Microsoft

Looking Over the Horizon:
How Basic Research Helps Everyone

Jeannette Wing
Corporate Vice President
Microsoft Research

Microsoft Research
Faculty Summit

Society

Science

Technology

What is computable?

P = NP?

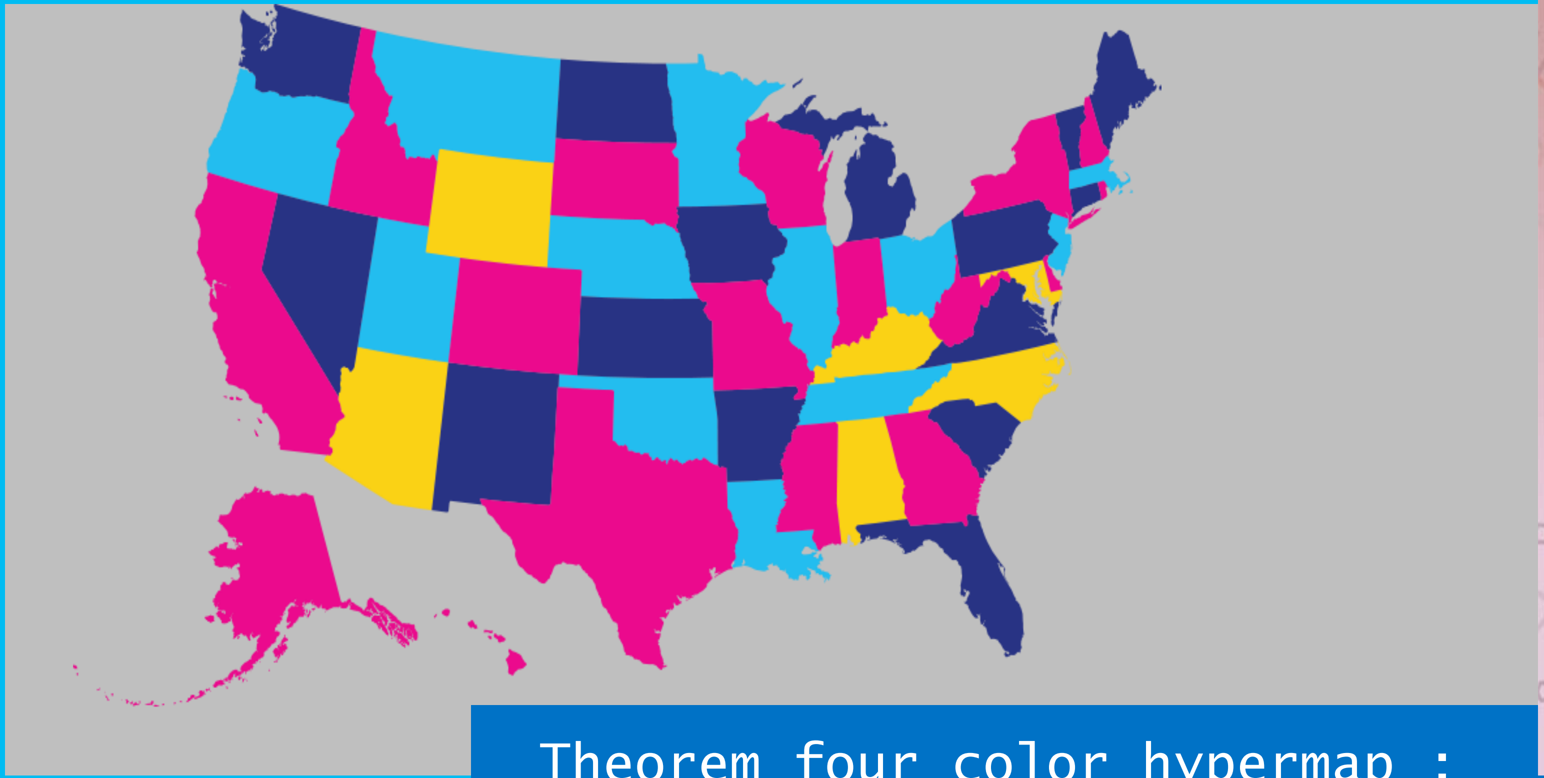
What is intelligence?

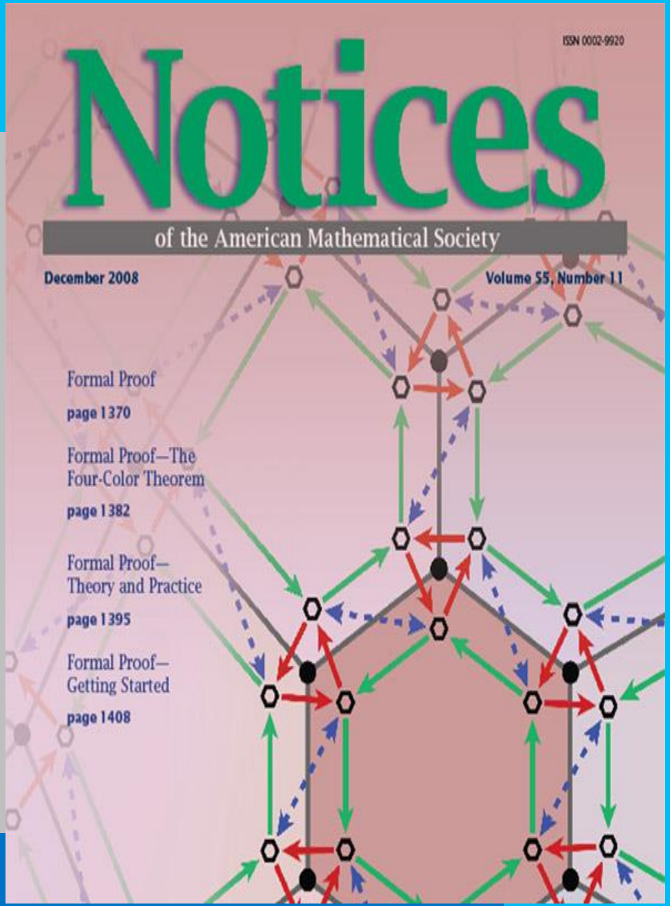
What is information?

(How) can we build complex systems simply?

