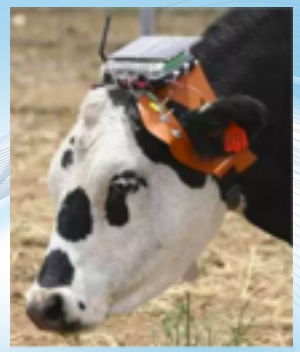
Laying the Computational Foundations of Image Analysis Tools for Application in Livestock Breeding

Catie McVey

Colorado State – Dairy Systems – Pinedo Lab

A Data Rich Future

- Developing Technologies
  - wearable sensors
    - movement/behavior
    - biologics
  - RFID/GPS
  - genomoics/microbiome
  - automated management
- Where will these technologies lead us?
- Where will the technological gaps lead us astray?

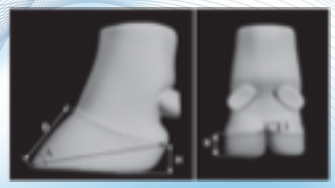


dxc.technology

Future of Anatomical Phenotypes?

- Scale
- Frequency
- Accuracy

https://www.dpi.nsw.gov.au/animals-and-livestock/beef-cattle/breeding/bull-selection/structural-soundness

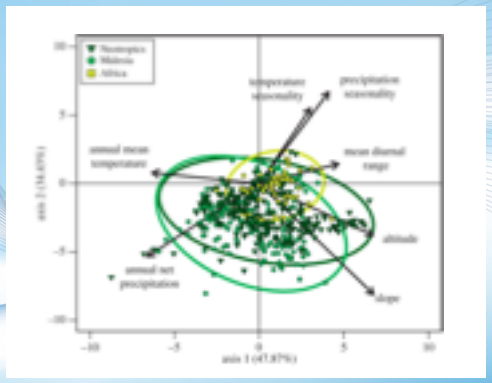


http://dairyhoofhealth.info/lesions/digital-dermatitis/dd-heifers-alters-claw-conformation-increases-heel-horn-erosion/

Guiding Questions

- What existing algorithms best fit this application?
- What modifications need to be make these algorithms better adapted to the demands of a production environment?
- Will the measurements produced from images have suitable characteristics to be incorporated in standard statistical analyses?

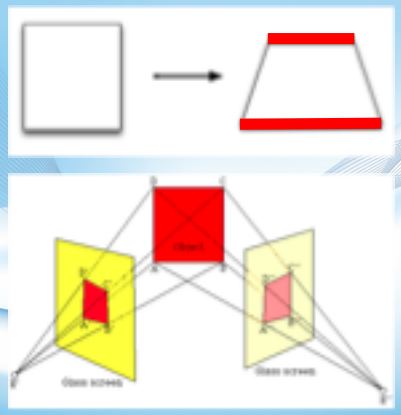
Image Hyperspace

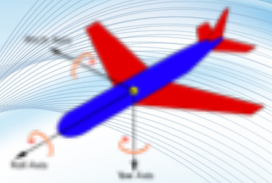


1) Temporal Compression

- Growth?
- Microexpressions?

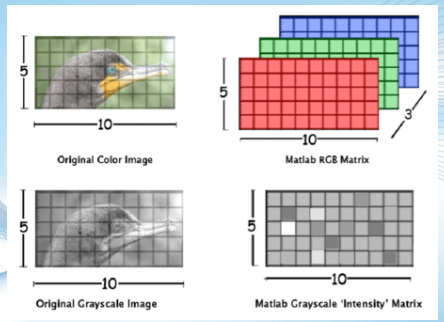
2) Projection Onto a Plane





3) Projection Onto a Plane

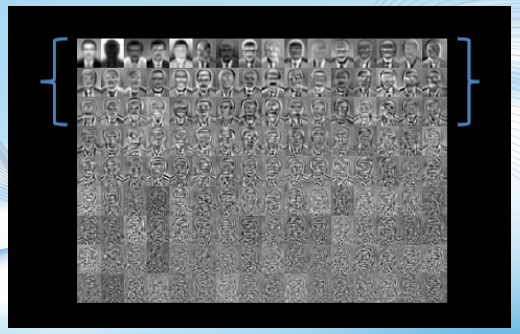
3) Pixel to Coordinate Annotations



Singh, Bhupendra Pratap. "Imaging Applications of Charge Coupled Devices (CCDs) for Cherenkov Telescope" 2012. Project Report Bhabha Atomic Research Centre. Online.

What's already out there?

