Query-Dependent Image Re-Ranking Using Click Data

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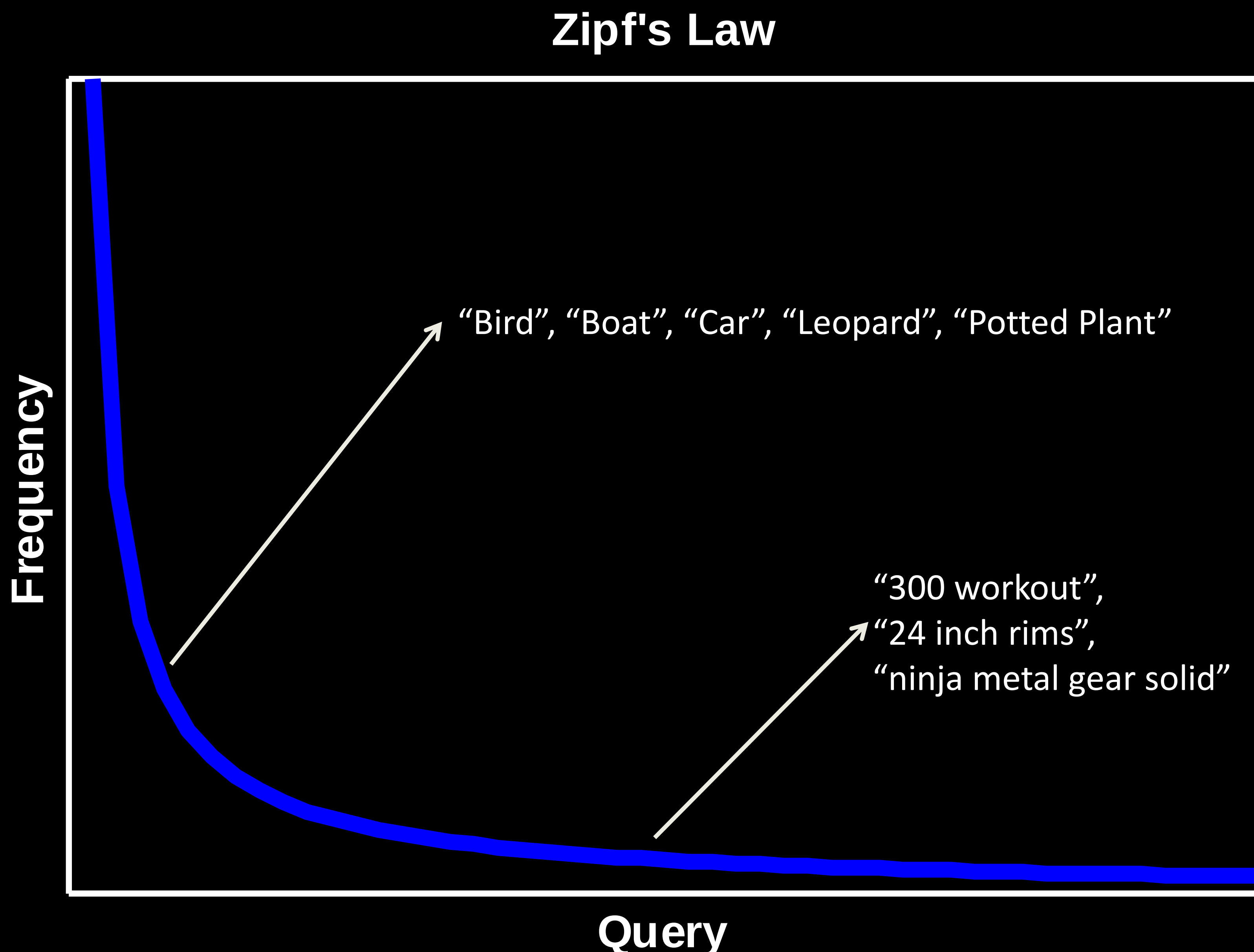
Distribution of Image Search Queries



Yahoo! Image Search Results for top computer vision researchers - Windows Internet Explorer

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1-5 of 5 for **top computer vision researchers**

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WoWdarkportal jpg
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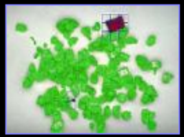

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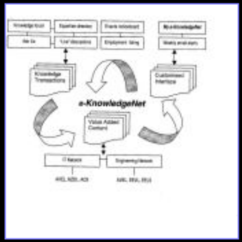

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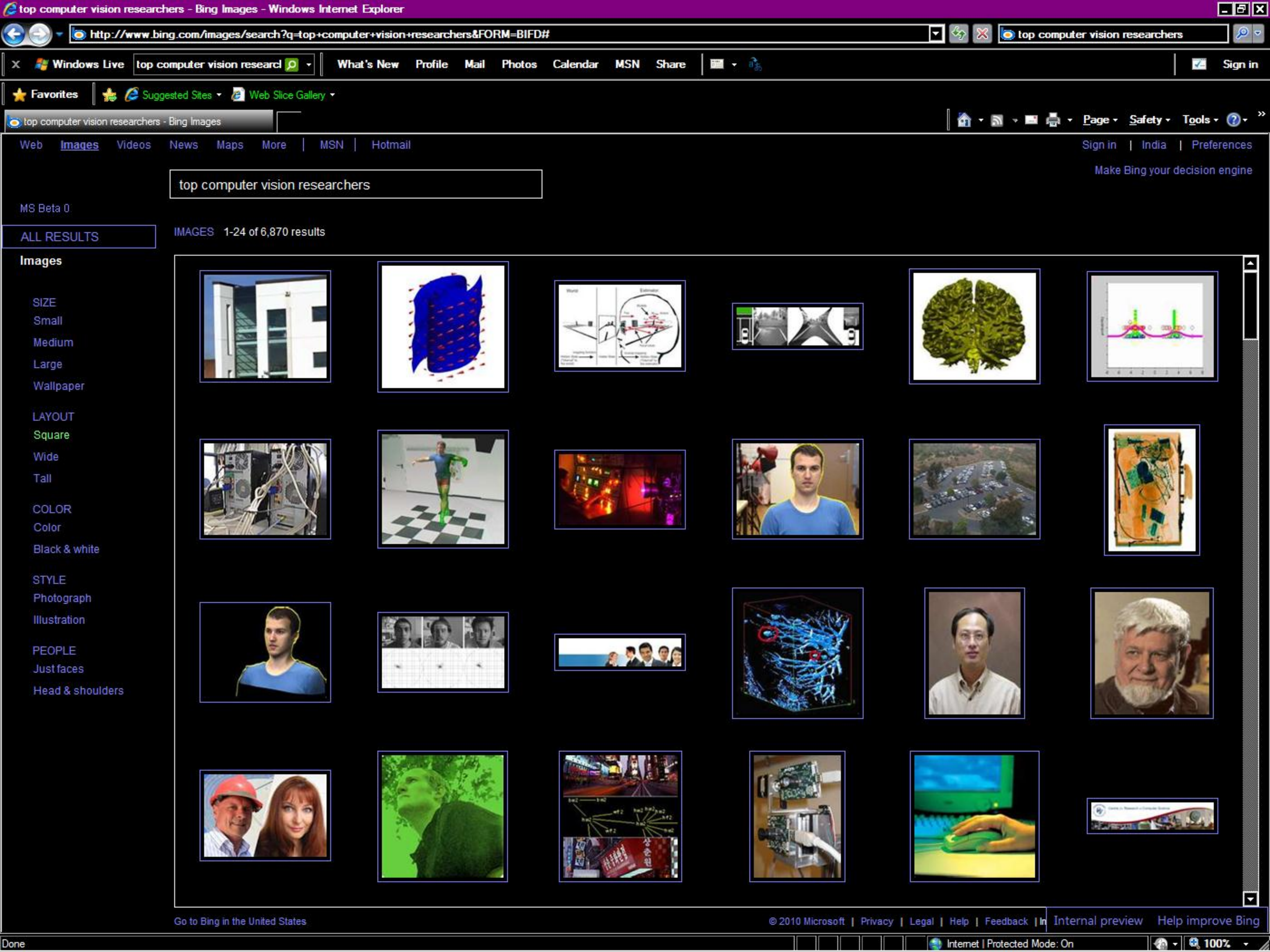
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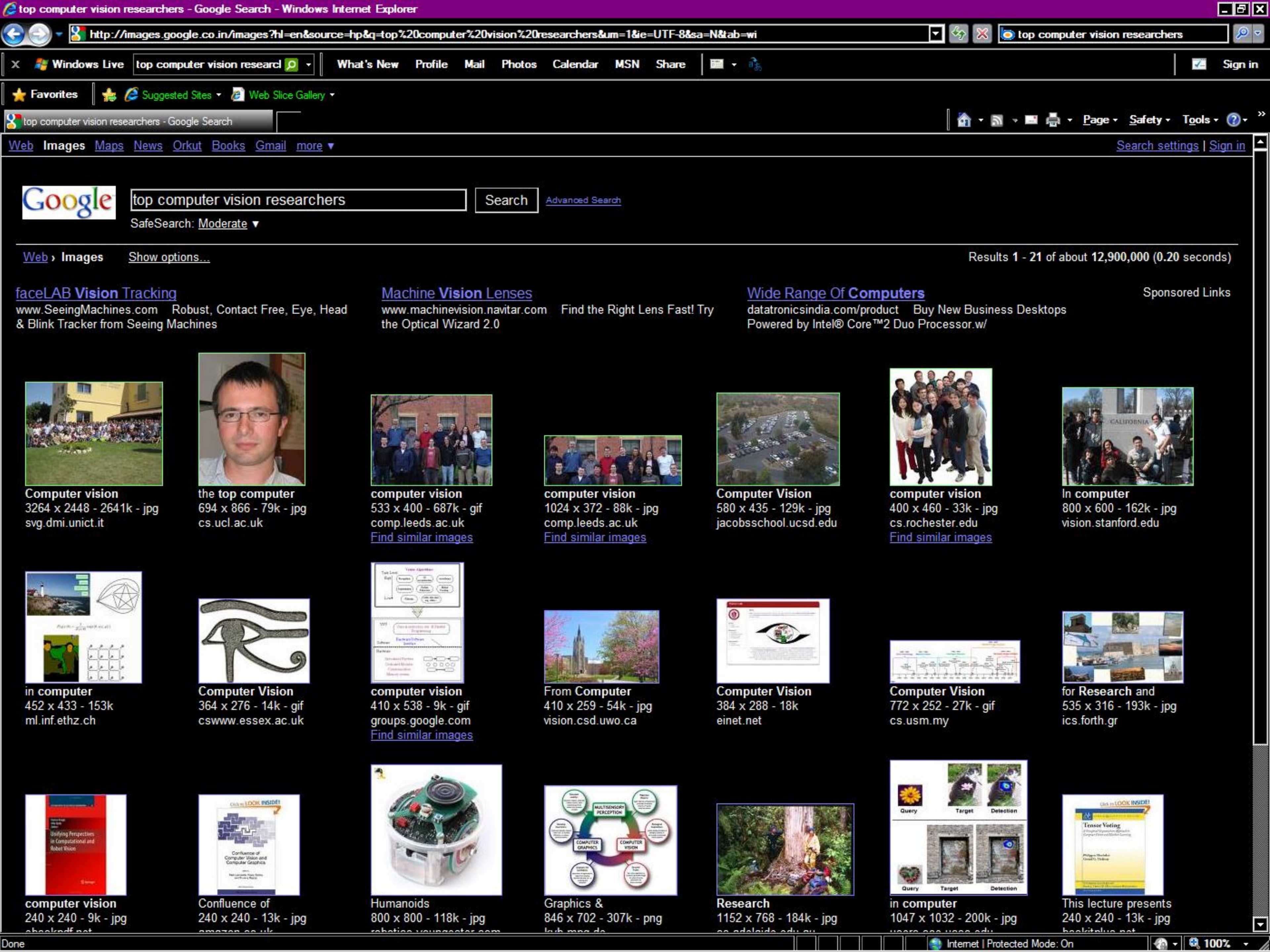
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Results 1 - 21 of about 12,900,000 (0.20 seconds)
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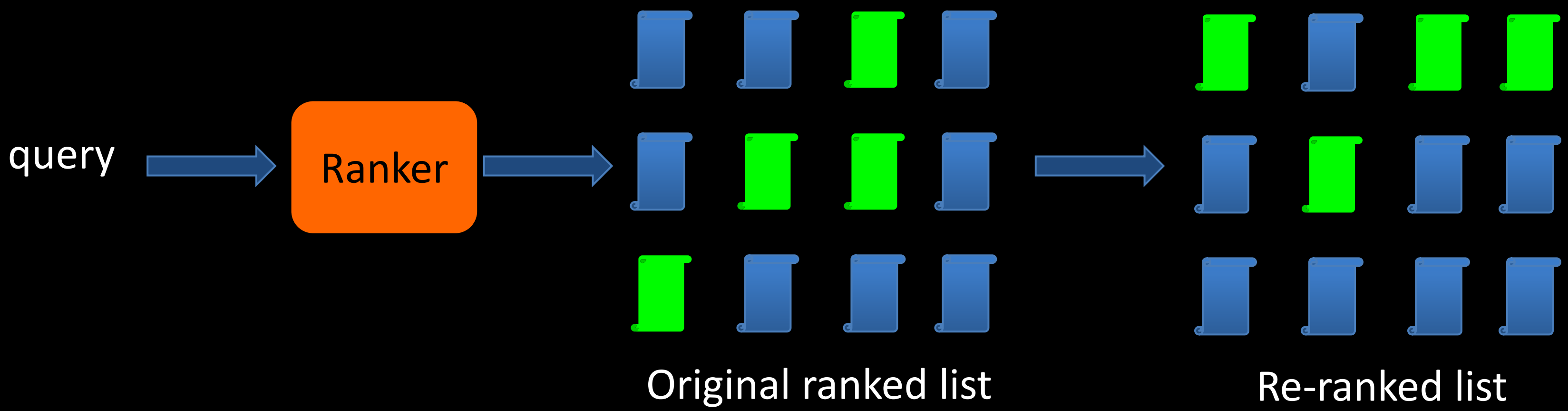
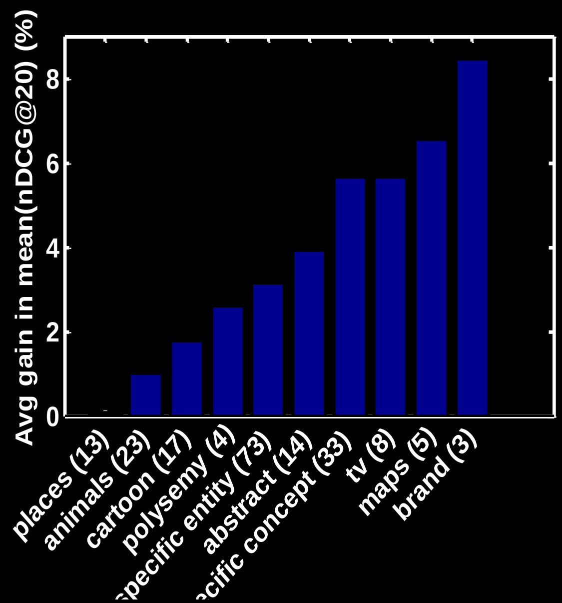
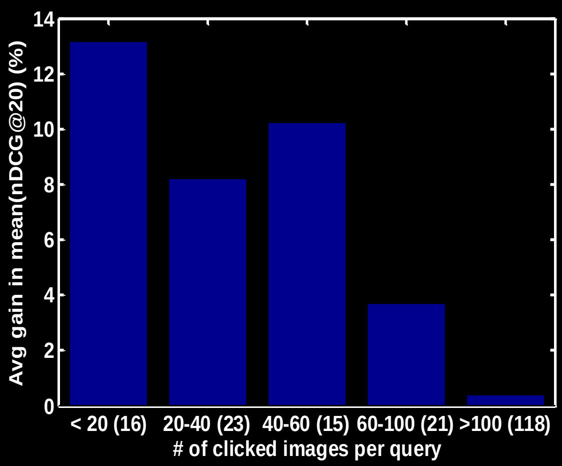
Re-Ranking Using Click Data



