1, r_4\}$ ✓

Conflict sets

id	price	mpixel	zoom	LCD	video	sound	wproof
i_1	148	8.0	4×	2.5	no	no	yes
i_2	182	8.0	5×	2.7	yes	yes	no
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r_1: *price* <= 150
r_2: *zoom* = 5×
r_3: *sound* = yes
r_4: *wproof* = yes

CS_1: $\{r_1, r_2\}$ ✗
CS_2: $\{r_1, r_3\}$ ✗
CS_3: $\{r_2, r_3\}$ ✓

Conflict sets

id	price	mpixel	zoom	LCD	video	sound	wproof
i_1	148	8.0	4×	2.5	no	no	yes
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r_1: *price* <= 150
r_2: *zoom* = 5×
r_3: *sound* = yes
r_4: *wproof* = yes

CS_1: $\{r_1, r_2\}$ ✗
CS_2: $\{r_1, r_3\}$ ✗
CS_3: $\{r_2, r_4\}$ ✗

Conflict sets

id	price	mpixel	zoom	LCD	video	sound	wproof
i_1	148	8.0	4×	2.5	no	no	yes
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r_1: *price* <= 150
r_2: *zoom* = 5×
r_3: *sound* = yes
r_4: *wproof* = yes

CS_1: $\{r_1, r_2\}$ ✗
CS_2: $\{r_1, r_3\}$ ✗
CS_3: $\{r_2, r_4\}$ ✗
CS_4: $\{r_3, r_4\}$ ✓

Conflict sets

id	price	mpixel	zoom	LCD	video	sound	wproof
i_1	148	8.0	4×	2.5	no	no	yes
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r_1: *price* <= 150
r_2: *zoom* = 5×
r_3: *sound* = yes
r_4: *wproof* = yes

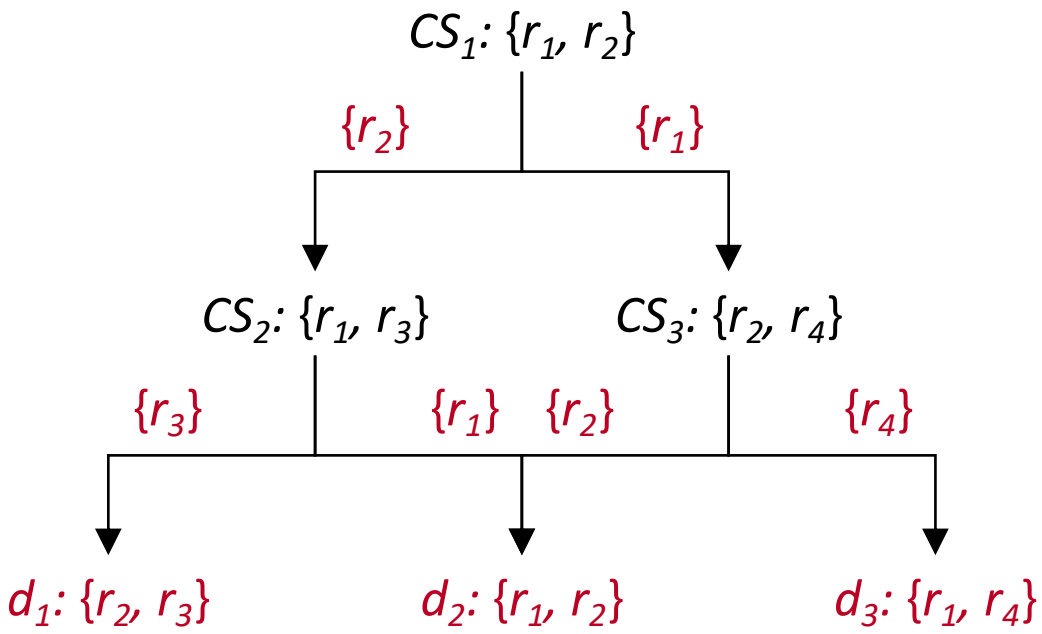
CS_1: $\{r_1, r_2\}$ ✗
CS_2: $\{r_1, r_3\}$ ✗
CS_3: $\{r_2, r_4\}$ ✗