Impact on Science

Computer Proofs of Mathematics



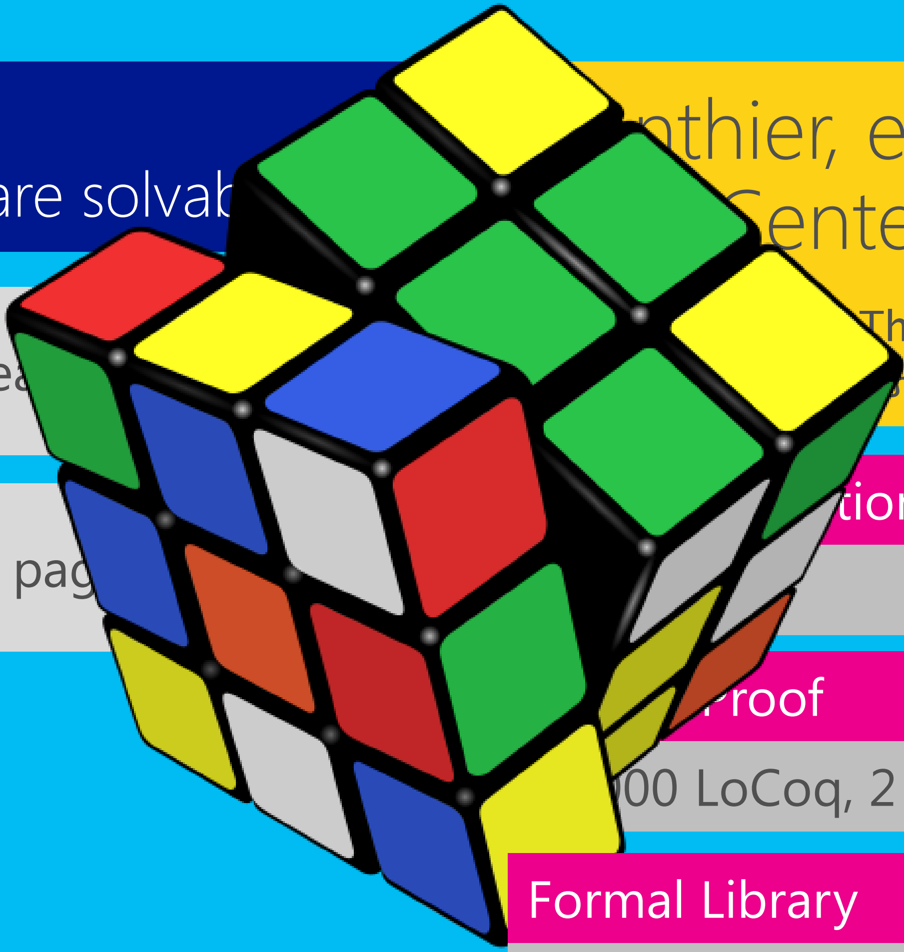



```
Theorem four_color_hypermap :
forall g : hypermap, planar_bridgeless g ->
four_colorable g.
```

The Odd Order Theorem

Feit and Thompson, 1963:
All finite groups of odd order are solvab

Proof	255 pages, 50 years + 25 yea
Use	The Classification, 6-10,000 pag



nthier, et al., MSR-INRIA
Center, 2012 [ITP’13]:

```
Thompson gT
) : odd #|G| -> solvable G.
```

tion

roof

00 LoCoq, 2 years

Formal Library

125,000 LoCoq, 4 years

The SSReflect/Math Components Library

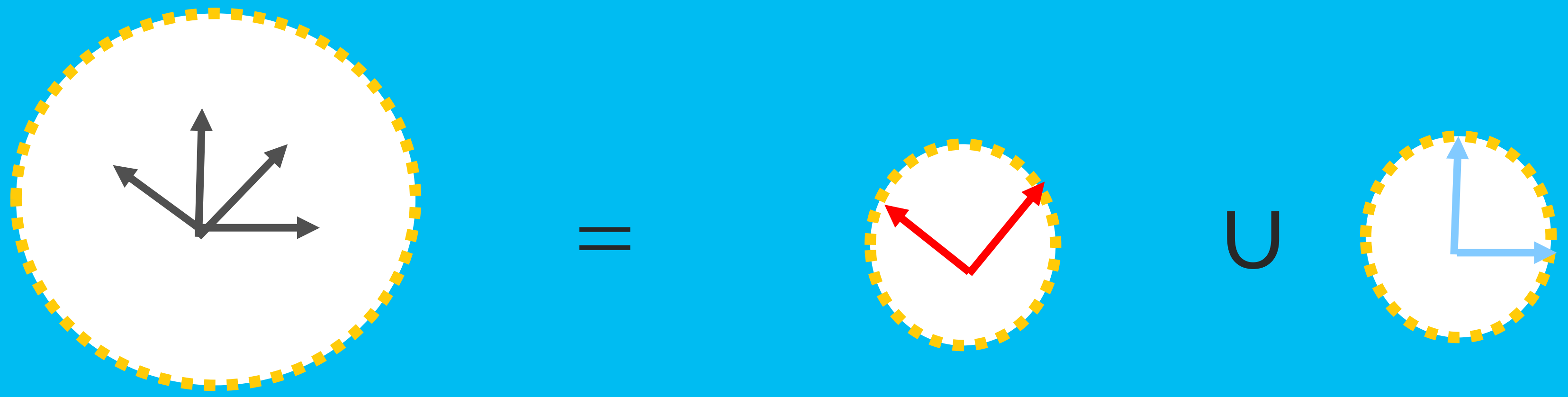
```
Section Lagrange.

Variable gT : finGroupType.
Implicit Types G H K : {group gT}.

Lemma LagrangeI G H : (#|G :&: H| * #|G : H|)%N = #|G|.
Proof.
rewrite -[#|G|]sum1_card (partition_big_imset (rcoset H)) /=.
rewrite mulnC -sum_nat_const; apply: eq_bigr => _ /rcosetsP[x Gx ->].
rewrite -(card_rcoset _ x) -sum1_card; apply: eq_bigl => y.
rewrite rcosetE eqEcard mulGS !card_rcoset leqnn andbT.
by rewrite group_modr sub1set // inE.
Qed.

Lemma divgI G H : #|G| %/ #|G :&: H| = #|G : H|.
Proof. by rewrite -(LagrangeI G H) mulKn ?cardG_gt0. Qed.

Lemma divg_index G H : #|G| %/ #|G : H| = #|G :&: H|.
Proof. by rewrite -(LagrangeI G H) mulnK. Qed.

Lemma dvdn_indexg G H : #|G : H| %| #|G|.
Proof. by rewrite -(LagrangeI G H) dvdn_mull. Qed.

Theorem Lagrange G H : H \subset G -> (#|H| * #|G : H|)%N = #|G|.
Proof. by move/setIidPr=> sHG; rewrite -{1}sHG LagrangeI. Qed.
```