In This Talk

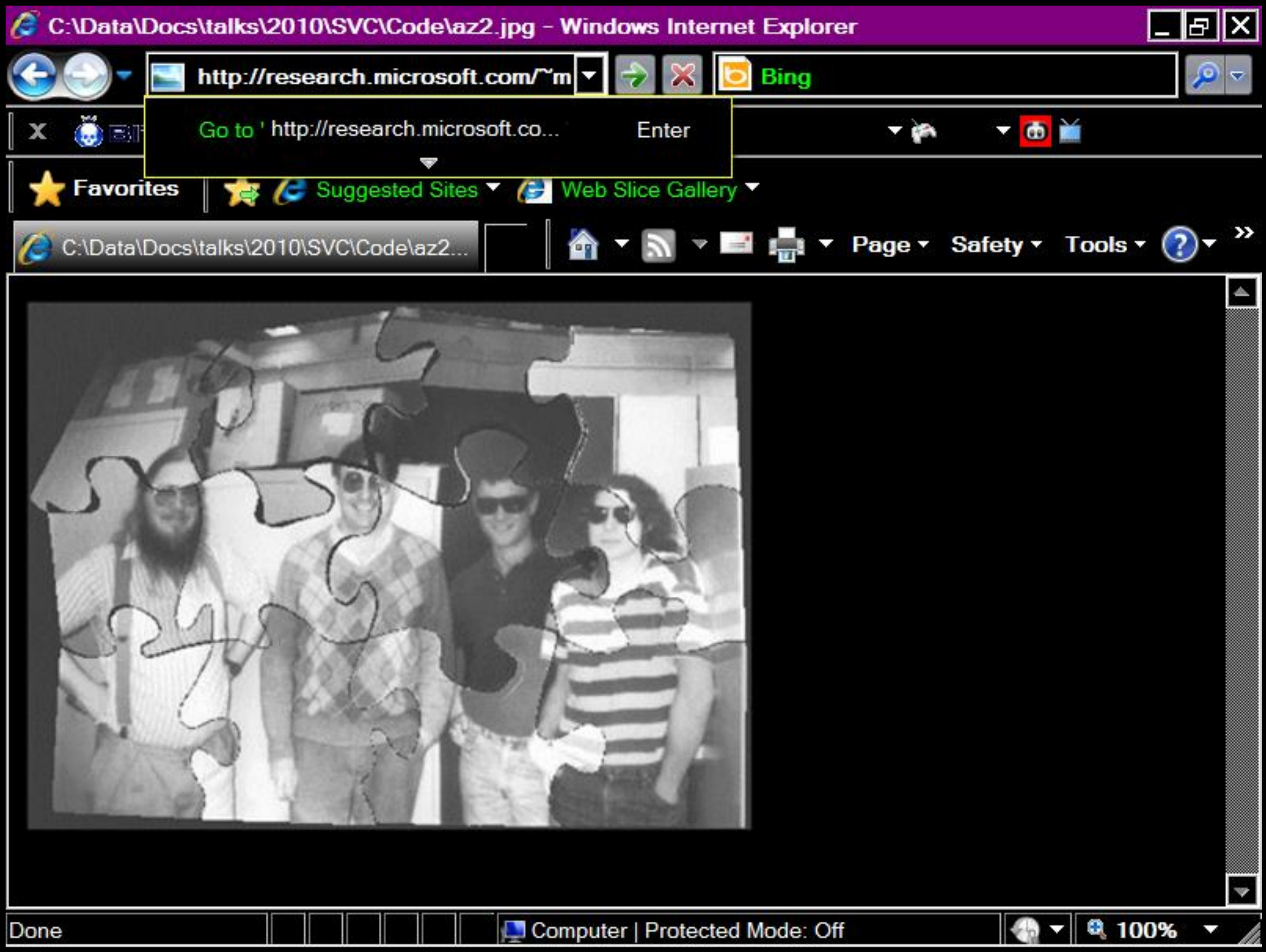
- We mitigate 3 problems of existing search engines
- Leverage user click data to perform re-ranking
- Use Gaussian Process regression to predict click counts for unclicked images





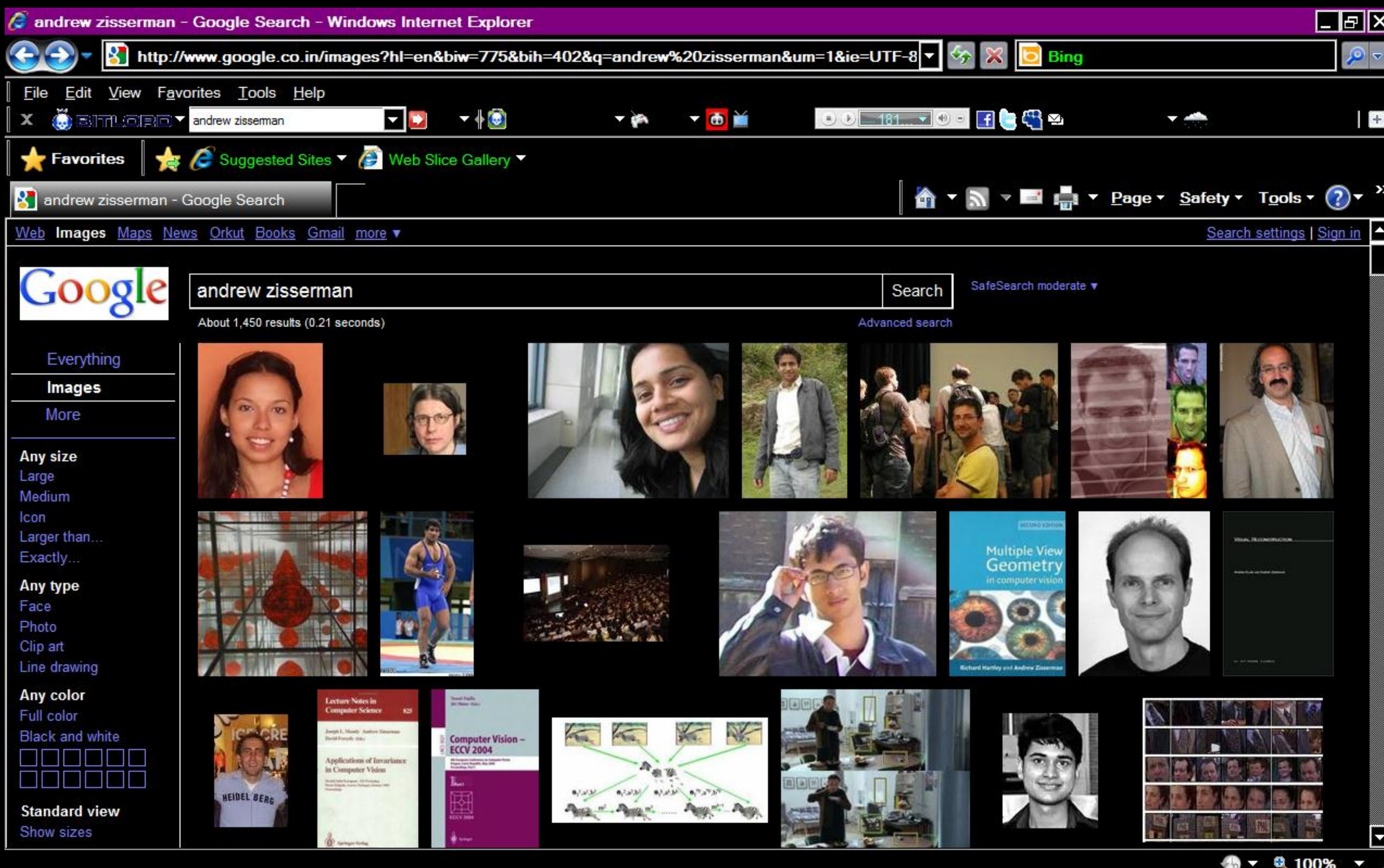
Limitations of Existing Rankers

- Ignore image content



Limitations of Existing Rankers

- Ignore image content

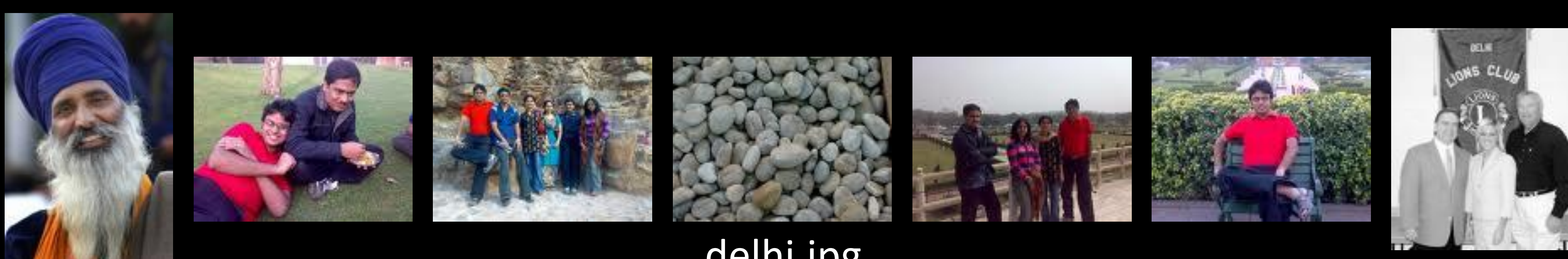


Limitations of Existing Rankers

- A single prediction model is learnt for all queries
- Score($\mathbf{x}$) = $\mathbf{w}^t\mathbf{x} = \Sigma_j \, w_j \, x_j$ with query-independent $\mathbf{w}$
- Query : “tom cruise”