Relaxing constraints

Calculate diagnosis for CSs

- r_1: price <= 150
- r_2: zoom = 5×
- r_3: sound = yes
- r_4: wproof = yes

- CS_1: $\{r_1, r_2\}$ ✗
- CS_2: $\{r_1, r_3\}$ ✗
- CS_3: $\{r_2, r_4\}$ ✗



Repairing constraints

Identify possible adaptations

- Query the catalog I with $\pi_{[attr(d)]}\ \sigma_{[criteria-d]}(I)$

Example

- *Rep*$_1$: $\pi_{[attr(d_1)]}\ \sigma_{[criteria-d_1]}(I)$ = {*zoom*=4×, *sound*=no}

  - r_1: price <= 150
  - r_2: zoom = 5×
  - r_3: sound = yes
  - r_4: wproof = yes

d_1: {r_2, r_3}

repair	price	zoom	sound	wproof
Rep_1	148	4×	no	yes

Repairing constraints

Identify possible adaptations

- Query the catalog I with $\pi_{[attr(d)]}\ \sigma_{[criteria-d]}(I)$

Example

- *Rep*$_1$: $\pi_{[attr(d_2)]}\ \sigma_{[criteria-d_2]}(I)$ = {*price*=278, *zoom*=10×}

  - r_1: price <= 150
  - r_2: zoom = 5×
  - r_3: sound = yes
  - r_4: wproof = yes

	repair	price	zoom	sound	wproof
d_1: {r_2, r_3}	Rep$_1$	148	4×	no	yes
d_2: {r_1, r_2}	Rep$_2$	278	10×	yes	yes

Repairing constraints

Identify possible adaptations

- Query the catalog I with $\pi_{[attr(d)]}\ \sigma_{[criteria-d]}(I)$

Example

- *Rep*$_1$: $\pi_{[attr(d_3)]}\ \sigma_{[criteria-d_3]}(I)$ = {*price*=182, *wproof*=no}

- r_1: price <= 150
- r_2: zoom = 5×
- r_3: sound = yes
- r_4: wproof = yes

	repair	price	zoom	sound	wproof
d_1: {r_2, r_3}	Rep$_1$	148	4×	no	yes
d_2: {r_1, r_2}	Rep$_2$	278	10×	yes	yes
d_3: {r_1, r_4}	Rep$_3$	182	5×	yes	no

Ranking the items

Multi-attribute utility

- Each item is evaluated wrt a set of dimensions
- e.g., for digital cameras
  - Quality
  - Economy

User interest

user	quality	economy
u_1	80%	20%
u_2	40%	60%

attrib	value	quality	economy
price	≤250	5	10
	>250	10	5
mpixel	≤8	4	10
	>8	10	6
zoom	≤9	6	9
	>9	10	6
LCD	≤2.7	6	10
	>2.7	9	5
video	yes	10	7
	no	3	10
sound	yes	10	8
	no	7	10
wproof	yes	10	6
	no	8	10

$$\hat{r}_{ui} = \sum_{k \in \{q,e\}} interest(u,k) \sum_{a \in att(i)} contribution(a,k)$$

Example

etown's Ask Ida

- No longer exists (old screenshots)
- Uses an interview process to elicit preferences
- ***Not intended as permanent preferences***

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Sale $149.99

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Minidisc Portable Recorder

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$169.70

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Free Shipping!
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$879.88

JBL PSWD 112

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Choosing a digital camera

Picking out the right digital camera is a matter of finding out which features and benefits will work best for you. Answer a few questions for us, and we'll help you pick one that you'll like. There are 50 digital cameras to choose from so let's get started.

How are you planning on using the images that you'll shoot with your new digital camera? (Check all that apply.)

- ☐ **Post them to a Web site.** I need enough picture quality for my shots to look good on screen, though I don't need to print them.
- ☐ **Email them to friends and family.** I need a wide range of picture quality; some people may want to print the pictures I send.
- ☐ **Make prints out of them.** I need an upper-level camera with the best possible picture resolution, because at some point, there'll be hard copies.

Next question

Picture quality

While no digital camera produces pictures with the same quality as a good film-based camera, the gap is closing, particularly with the advent of the new "megapixel" digital cameras, which feature more than a million pixels of image quality. However, for casual exchange of photos, or use on Web sites, much of this resolution is unnecessary -- screen resolution on a PC is only 75 pixels per inch.

Of course, the better your original image -- in other words, the higher the resolution it was shot with -- the better your final presentation is, whether it's on screen or in a hard-copy print. As you look through your choices, consider how much resolution you really need for your intended use. If you don't need megapixel performance, there's no reason to pay extra for it, particularly when there are excellent digital cameras around that will do fine for Web or email work.

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Experience

Your answers to the next 2 questions will help me determine which digital cameras I should recommend to you.