Feit-Thompson

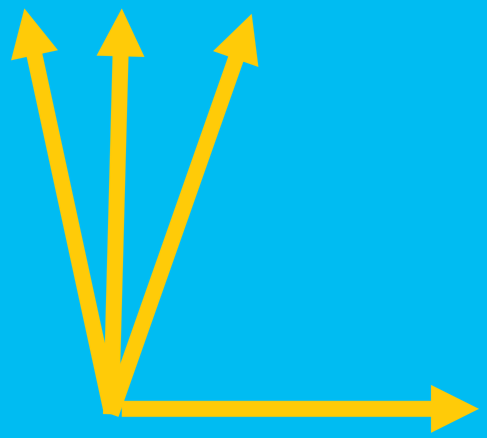
Math Components

Splitting A Quadratic Form in Half

[Marcus, Spielman, Srivatsava, Interlacing Families II: Mixed Characteristic Polynomials and The Kadison-Singer Problem, arXiv:1306.3969v3, June 2013]

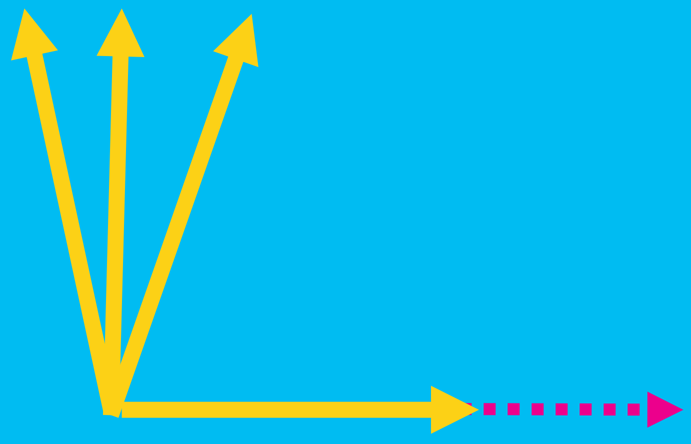


Quadratic Forms and Energy



$$v_1, v_2, v_3, v_4 \in \boldsymbol{R}^2$$

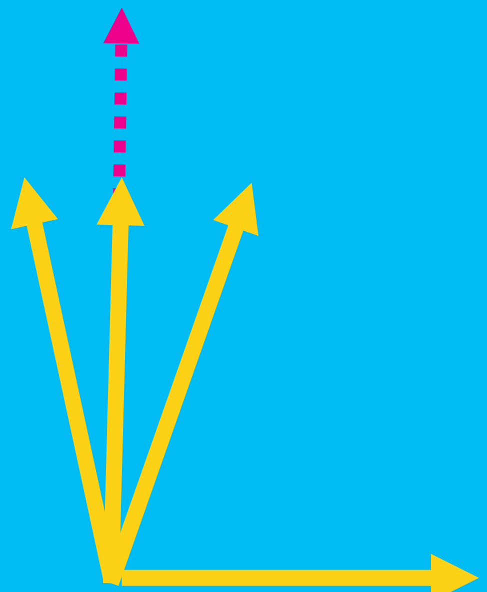
Quadratic Forms and Energy



$u = (1,0)$

$$Q(u) = \langle u, v_1\rangle^2 + \langle u, v_2\rangle^2 + \langle u, v_3\rangle^2 + \langle u, v_4\rangle^2$$
$$= 1 + 0 + ¼ + ¼$$
$$= 1.5$$