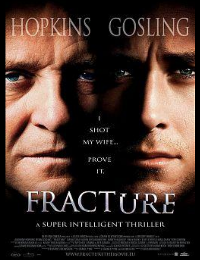
tom cruise.jpg

- Query : “delhi”



delhi.jpg

Obtaining Annotated Training Data

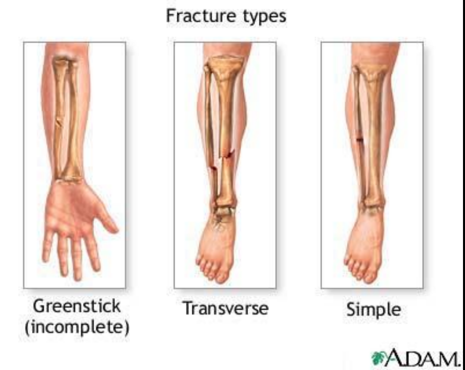
Query	**Thumbnail**	**Relevance** 
"night train"		1 (Not Relevant)
"fracture"		5 (Excellent Match)
"she who must be obeyed"		5 (Excellent Match)

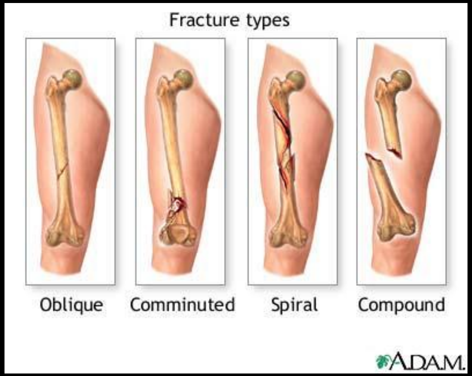
Limitations of Existing Rankers

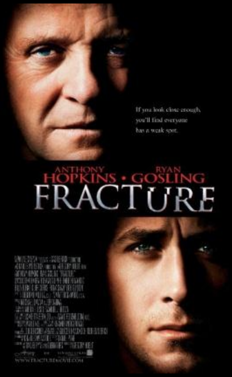
- Query : “night train”
- Training labels generated by human experts

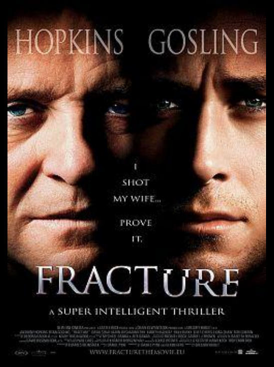
Limitations of Existing Rankers

- Query : “fracture”
- Training labels generated by human experts









Leveraging User Click Data

- We use clicks as surrogate training data
  - We avoid problems due to “expert” labels
  - We train a query-dependent re-ranker
  - We can compute visual features from the clicked images.

- Key assumption : user clicks are highly correlated with relevance
  - Documents : 2 line snippet
  - Videos : 30 second clip ?
  - Images : Thumbnails

Clicks and Relevance

- Query : “fracture”


- Query : “child drinking water”



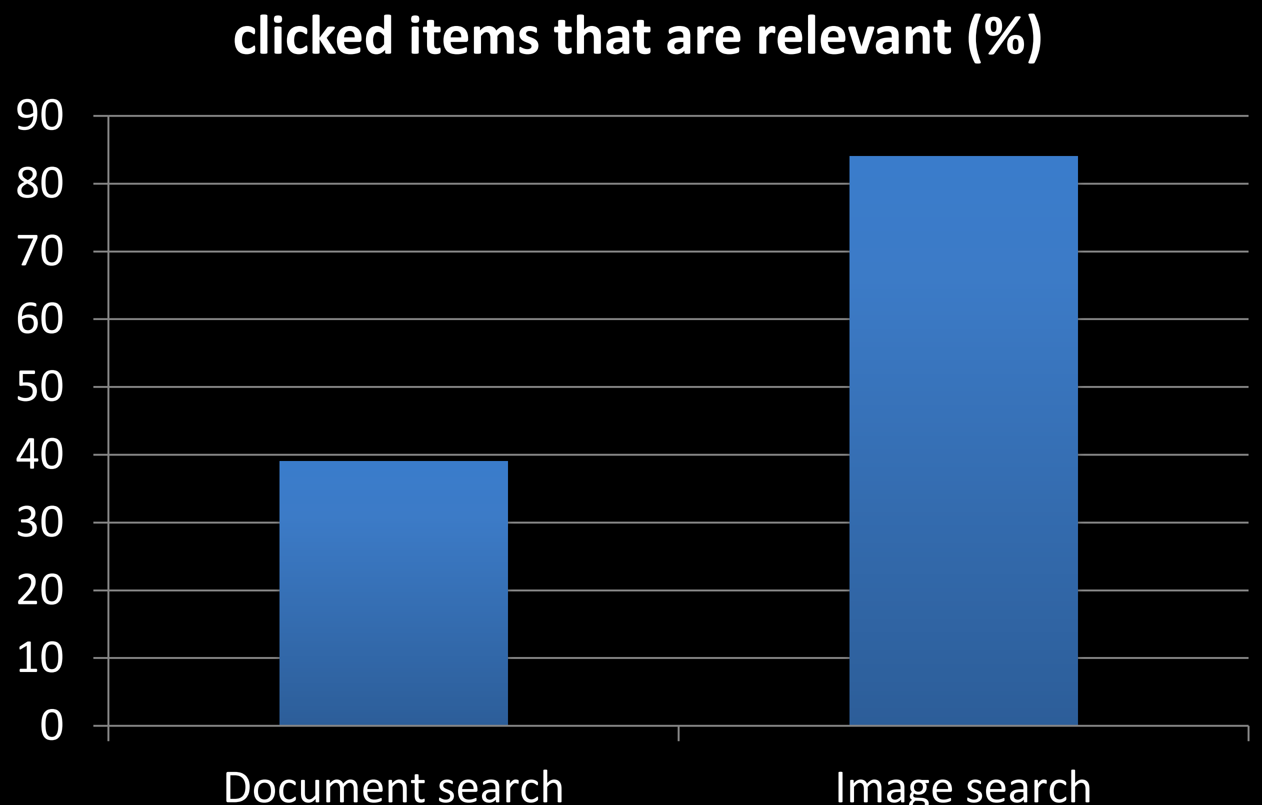


- Query : “Spring Break 2007”





Evidence for clicks-relevance relationship

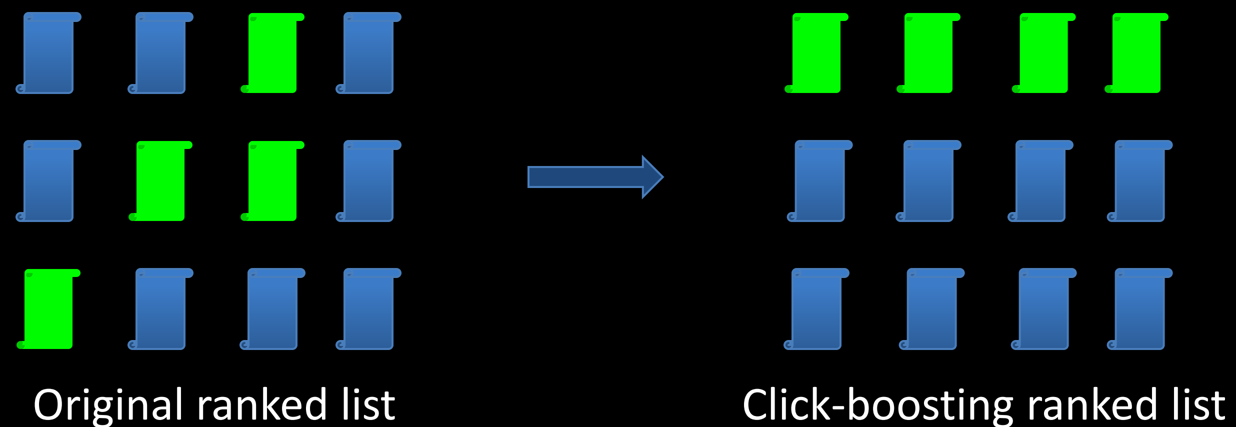


[Agichtein06]

(short snippet)

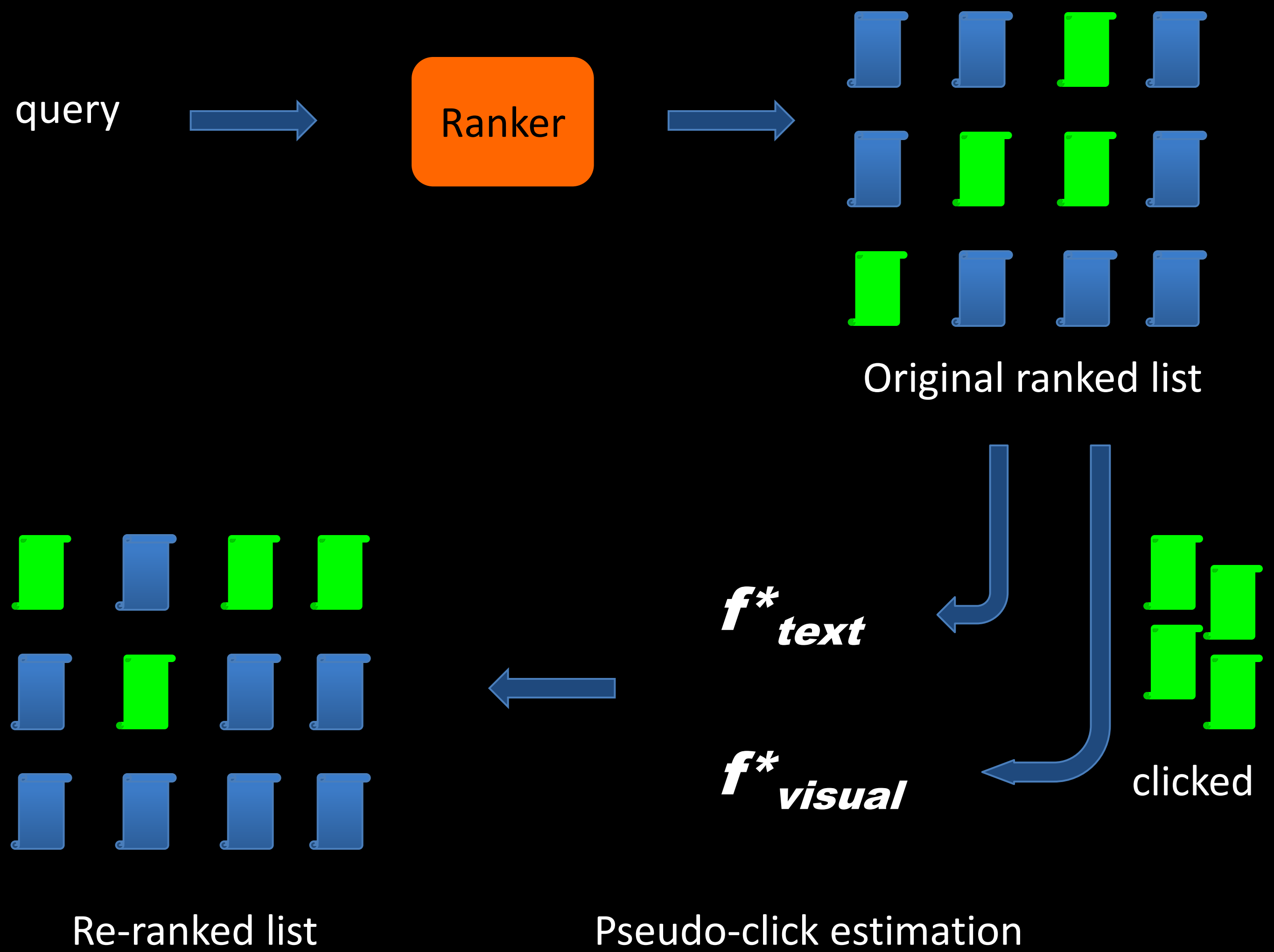
(thumbnail)