In general, how experienced a photographer are you?

- ○ **I'm a casual user.** I like to shoot pictures, and I don't like to fuss with technology. The simpler my camera is, the better I like it.
- ◉ **I know my way around a camera.** I'm interested in a digital camera with features that can make my work better and more enjoyable.
- ○ **I'm an avid photographer.** I want an advanced digital camera that can keep up with my ideas and provide me with the most creative options.

Next question

High-end features

All digital cameras are capable of point-and-shoot simplicity, but some have more options and features than others. If you're a casual photographer, many of these features can appear intrusive, and in most shooting situations, you may not ever need them. However, If you're an experienced photographer, you'll want a model with an extensive feature set that includes manual overrides, so that you'll have control over exposure and focus for creative effects.

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Budget choice

I have divided all the digital cameras into 4 budget categories. If you would like, I can exclude products that cost more than you are willing to spend.

About how much would you consider spending on a new digital camera?

- ○ **Up to $300.** In this price range you can expect to find a fairly basic digital camera with no zoom lens and standard picture resolution (under a megapixel). These cameras will produce images that are fine for posting to the Web or emailing, but do less well when they're printed on paper. *All of the 6 digital cameras in this range fit your expressed needs well.*
- ◉ **Up to $600.** At the lower end of this price range you'll find some megapixel cameras that produce images that can be printed out at small sizes with acceptable results. Toward the high end, there are feature-rich cameras that produce fairly high-quality images that translate into sharp prints at sizes up to 4 x 6 inches. *All of the 24 digital cameras in this range fit your expressed needs well.*
- ○ **Up to $900.** If bigger-sized hard copies are what you're after, you'll probably have to step up to this price range. Cameras here generally have a zoom lens and a minimum resolution of 1.3 megapixels; some top the 2-megapixel mark. Most models in this category also have more flexibility in their operation, with more manual settings. *All of the 46 digital cameras in this range fit your expressed needs well.*
- ○ **$1000 or more.** This is "prosumer" territory -- the fine line between professional and consumer gear. Many models have 2-megapixel or better resolution, as well as plenty of manual options for more advanced users. Zoom is standard, and some models may have options for adding lenses (wide angle or telephoto). *All of the 50 digital cameras in this range fit your expressed needs well.*

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Ida: Your Interactive Decision Assistant

Initial recommendations

Here's my initial suggested shortlist of the products that best meet your needs, based on what you've told me so far. They all offer an LCD view screen, manual overrides, an optical viewfinder, a serial output connection, a video out connection, a built-in digital zoom, and are within your requested price range.

- **Olympus D450Z** See etown.com Review — $499
  Pros: it can store 18 pictures at its highest resolution, it has 1280 x 960 pixels resolution, it uses SmartMedia to store pictures, and it has an optical zoom lens.
- **Olympus D460 Zoom** Buy — $499
  Pros: it can store 18 pictures at its highest resolution, it has 1280 x 960 pixels resolution, it uses SmartMedia to store pictures, and it has an optical zoom lens.
- **Fuji MX1200** See etown.com Review Buy — $299
  Pros: it can store 23 pictures at its highest resolution, it has 1280 x 960 pixels resolution, and it uses SmartMedia to store pictures. Cons: it doesn't have an optical zoom lens.
- **Nikon 800** Buy — $599
  Pros: it has 1600 x 1200 pixels resolution, it has CompactFlash storage media, and it has an optical zoom lens. Cons: it can store only 8 pictures at its highest resolution.

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I can refine these recommendations if you tell me more about your needs. I suggest **Optical zoom** as the next question to consider, or you can select the topic you wish:

Next question Optical zoom

I can also show you a feature-by-feature comparison of any of the digital cameras listed on this page.

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Optical zoom

Not every digital camera has the ability to zoom in for closeups. Some can, but only by digitally enlarging what the lens sees, a technique which is not as effective as an optical zoom. Some models have an actual optical zoom lens.

How important is a zoom?

- ○ **Not very.** I'm not shooting from any great distances, I don't need to spend extra on a zoom feature.
- ○ **A digital zoom is fine.** I don't need anything too extensive, but some kind of zoom feature would be useful to me.
- ◉ **I need an optical zoom.** I need a the best possible zoom function on my digital camera.

See Recommendations

Optical and digital zoom

A zoom lens brings the subject you're shooting closer -- a useful feature if you're at a distance from your subject. However, there's a big difference between a digital and optical zoom.