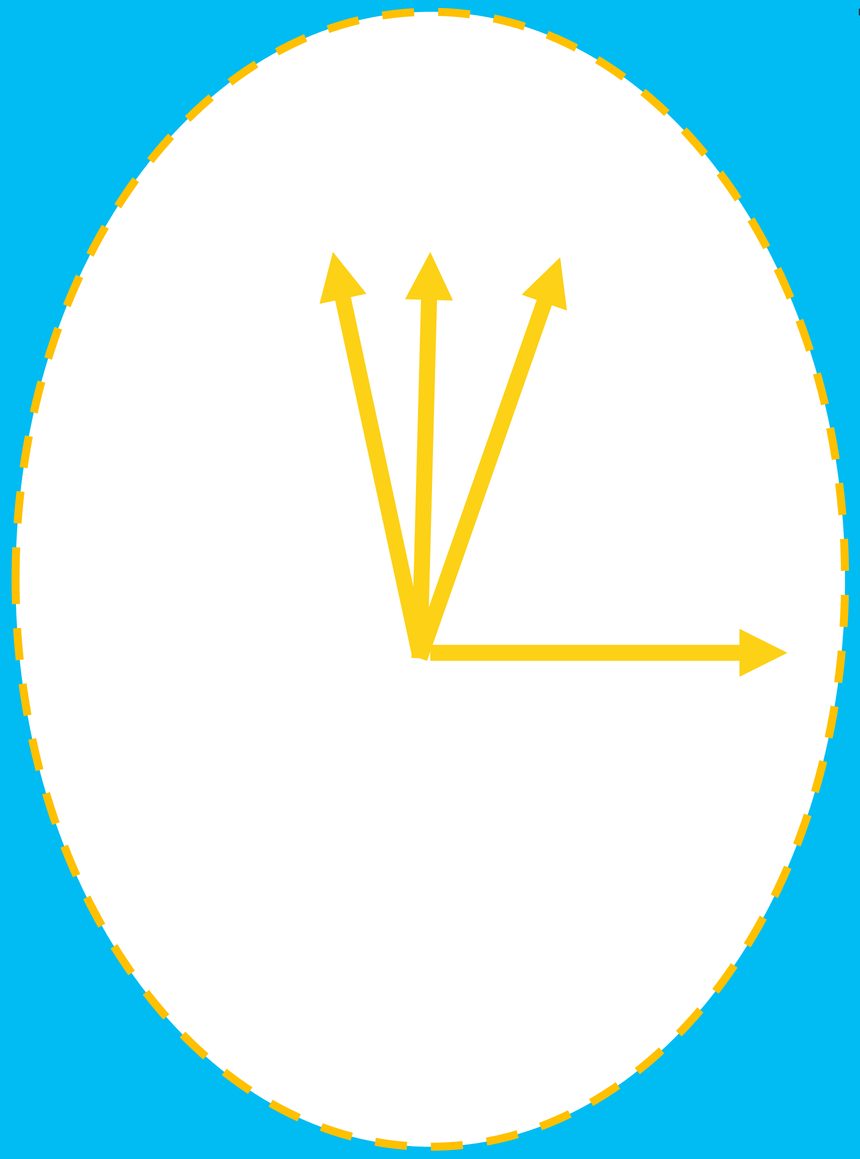
Quadratic Forms and Energy



$u = (1,0)$

$$Q(u) = \langle u, v_1\rangle^2 + \langle u, v_2\rangle^2 + \langle u, v_3\rangle^2 + \langle u, v_4\rangle^2$$
$$= 0 + 1 + 3/4 + 3/4$$
$$= 2.5$$

Quadratic Forms and Energy

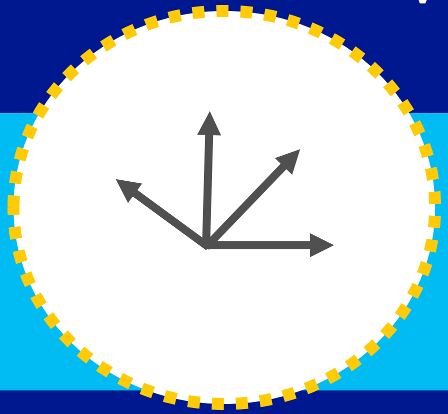


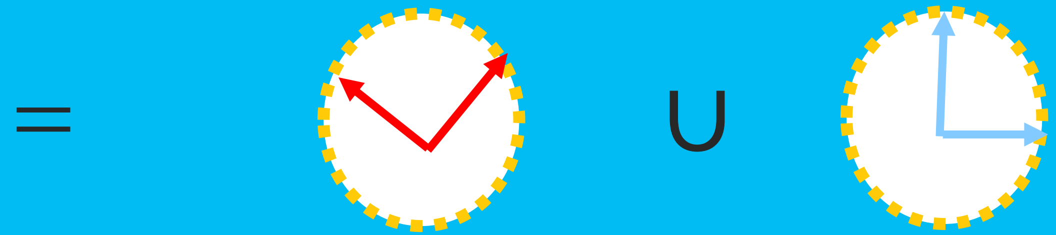
Splitting A Quadratic Form in Half

[Marcus, Spielman, Srivatsava, June 2013]

Main Theorem. Suppose $v_1, \ldots, v_m \in \boldsymbol{R}^n$ are vectors $||v_i|| \leq .01$ and energy one in each direction:

$$\forall ||u|| = 1 \qquad \sum_i \langle u, v_i \rangle^2 = 1$$

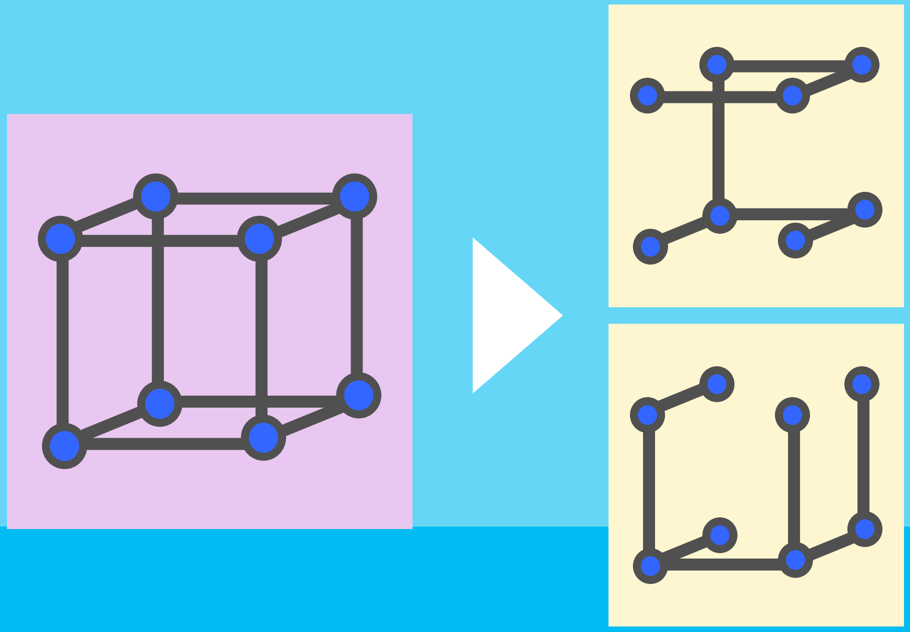




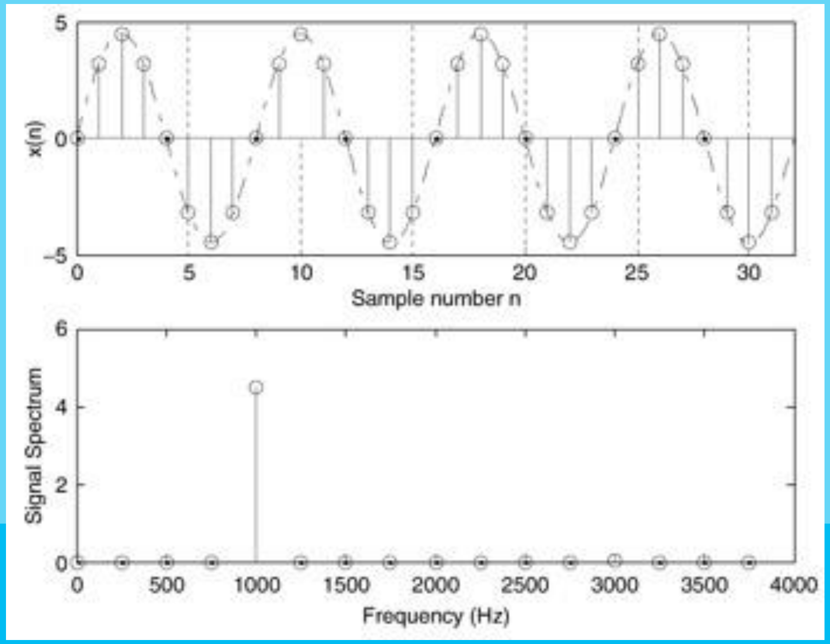
Then there is a partition $T_1 \cup T_2$ such that *each part* has energy close to half in each direction:

$$\forall ||u|| = 1 \qquad \sum_{i \in T_j} \langle u, v_i \rangle^2 = \frac{1}{2} \pm 0.05$$