Naïve solution – ClickBoosting



- Disadvantages
  - Self reinforcement loop
  - Distracter images promoted to the top
  - Relevant, un-clicked images will never get shown

Overview of our solution



GP Regression on Click Data

- Given a query, obtain the baseline image search results and the associated click data

- Train a regression model on the click data to predict the number of clicks for a novel image

- Re-rank the top 1000 images according to a linear combination of the predicted number of clicks and the original ranking score

Re-scoring Function

- Re-scoring function for image **x**

$$s_R(\mathbf{x}) = a_1\, s_O(\mathbf{x}) + a_2\, y_{Text}(\mathbf{x}) + a_3\, y_{Visual}(\mathbf{x})$$

- where
  - s_R and s_O are the re-ranked and original scores
  - y_{Text} and y_{Visual} are the predicted number of clicks estimated using text and visual features
  - a_1, a_2 and a_3 are global weighting constants

Measuring Search Performance – nDCG

- Given a ranked list of relevance judgments **R**

- Cumulative Gain at *P*

$$\mathrm{CG}_P(\mathbf{R}) = \Sigma_{i=1..P}\, 2^{R_i} - 1$$

- Discounted Cumulative Gain

$$\mathrm{DCG}_P(\mathbf{R}) = \Sigma_{i=1..P}\, (2^{R_i} - 1) / \log_2(i+1)$$

- Normalized Discounted Cumulative Gain

$$\mathrm{nDCG}_P(\mathbf{R}) = \mathrm{DCG}_P(\mathbf{R}) / \mathrm{DCG}_P(\mathbf{I})$$

where **I** is the judgment for the ideal ranked list

Measuring Search Performance – nDCG

- Query: "Andrew Zisserman"

R_1=0 R_2=5 R_3=0 R_4=0 R_5=5

CG = 62
DCG = 46

CG = 62
DCG = 73

R_1=5 R_2=5 R_3=0 R_4=0 R_5=0

- nDCG@5 = 46/73 = 0.63

Click Estimation

- Features
  - Query independent text features (Pagerank)
  - Query dependent text features (filename match)
  - Visual features based on shape, colour and texture (HOG, SIFT, LBP, colour histograms, etc)

- We have very few training images (approximately 20 – 100) and more than 3000 features

- It is therefore essential to perform dimensionality reduction to avoid over fitting

Click Estimation - Dimensionality Reduction

- We only have "positive" training data so discriminative methods did not work well (generating negative training data is non-trivial)

- Simple methods did work well

Approach	Mean nDCG at 20	Relative Improvement
Average click rank	0.6266	– 8.6%
Correlation with score	0.7209	+5.2 %
Correlation with clicks	0.7409	+8.1%
PCA	0.7692	+12.2%

Click Estimation – Regression

Query : “night train”


(#clicks) 50 20 5 2

35

Visual features are not enough

Query : “night train”

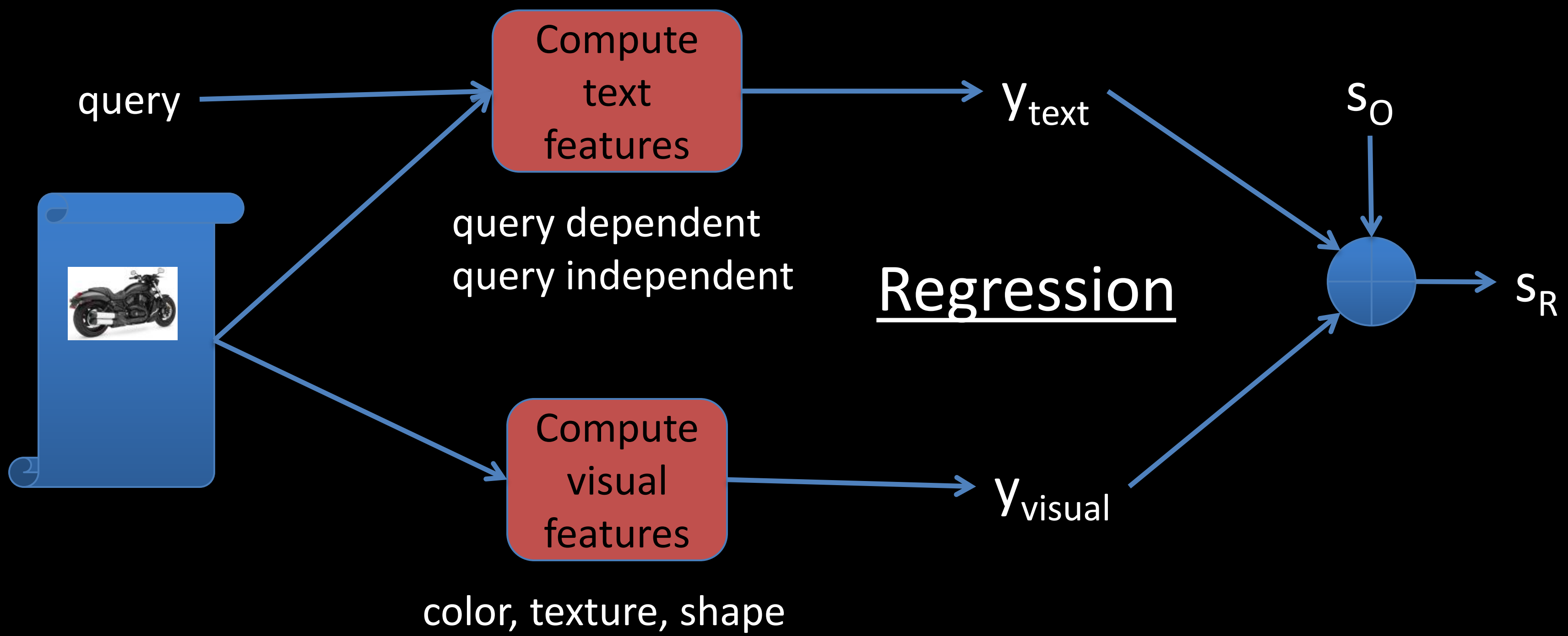
(#clicks) 50 20 5 2

“night rod”

23

Need both visual and text features

Re-ranking function



$$\text{Score: } s_R(\mathbf{x}) = a_1\, s_O(\mathbf{x}) + a_2\, y_{text}(\mathbf{x}) + a_3\, y_{visual}(\mathbf{x})$$

Click Estimation - Regression

- Gaussian Process Regression

$$y(\mathbf{x}) = \mathbf{k}(\mathbf{x}, \mathbf{x}_{\text{Train}}) \, [\, \mathbf{k}(\mathbf{x}_{\text{Train}}, \mathbf{x}_{\text{Train}}) + \sigma^2 \mathbf{I} \,]^{-1} \, \mathbf{y}_{\text{Train}}$$
$$= \mathbf{d}^t(\mathbf{x}, \mathbf{x}_{\text{Train}}) \, \mathbf{y}_{\text{Train}}$$
$$= \mathbf{w}^t \phi(\mathbf{x})$$

- where
  - y is the predicted number of clicks and $\mathbf{y}_{\text{Train}}$ the number of clicks for the set of training images
  - $\mathbf{x}$ are the features extracted from a novel image
  - $\mathbf{x}_{\text{Train}}$ are the training set features
  - σ is a noise parameter
  - $\mathbf{k}$ is a Gaussian kernel function

Click Estimation - Regression

Approach	Mean nDCG at 20	Relative Improvement
Linear Regression	0.6871	– 0.2%
Support Vector Regression	0.6997	+2.1 %
Nearest Neighbour	0.7428	+8.3%
GP Regression	0.7692	+12.2%