A digital zoom doesn't really zoom at all. What it does is electronically enlarge the information that the lens is seeing. While this does make the image larger (more close up), the image quality suffers from the digital manipulation.

An optical zoom is part of the lens itself -- there's no digital sleight-of-hand, and no degradation of the image, no matter how much you zoom. Because an optical zoom is hardware, as opposed to a digital zoom, which is done in software, a digital camera with an optical zoom is usually more costly.

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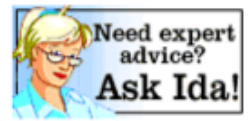

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Recommendations

Here's my shortlist of the products that best meet your needs, based on the new information you gave me. They all offer an LCD view screen, manual overrides, an optical viewfinder, a built-in digital zoom, an optical zoom lens, and are within your requested price range.

- **Olympus D450Z** See etown.com Review — $499
  Pros: it can store 18 pictures at its highest resolution, it has 1280 x 960 pixels resolution, it uses SmartMedia to store pictures, and it has a video out connection.
- **Olympus D460 Zoom** Buy — $499
  Pros: it can store 18 pictures at its highest resolution, it has 1280 x 960 pixels resolution, it uses SmartMedia to store pictures, and it has a video out connection.
- **Fuji FinePix1400** Buy — $399
  Pros: it has 1280 x 960 pixels resolution, it uses SmartMedia to store pictures, and it has a USB connection. Cons: it can store only 6 pictures at its highest resolution, it doesn't have a serial output connection, and it doesn't have a video out connection.
- **Nikon 800** Buy — $599
  Pros: it has 1600 x 1200 pixels resolution, it has CompactFlash storage media, and it has a video out connection. Cons: it can store only 8 pictures at its highest resolution.

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I can refine these recommendations if you tell me more about your needs. I suggest **Shooting aids** as the next question to consider, or you can select the topic you wish:

Next question Shooting aids

I can also show you a feature-by-feature comparison of any of the digital cameras listed on this page.

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Nikon 800 - $599.00 (msrp)

Given the information you have provided, the Nikon 800 is one of my top recommendations. Click the link to go directly to a question that will explain the feature and help you decide if that feature makes sense for you!

Pros: Its advantages include:

- it has an LCD view screen.
- it has manual overrides.
- it has an optical viewfinder.
- it has 1600 x 1200 pixels resolution.
- it has a serial output connection.
- it has CompactFlash storage media.
- it has a video out connection.
- it has a built-in digital zoom.
- it has an optical zoom lens.

Cons: Possible disadvantages include:

- it can store only 8 pictures at its highest resolution.
- it doesn't have a USB connection.

*The Nikon 800 is available for online purchase.

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Show full specification

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Your Product Comparisons

Products are compared by key features. When a product lacks a feature, the feature appears in pale grey. To view a ful
products, click on Modify Comparison List (above).

Digital Cameras:	Digital Cameras:	Digital Cameras:
		
Fuji	Nikon	Olympus
Model No: FinePix1400	Model No: 800	Model No: D450Z
1.2-megapixel digital camera	CoolPix 2.1-megapixel digital camera	1.2-megapixel digital camera
1 year parts & labor	1 year parts & labor	1 year parts & labor
List Price: $399.00	List Price: $599.00	List Price: $499.00
Low Price: $329.00	Low Price: $489.99	--- --- ---
High Price: $329.00	High Price: $498.00	--- --- ---
Buy Now!	Buy Now!	Find Local Retailer
Find Local Retailer	Find Local Retailer	
~~320 x 240~~	~~320 x 240~~	~~320 x 240~~
~~640 x 480~~	~~640 x 480~~	~~640 x 480~~
~~800 x 600~~	~~800 x 600~~	~~800 x 600~~
~~1024 x 768~~	~~1024 x 768~~	~~1024 x 768~~
~~1280 x 1024~~	~~1280 x 1024~~	~~1280 x 1024~~
~~1536 x 1024~~	~~1536 x 1024~~	~~1536 x 1024~~
~~1344 x 1000~~	~~1344 x 1000~~	~~1344 x 1000~~

Summary

Knowledge-based systems

- No user or item cold-start problems
- Good for ephemeral, conversational interactions

Constraint-based systems

- Particularly useful for specialist users
- Could always resort to explanations

Key limitation: knowledge acquisition

References

Recommender Systems: An Introduction (Sec. 4.1-4.3)

Recommender Systems Handbook (Ch. 6)

Recommender Systems: The Textbook (Sec. 5.1-5.2)