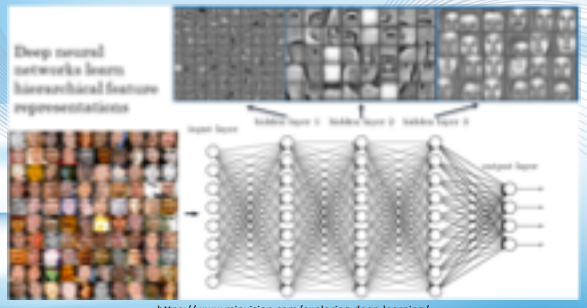
- Eigen face algorithms



http://laid.delanover.com/explanation-face-recognition-using-eigenfaces/

What's already out there?

- Eigen face algorithms
- Neural Networks



https://www.rsipvision.com/exploring-deep-learning/

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- Eigen face algorithms
- Neural Networks
- Face Mesh

https://steemit.com/science/@stormblaze/how-does-a-computer-detect-a-face

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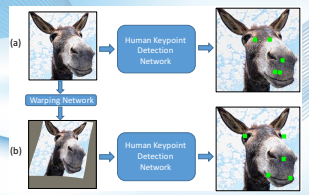

Rashid *et al* 2017

https://steemit.com/science/@stormblaze/how-does-a-computer-detect-a-face

Guiding Questions

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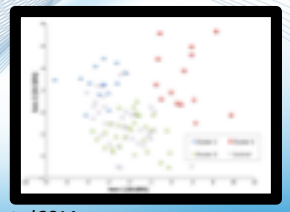
4) 2D Coordinate to Descriptive Covariate

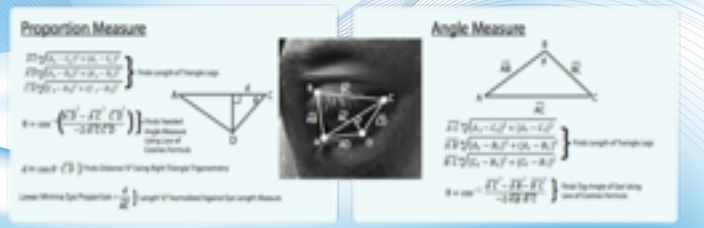
- Euclidean/Geodisic Distances
  - Pairwise Distances => Data Compression => Statistical Analysis
  - PCA/Factor Analysis
  - Unsupervised Learning (Clustering/ISOMAP)



Miles *et al* 2014

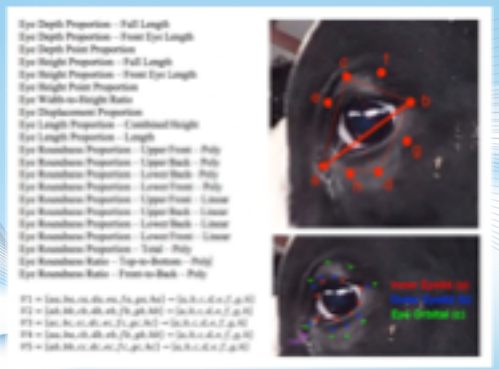
Image Recognition => Image Description

- Geometric Biometric Analysis
  - Projections against anatomical reference planes
  - Anatomical and auxiliary points



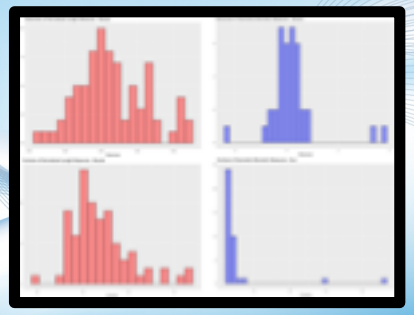
Methods

- Image Data Base
  - 108 Holstein Cows Photographed Over 3 Days
  - 551 Unique Images
  - 2 Reps of Coordinate Selection
- Compute Geometric Biometrics and Locally Normalized Length Measures for four regions of the face
  - Eye
  - Muzzle
  - Topline
  - Forehead/Jowl
- Normality (Skew & Kurtosis)
- Robustness to Variations in Image Quality
- Overall Repeatability
- Correlation Structures in Observed Values and Error



1) Normality

- Hypothesis: Will geometric biometrics prove show superior distribution traits for linear models