Can encode a lot of things as quadratic forms



Graph Sparsification

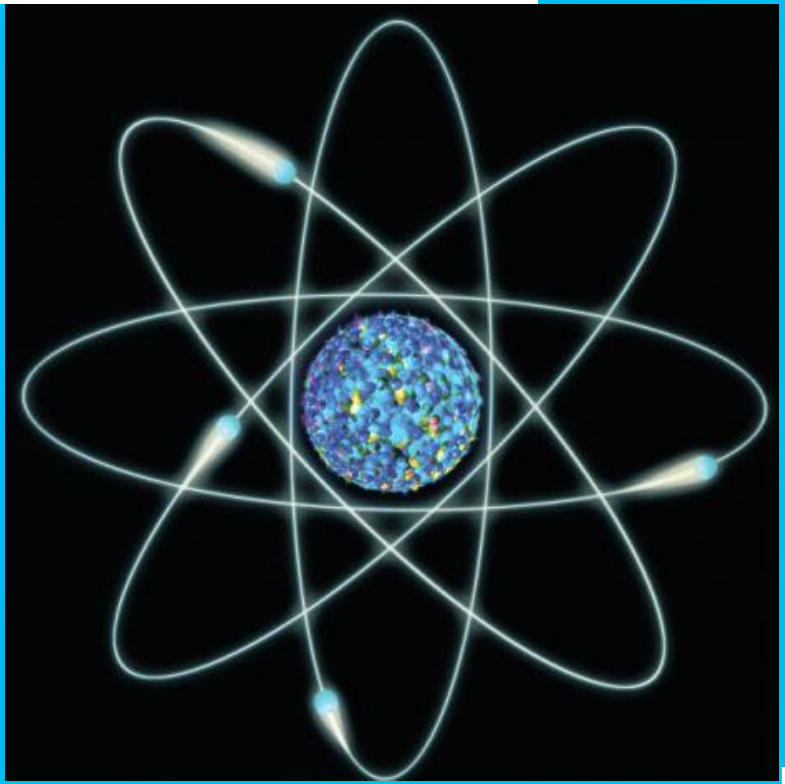


Signal Processing

The Kadison-Singer Conjecture, 1959

… The results that we have obtained leave the question of uniqueness of extension of the singular pure states of $\mathcal{A}_d$ open. We incline to the view that such extension is non-unique …

[MSS'13] implies the conjecture is indeed **true**.



Impact on Technology

Face Verification

Same

Different

LFW (Labeled Faces in the Wild) Dataset

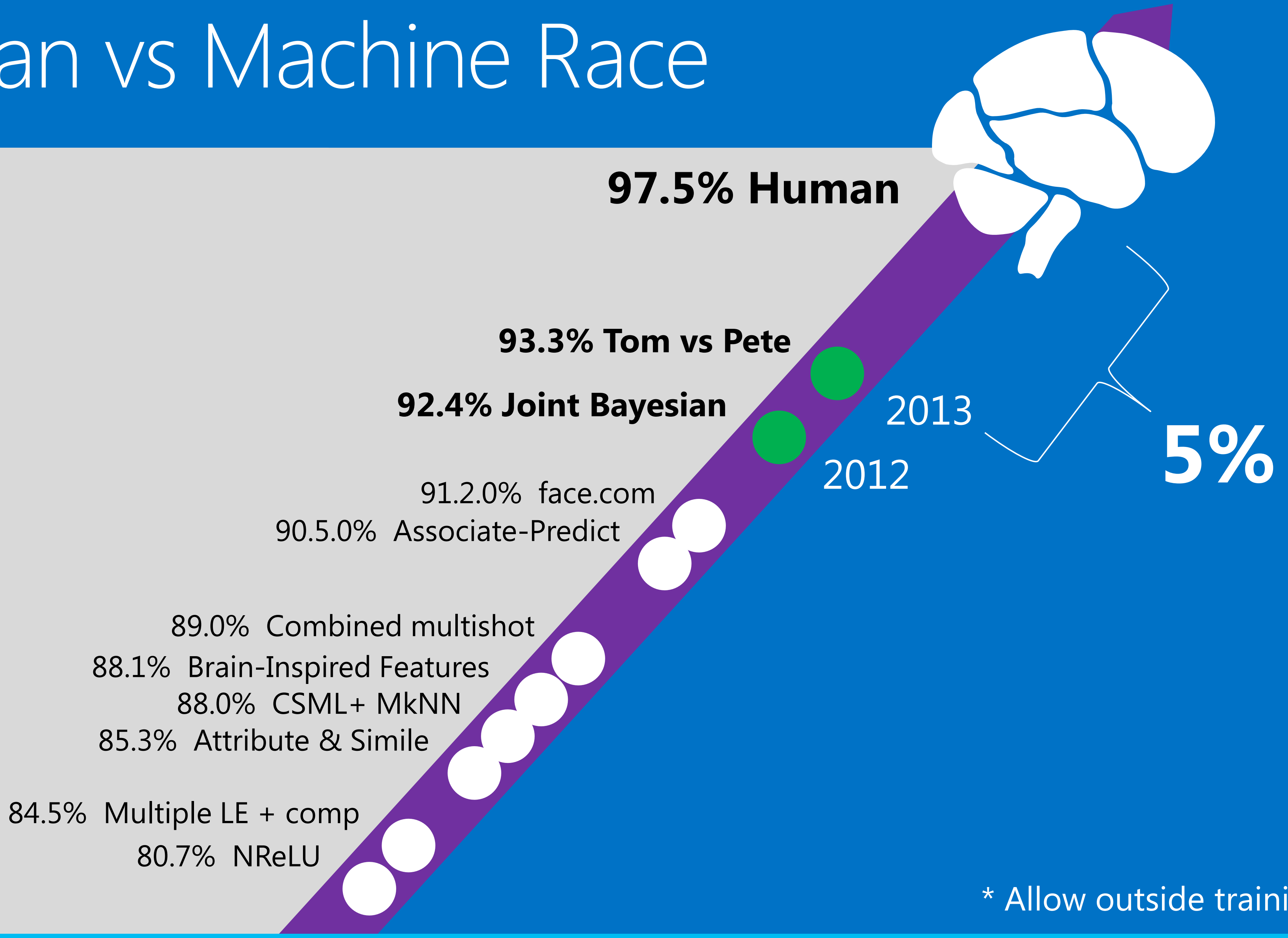
13,000+
images from web

1,680
subjects

"Real" images from the web
(not acquired under artificially controlled conditions)