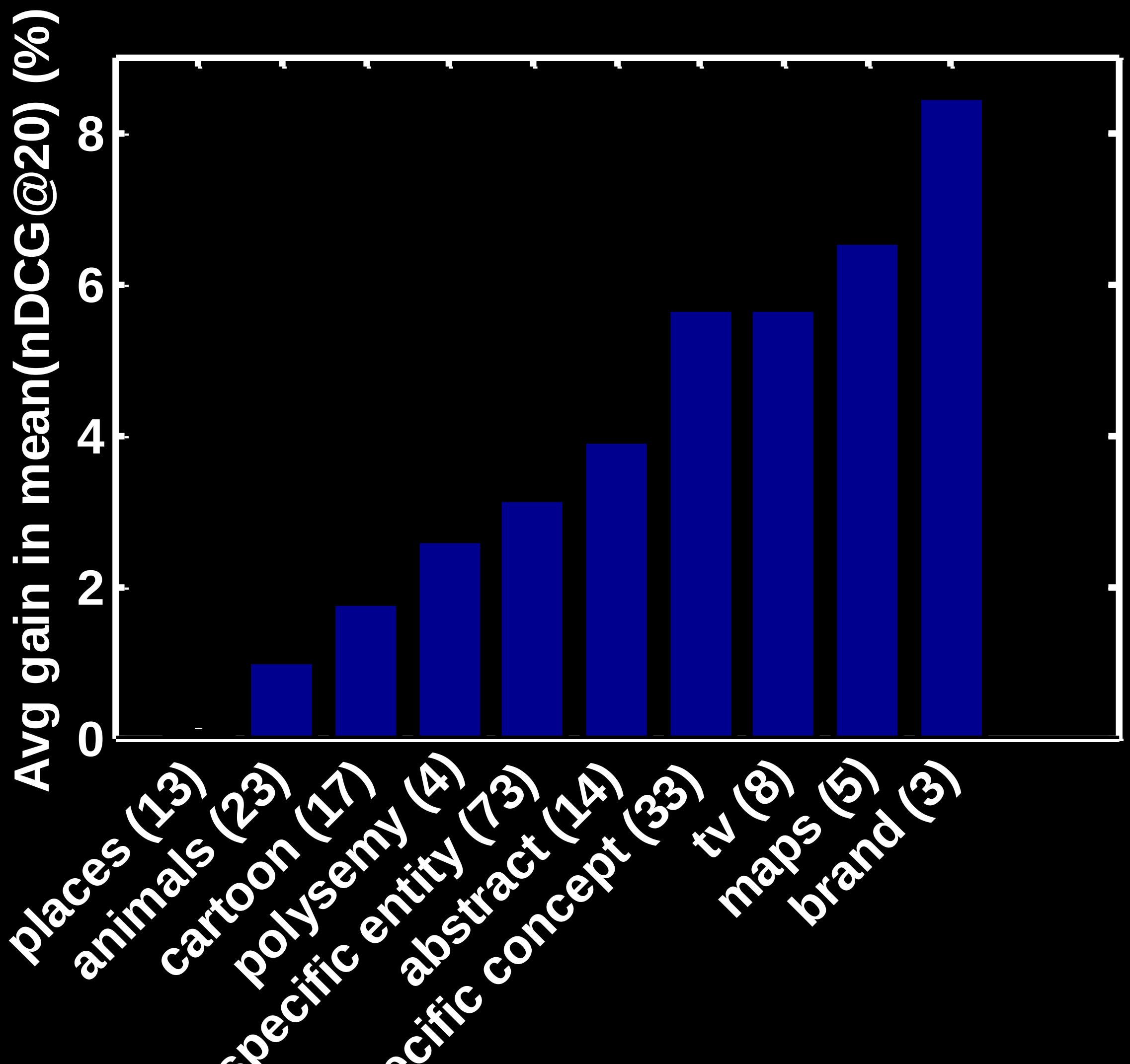
Re-scoring Function

- Re-scoring function for image **x**

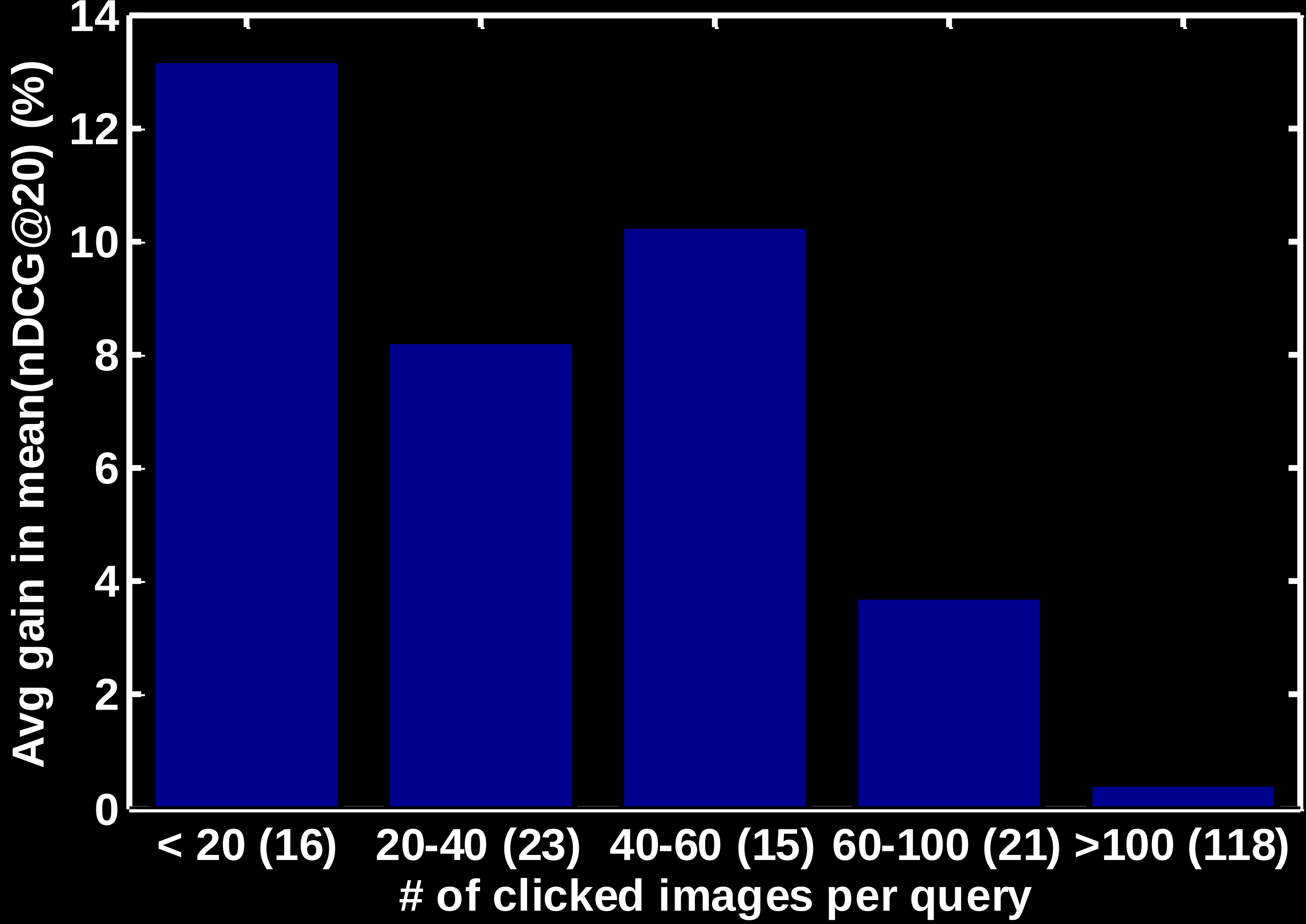
$$s_R(\mathbf{x}) = a_1\, s_O(\mathbf{x}) + a_2\, y_{Text}(\mathbf{x}) + a_3\, y_{Visual}(\mathbf{x})$$

Approach	**Mean nDCG at 20**	**Relative Improvement**
Baseline ($a_2 = a_3 = 0$)	0.6854	–
Baseline + y_{Text} ($a_3 = 0$)	0.7077	+3.3 %
Baseline + y_{Visual} ($a_2 = 0$)	0.6136	–10.5%
Baseline + y_{Text} + y_{Visual}	0.7692	+12.2%