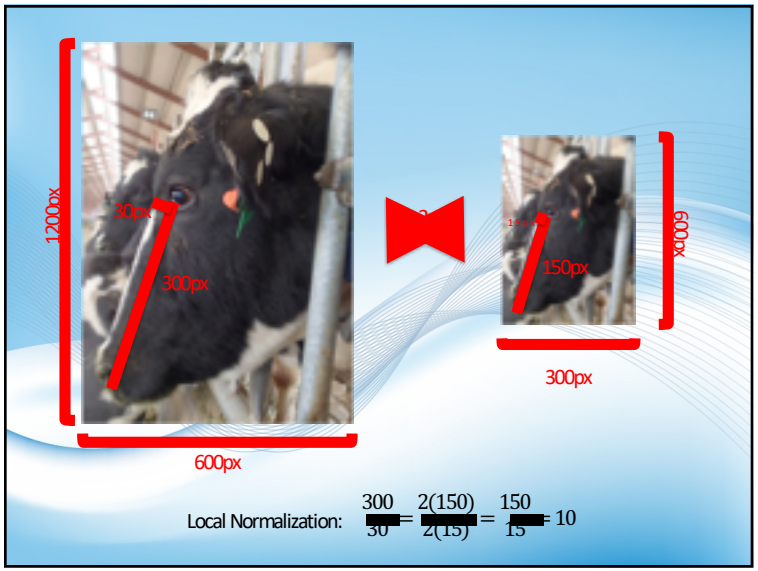


2) Resistance to Variation in Resolution

- Hypothesis: Will geometric biometrics prove more resistant to variations in image resolution/quality
- Sources of Variation:
  - Camera Quality
  - Distance from animal
  - Zooming/Cropping
  - Image Compression

Image Resolution

Image Resolution



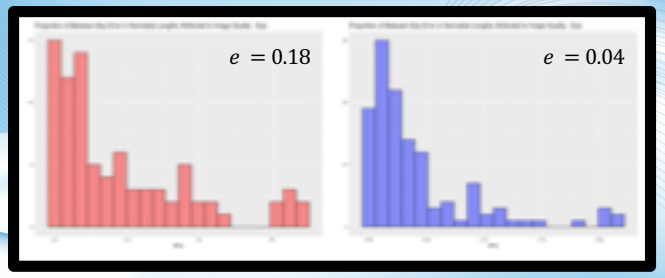
Resistance to Variation in Resolution

- Frame-to-Face Ratio = Pixel area occupied by cows head relative to overall size of the frame
  - Camera quality and zoom held constant
  - Only distance between camera and cow varied
  - Proxy measure for image resolution

$$FFR = \frac{Area\ Head}{Frame\ Height \times Frame\ Weight}$$

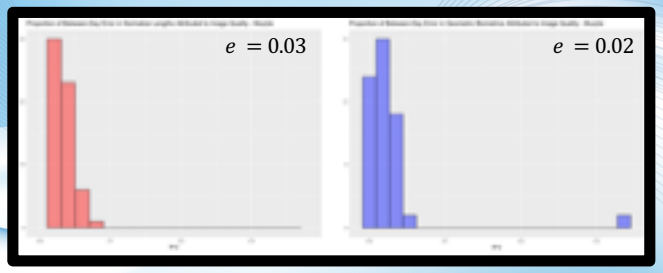
Resistance to Variation in Resolution: Eye Biometrics

$$\Delta biometric = \Delta FFR + \Delta OFA + (\Delta FFR)^2 + (\Delta OFA)^2 + \Delta FFR \times \Delta OFA$$



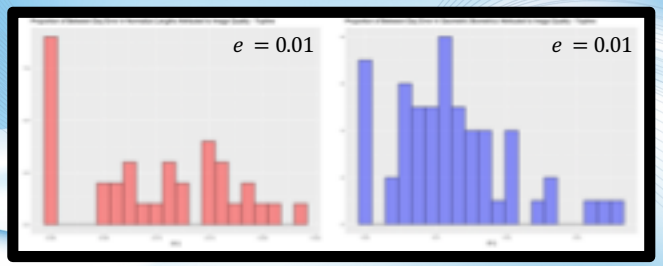
Resistance to Variation in Resolution: Muzzle

$$\Delta biometric = \Delta FFR + \Delta OFA + (\Delta FFR)^2 + (\Delta OFA)^2 + \Delta FFR \times \Delta OFA$$



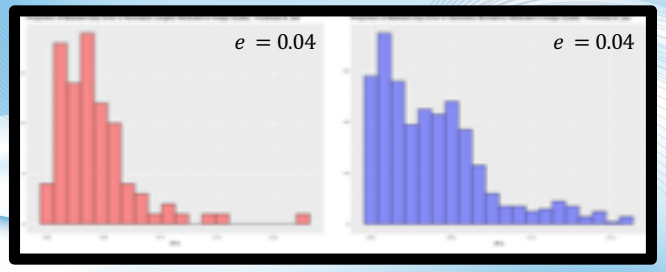
Resistance to Variation in Resolution: Topline

$$\Delta biometric = \Delta FFR + \Delta OFA + (\Delta FFR)^2 + (\Delta OFA)^2 + \Delta FFR \times \Delta OFA$$