[Huang et al. 2007]

Human vs Machine Race

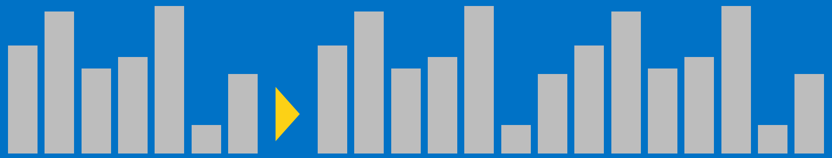


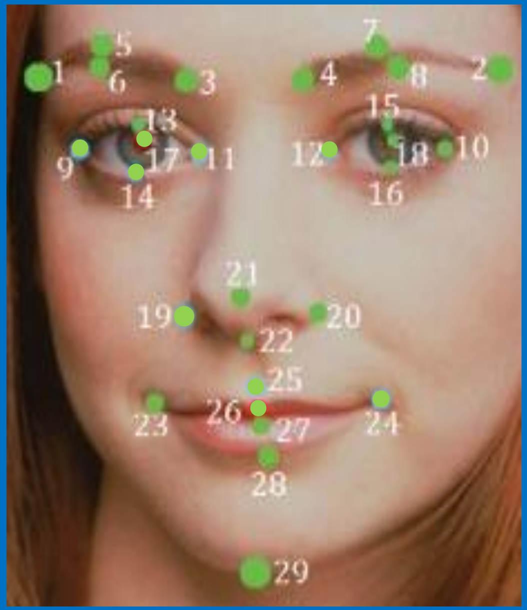
* Allow outside training data

Blessing of Dimensionality for Face Recognition

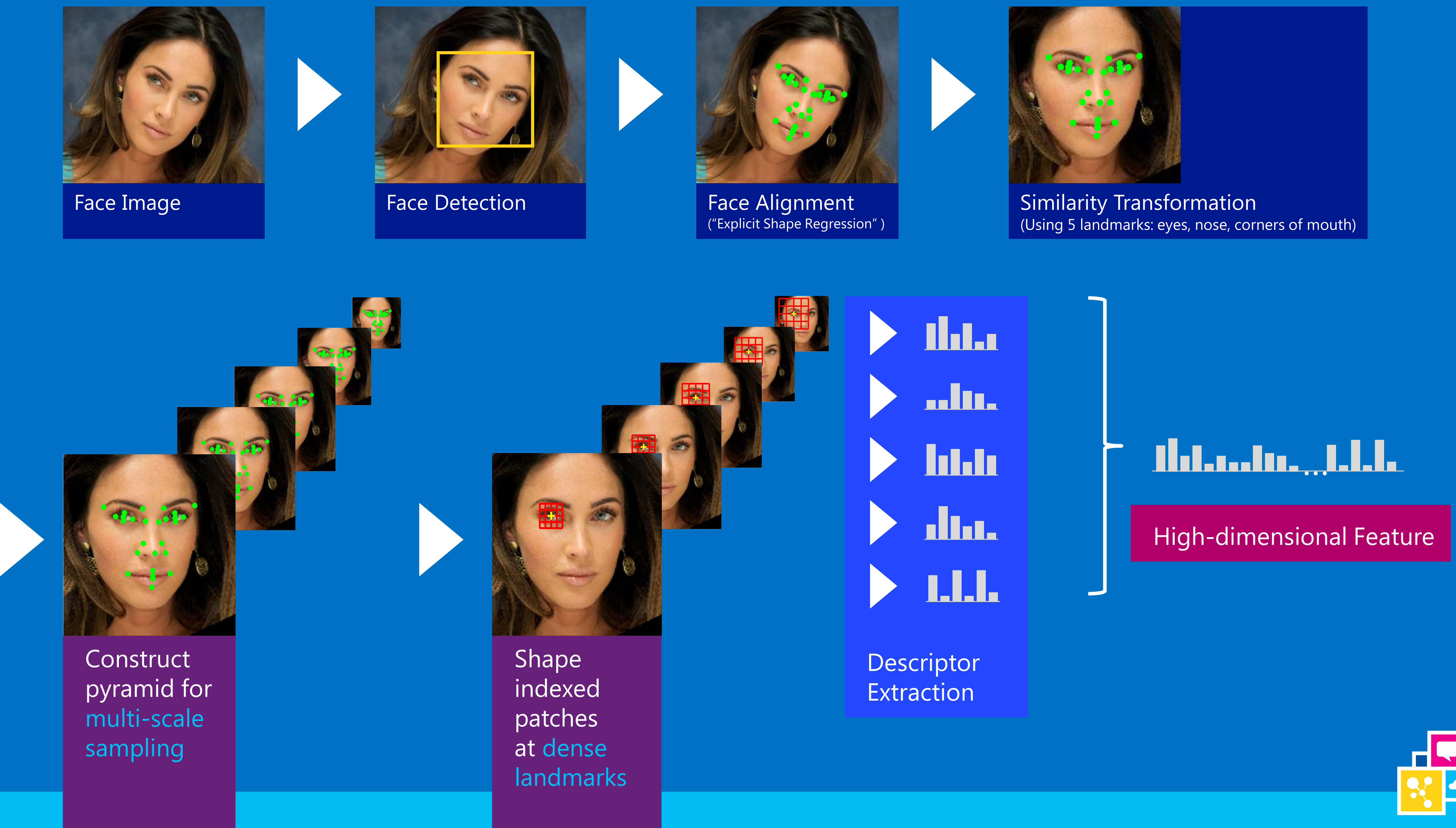
100K dim (our work) vs 1K dim (prior work)