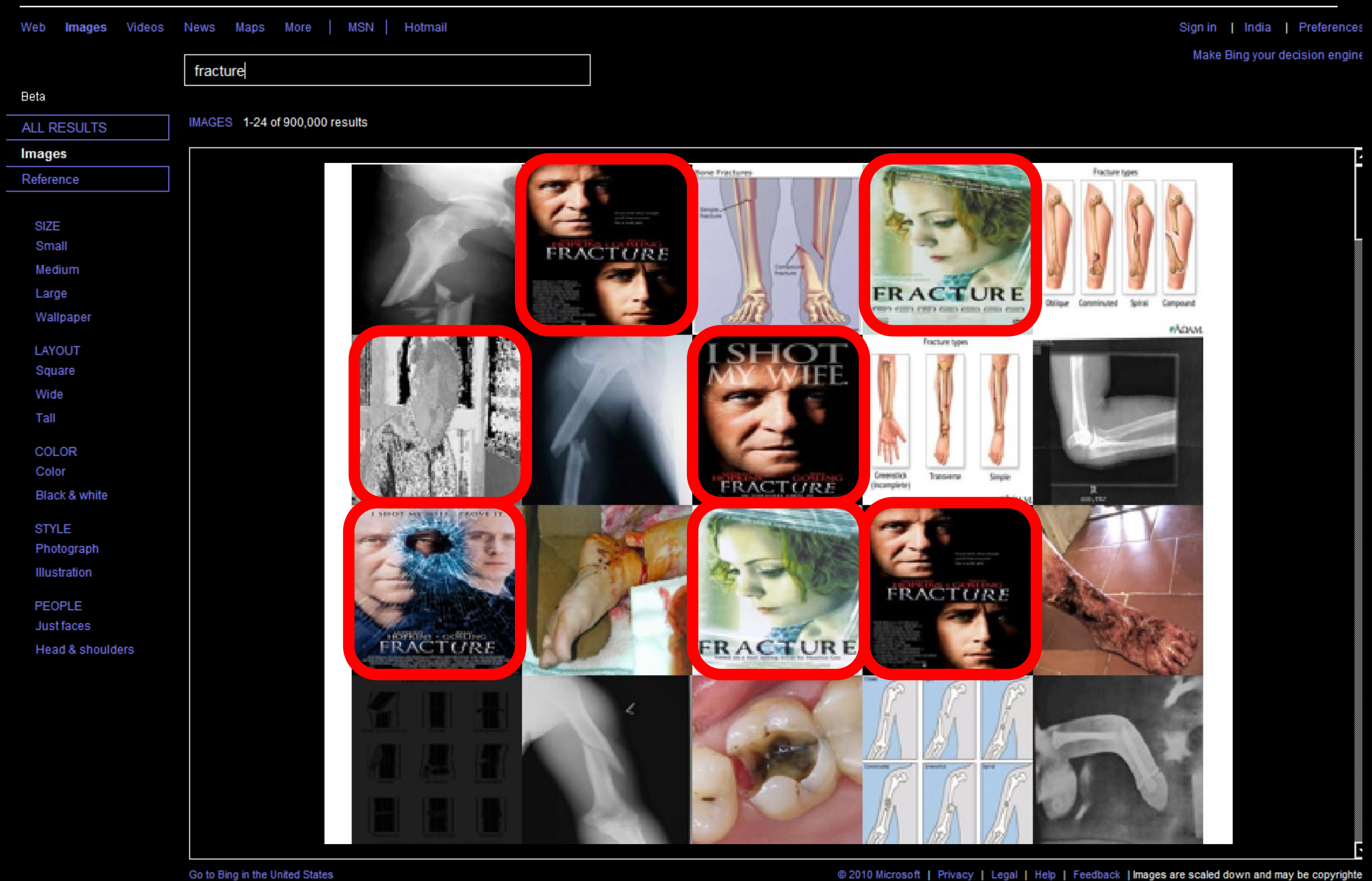
Evaluation on 193 Queries



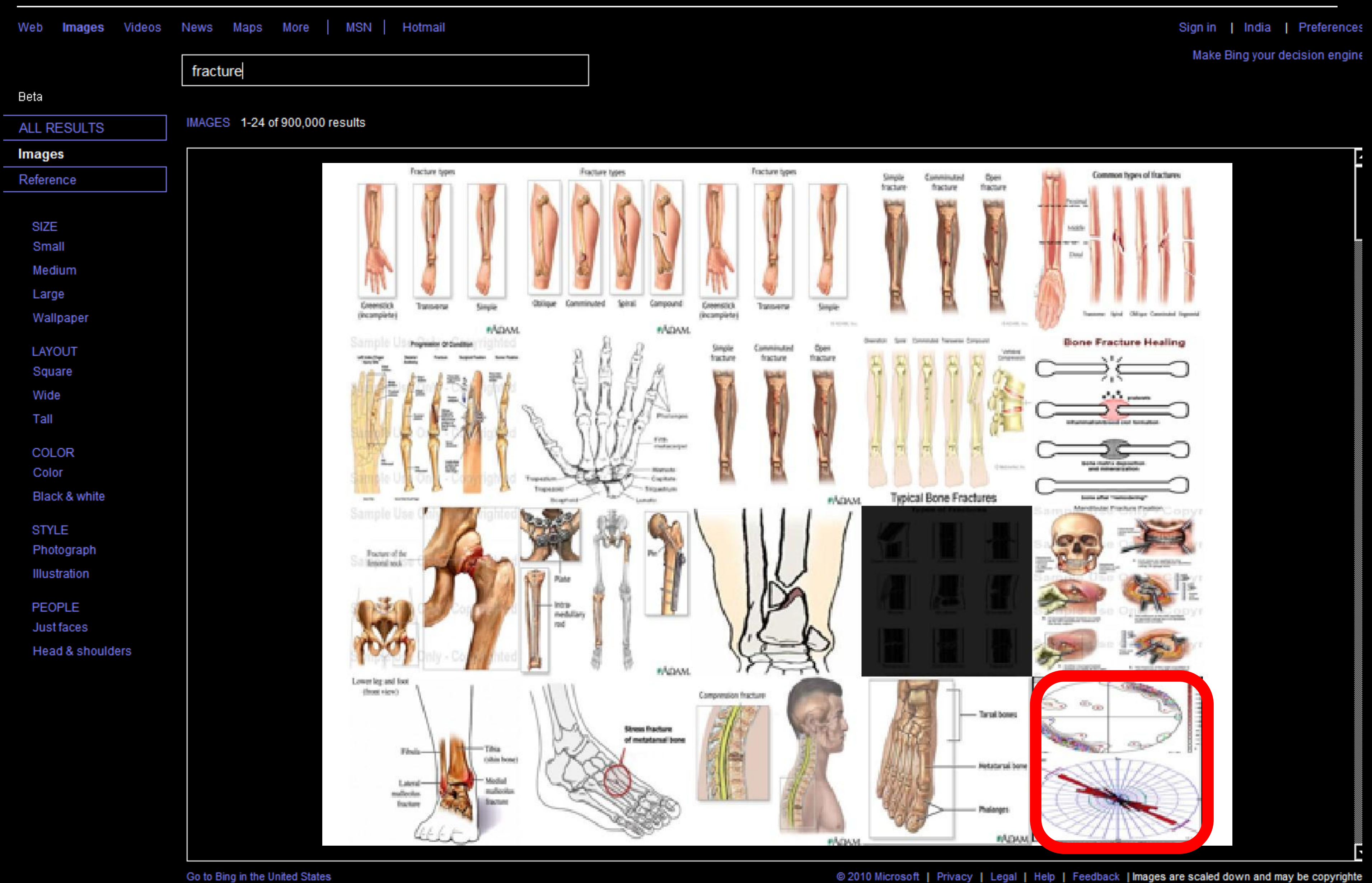
Evaluation on 193 Queries



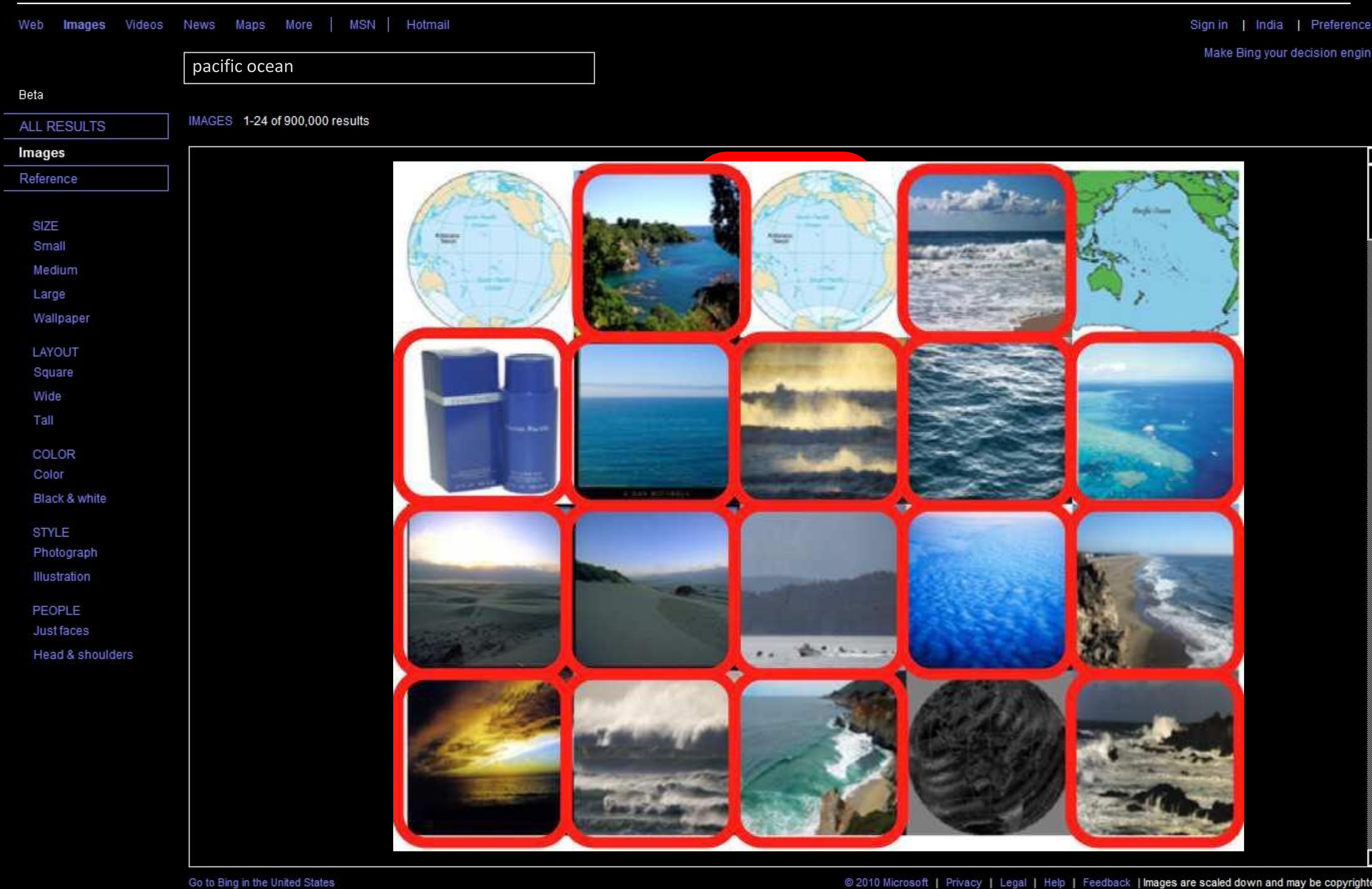
Bing Results – “fracture”



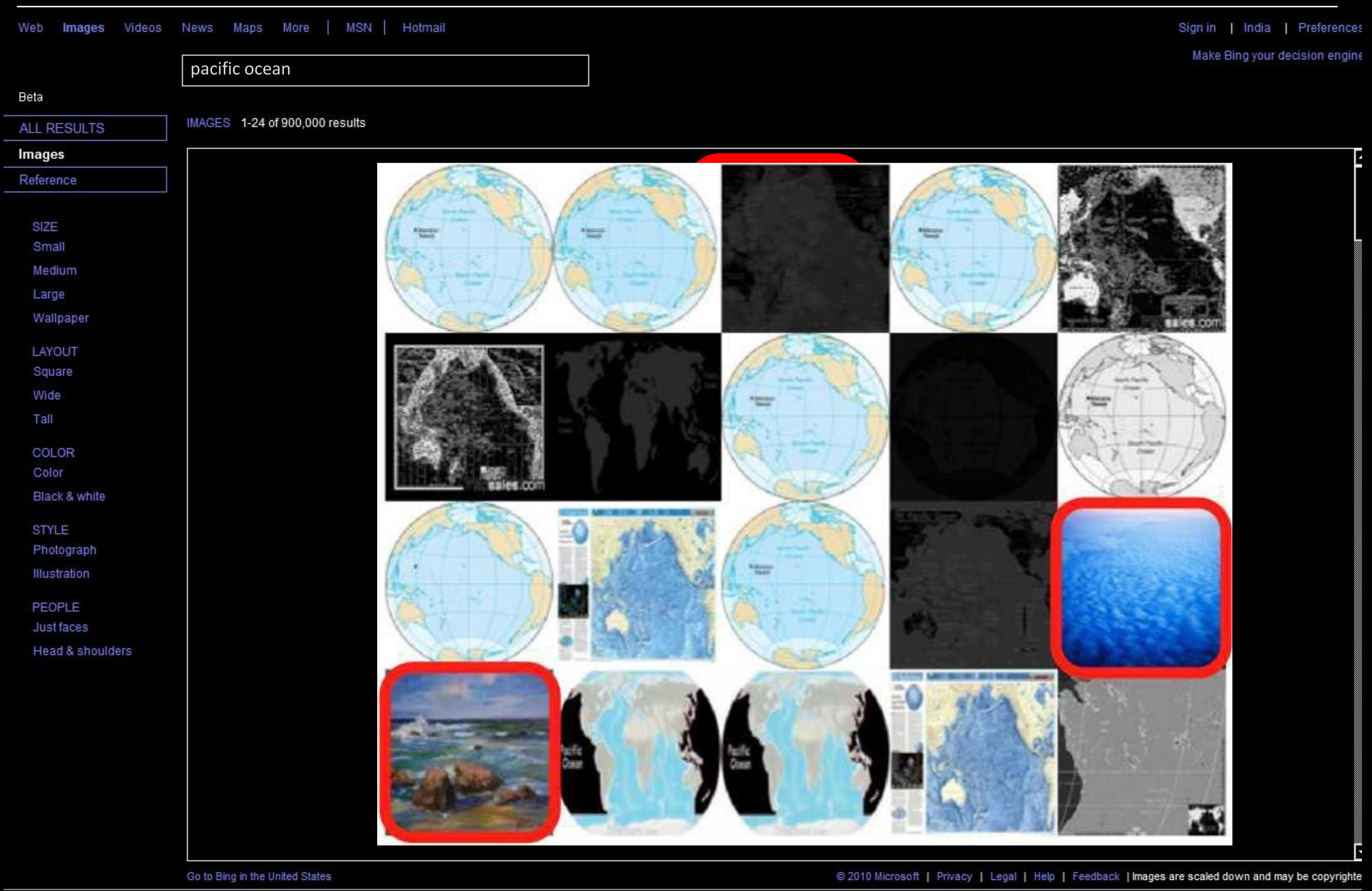
GP Regression Results – “fracture”



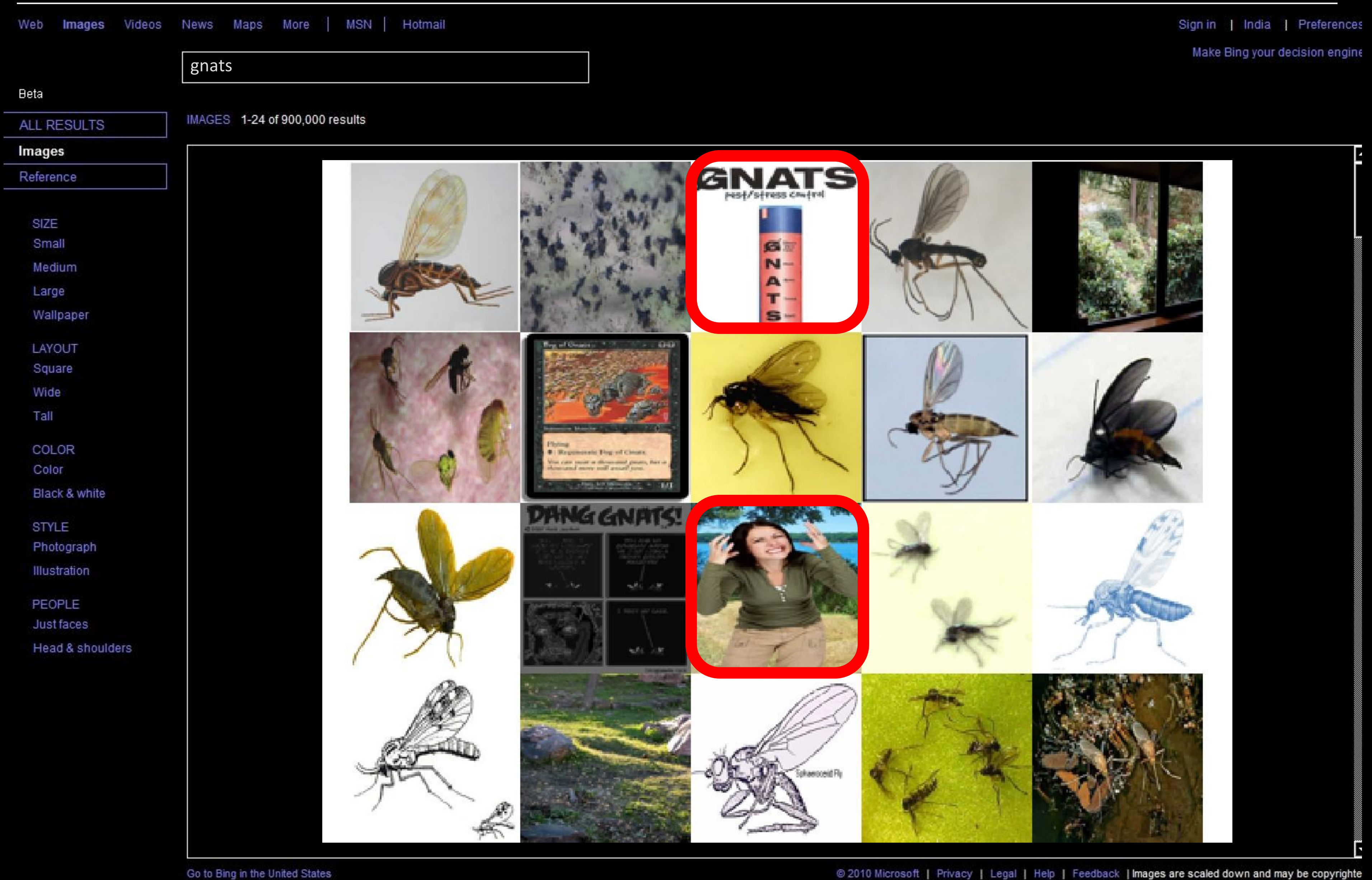
Bing Results – “pacific ocean”



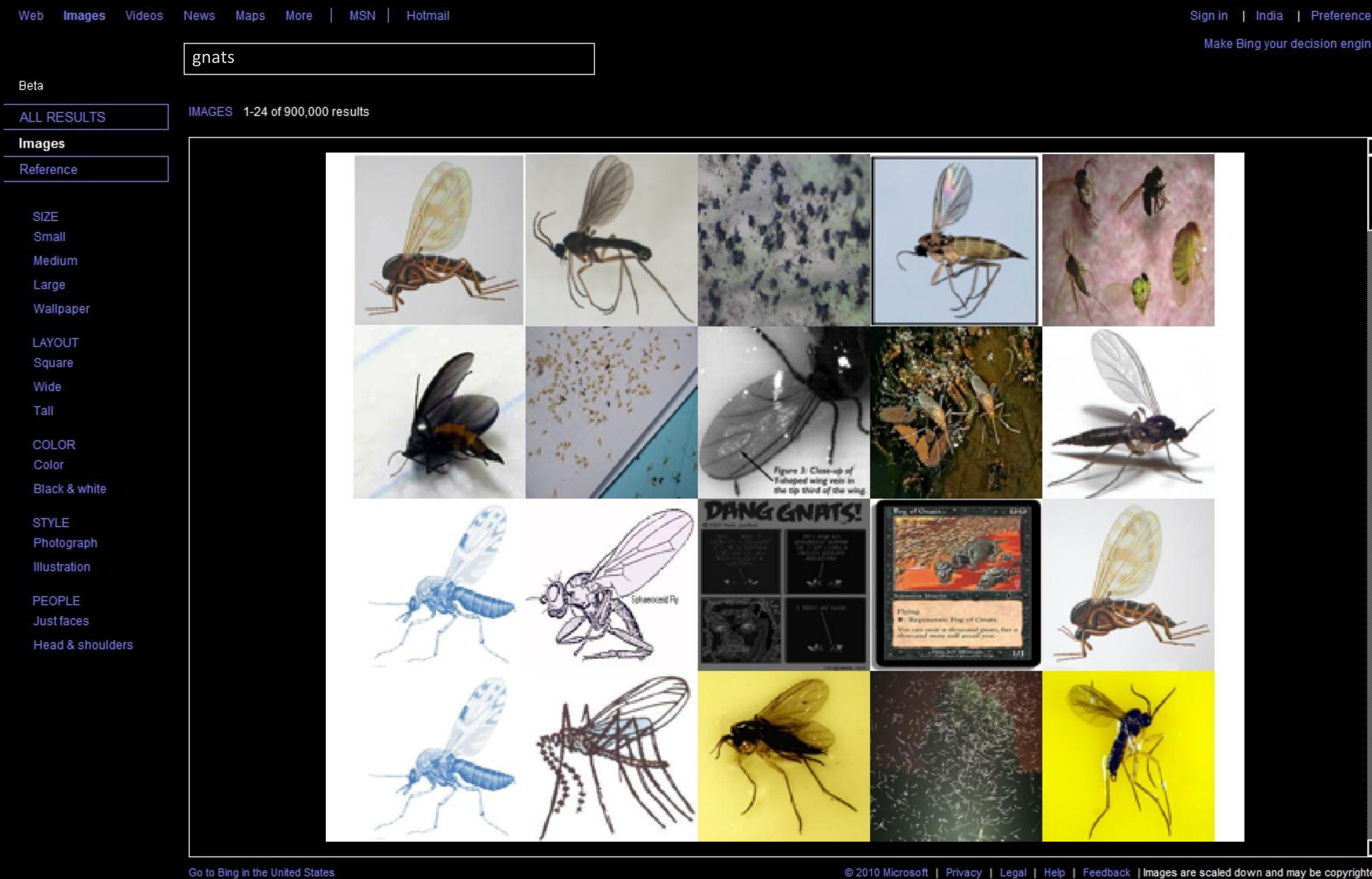
GP Regression Results – "pacific ocean"



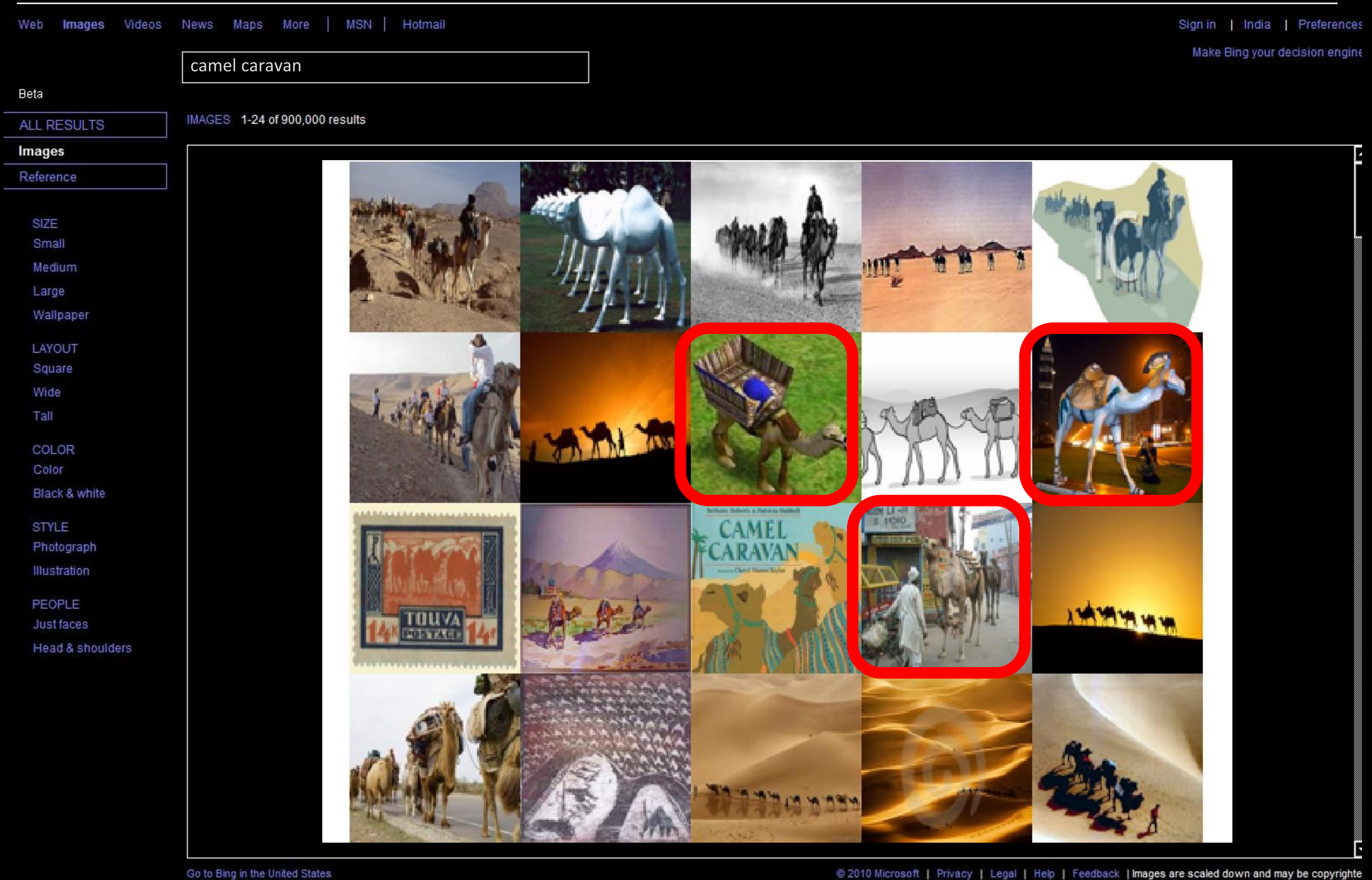
Bing Results – “gnats”



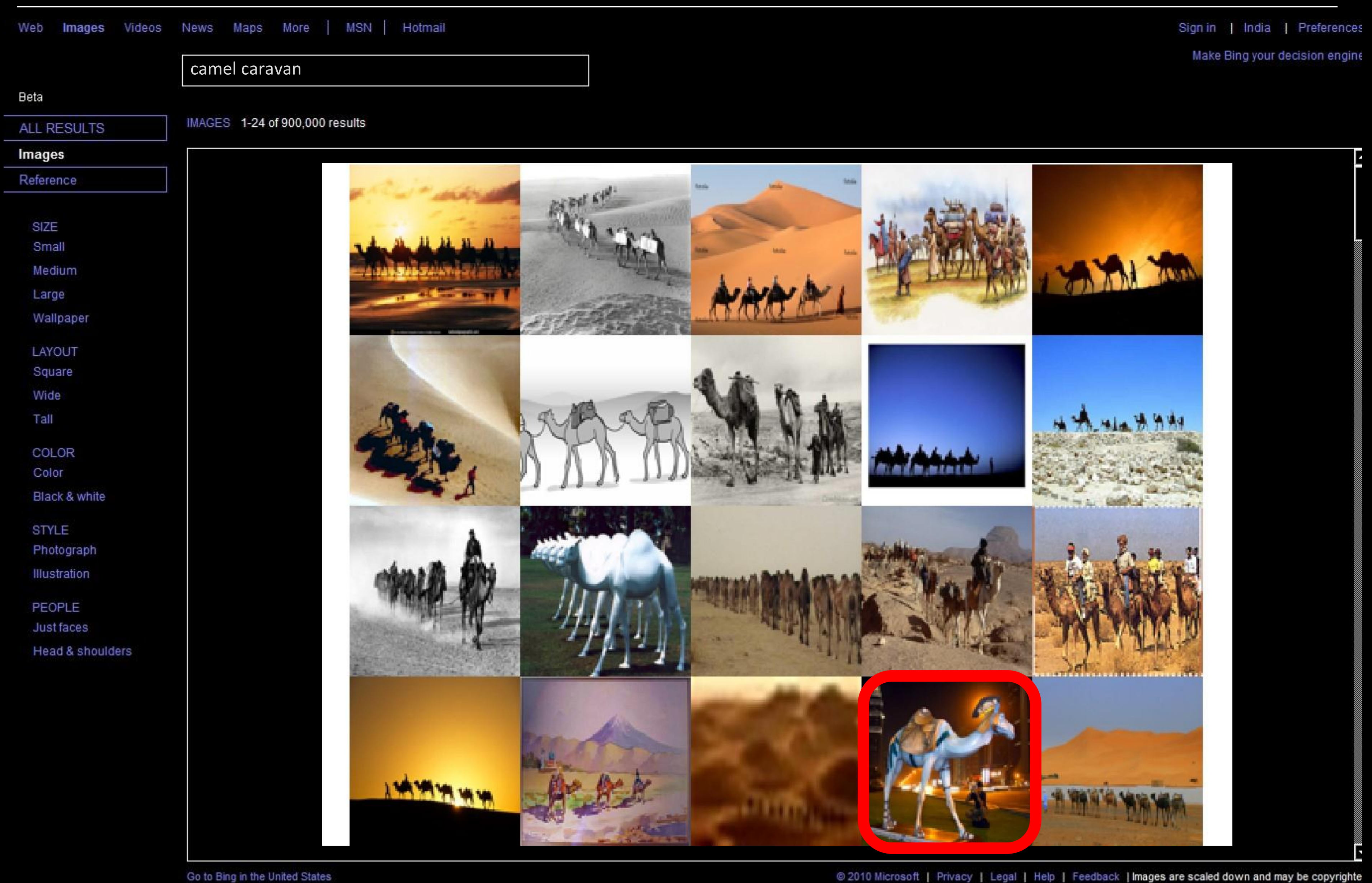
GP Regression Results – “gnats”