Constructing the feature by sampling at landmarks:

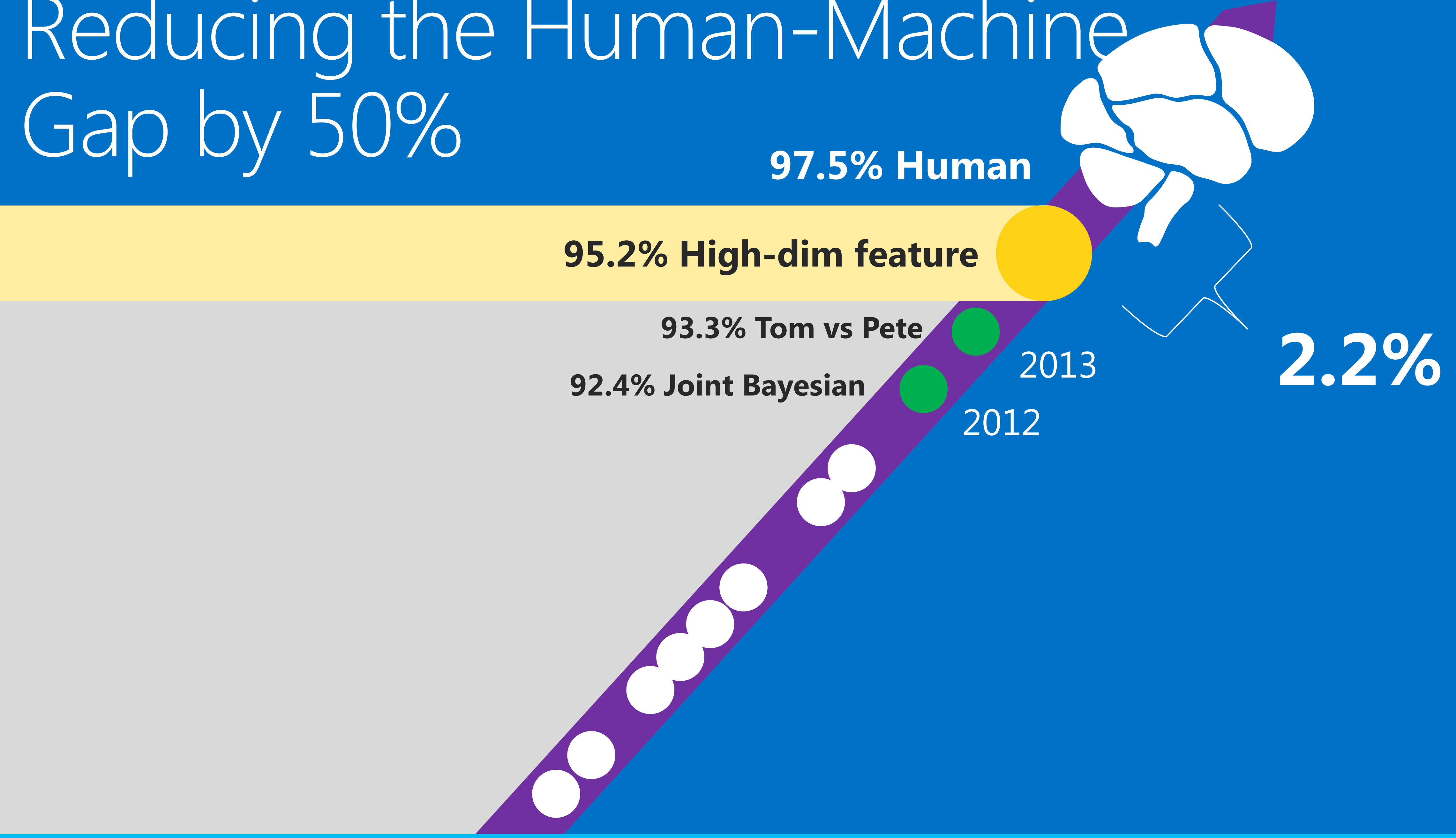




D. Chen, Cao, F. Wen, & J. Sun. **Blessing of Dimensionality: High-Dimensional Feature and Its Efficient Compression for Face Verification.** CVPR 2013 (oral).


Face Image
Face Detection
Face Alignment
("Explicit Shape Regression")
Similarity Transformation
(Using 5 landmarks: eyes, nose, corners of mouth)
Construct pyramid for multi-scale sampling
Shape indexed patches at dense landmarks
Descriptor Extraction
High-dimensional Feature