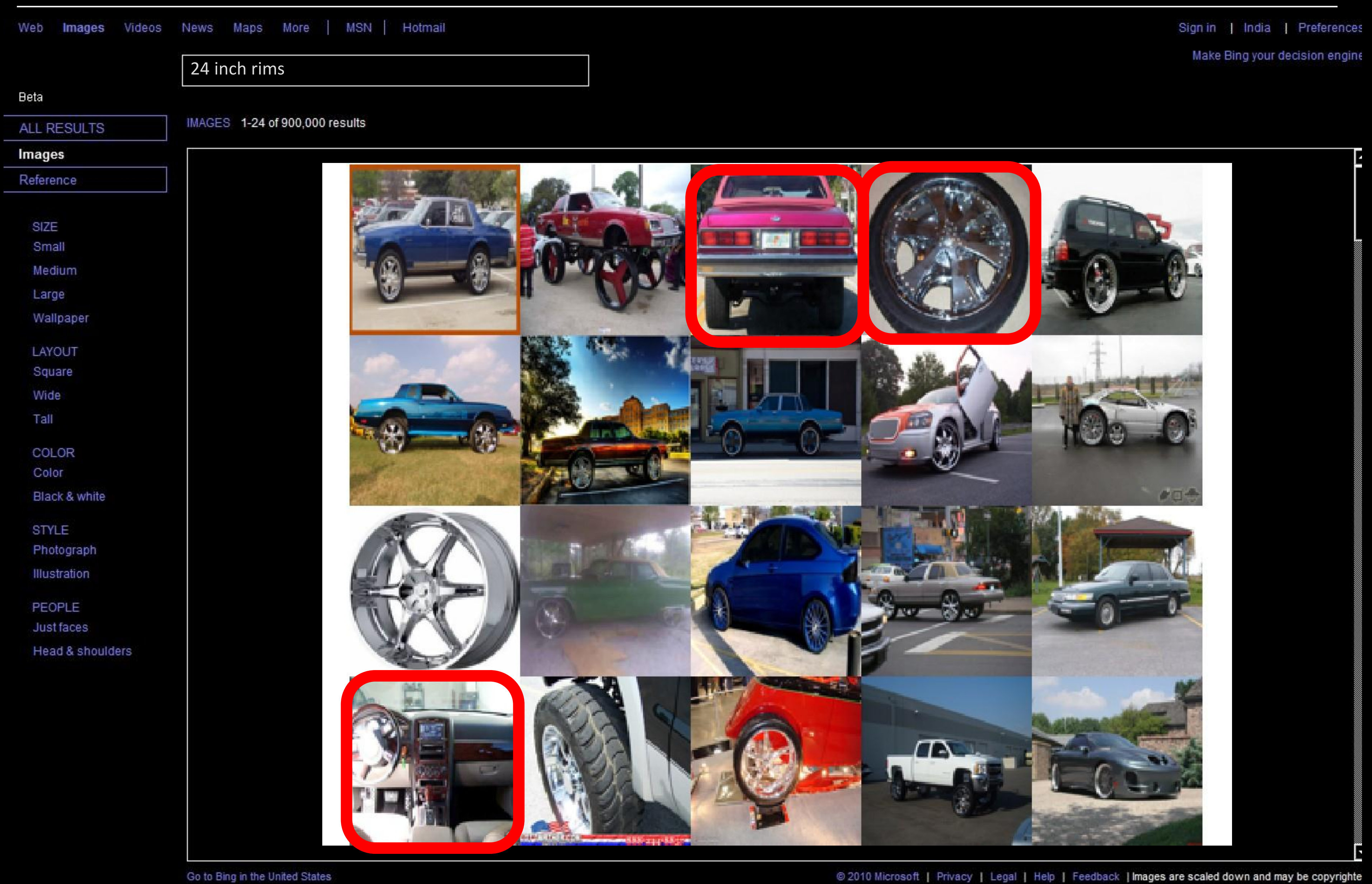
Bing Results – "camel caravan"



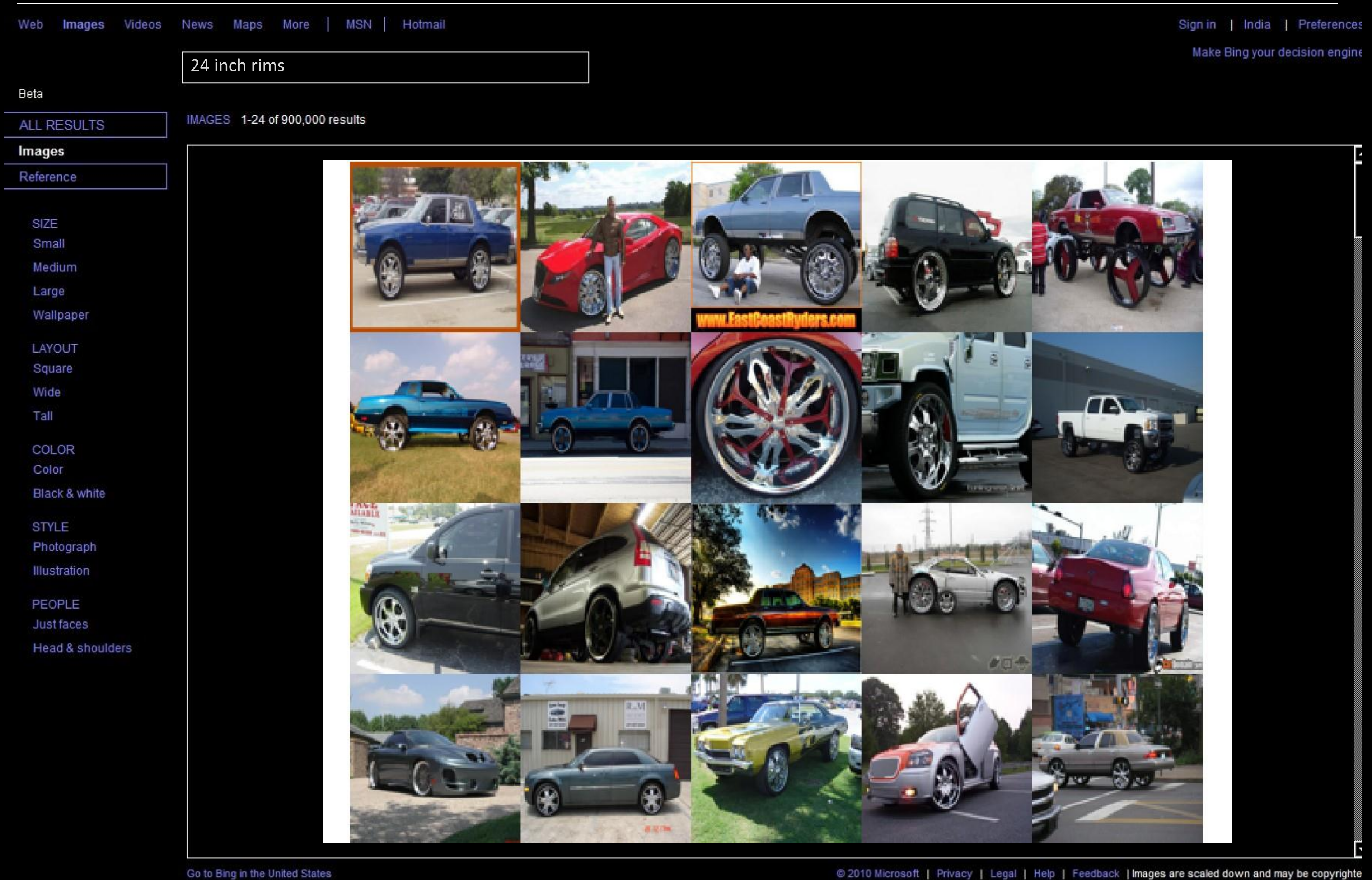
GP Regression Results – “camel caravan”



Bing Results – “24 inch rims”



GP Regression Results – “24 inch rims”



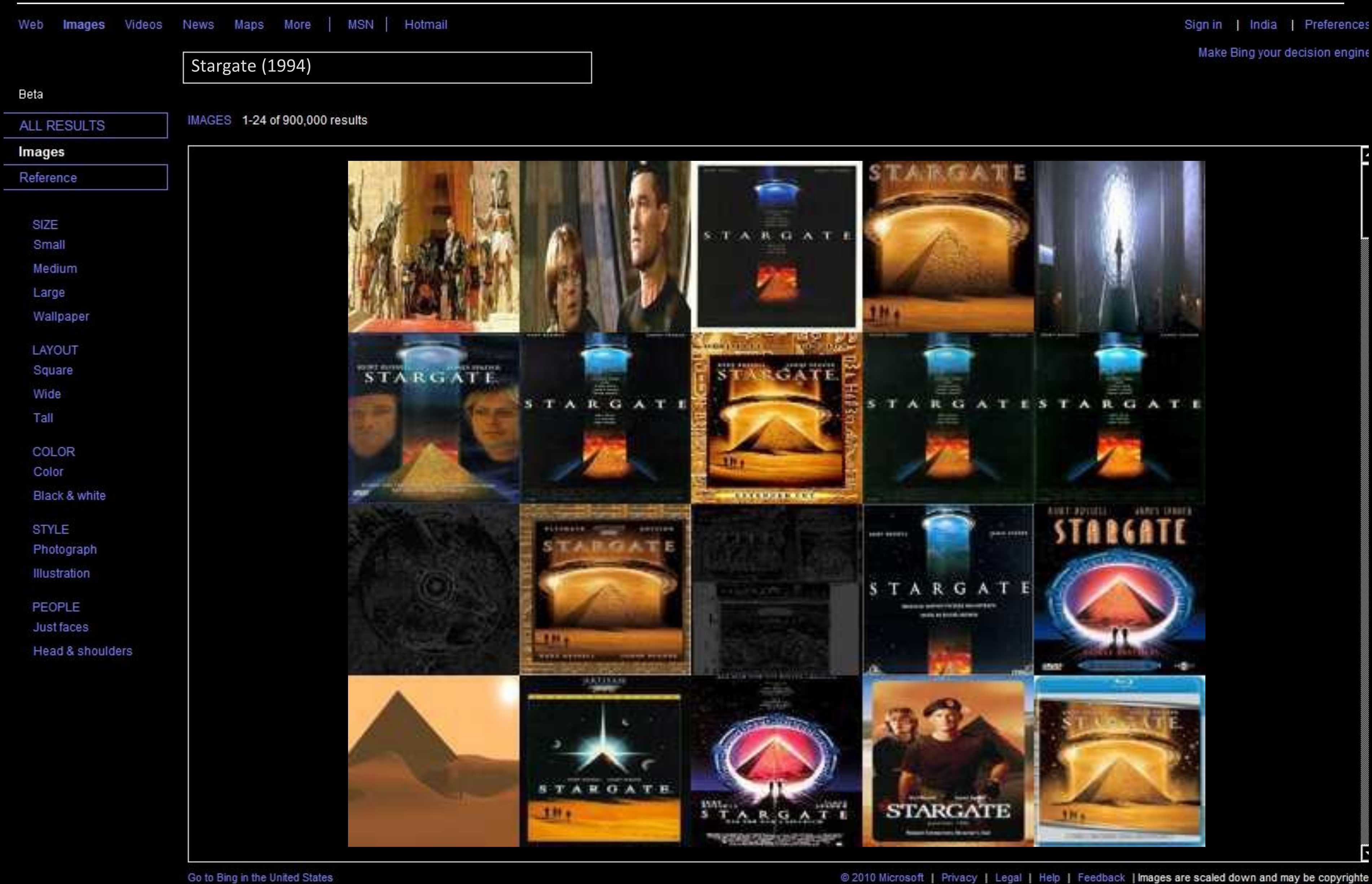
Query: “turkey”

Bing

GP Regression

Multiple interpretations are retained if manifested by clicks

Bing Results – "Stargate (1994)"



GP Regression Results – "Stargate (1994)"

Acknowledgements

- Deepak Agarwal
- James Allan
- Mark Bolin
- Michael Bendersky,
- Qifa Ke