Reducing the Human-Machine Gap by 50%



What we can do now that we missed before

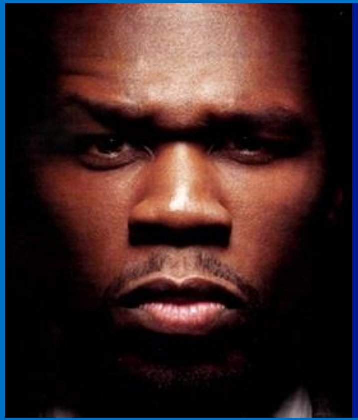
Pose

Decoration

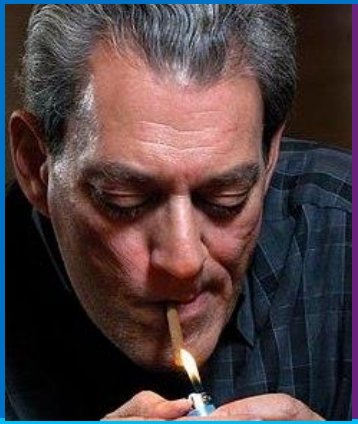
Glasses

Expression

What we still miss compared to humans








What humans and machines still get wrong

Alice Cooper

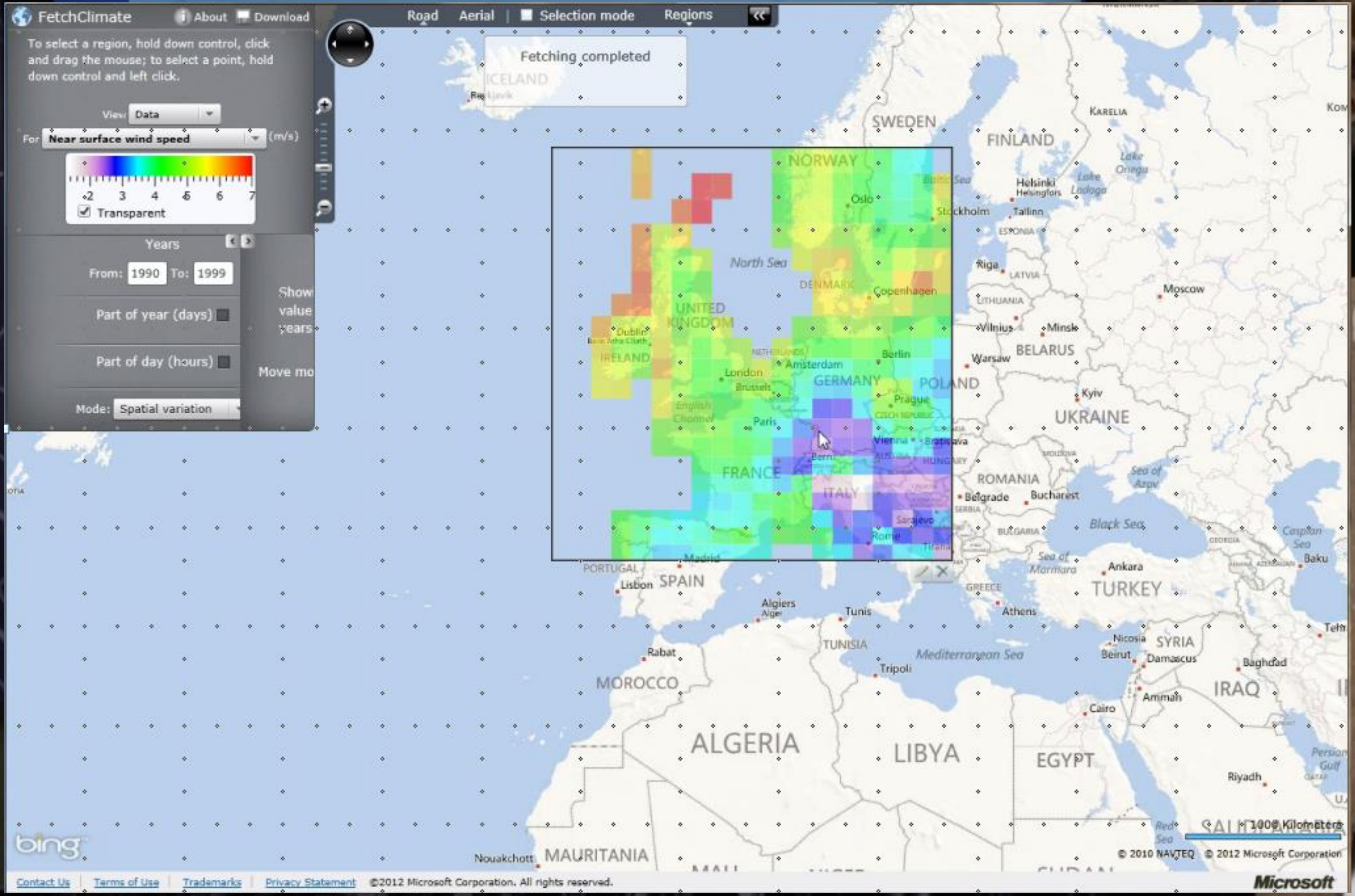
The human vs machine race is still on. Join the race!

Landmarks/Raw features are available at http://home.ustc.edu.cn/~chendong/

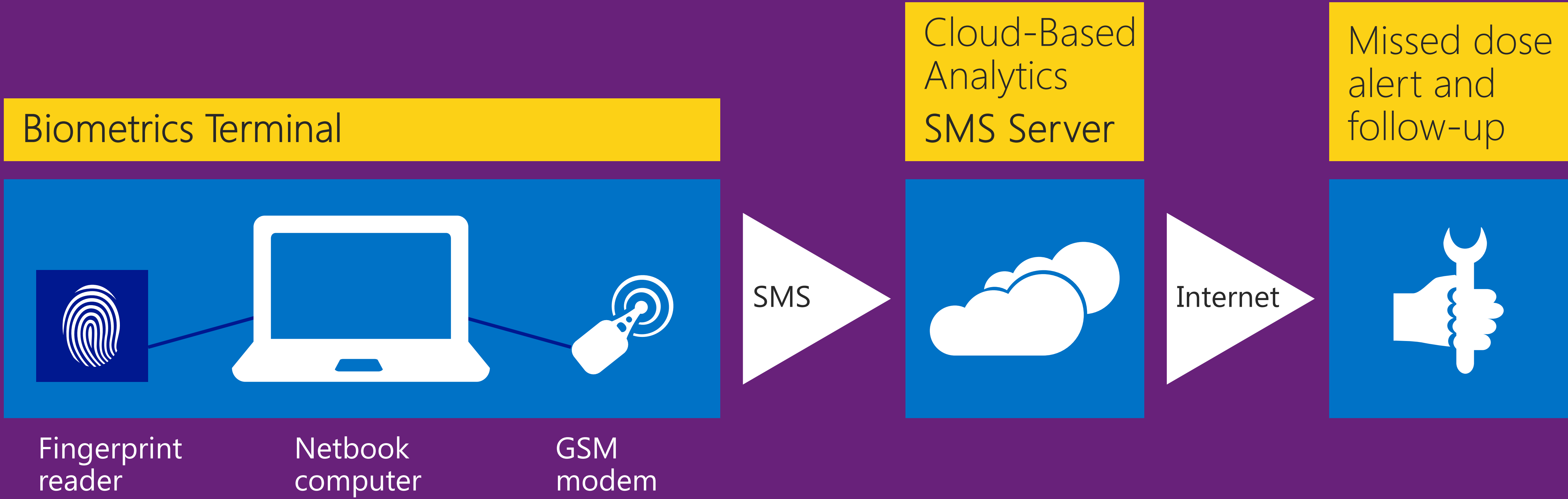
What humans and machines still get wrong

Impact on Society

FetchClimate



Using Biometrics to Fight Tuberculosis
Microsoft Research and Operation ASHA



Bhatnager, Sinha, Samdaria, Gupta, Batra, Bhardwaj, and Thies, Int'l Conf. on Persuasive Technology, June 2012

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