Resistance to Variation in Resolution: Forehead

$$\Delta biometric = \Delta FFR + \Delta OFA + (\Delta FFR)^2 + (\Delta OFA)^2 + \Delta FFR \times \Delta OFA$$



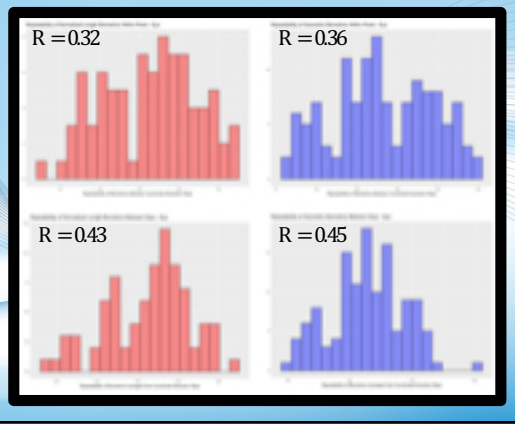
3) Reduction in Noise

- Sources of Error
  - Within-Photos Variation
    - Point Selection
  - Between-Day Variation
    - Face Angle
    - Facial Expression

$$Rep = \frac{Variation\ Between\ Cow}{Total\ Variation\ in\ Metric}$$

Reduction in Noise: Eye

$$biometric_{obs} = \mu + r_{cow} + r_{side} + r_{day} + e = biometric_{true} + error_{day} + error_{click}$$



Reduction in Noise: Muzzle

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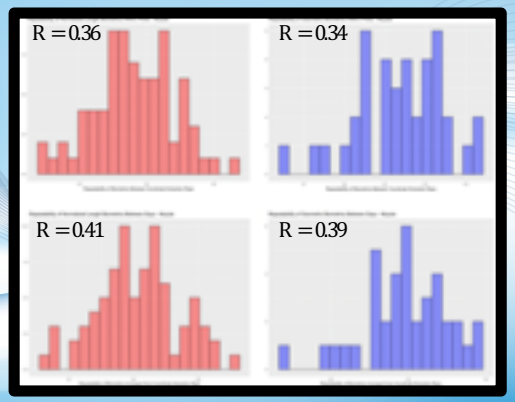

Reduction in Noise: Topline

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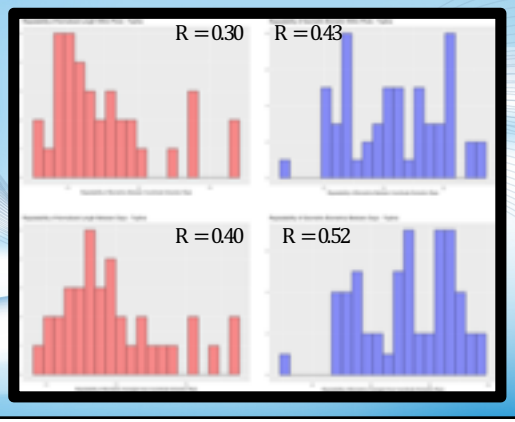

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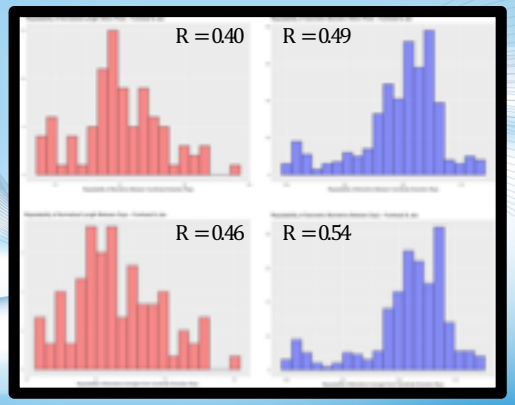

4) Resistance to Correlated Errors

- Hypothesis: Will geometric biometrics prove more resistant to error in selection of anatomical coordinates compared to pairwise distances
- Absolute Distance:

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- Absolute Distance:

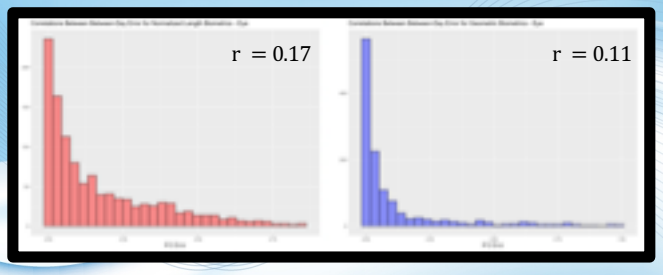
Eye Height Proportion:

$$EHP = \frac{\overline{CD} + e}{\overline{AB}}$$

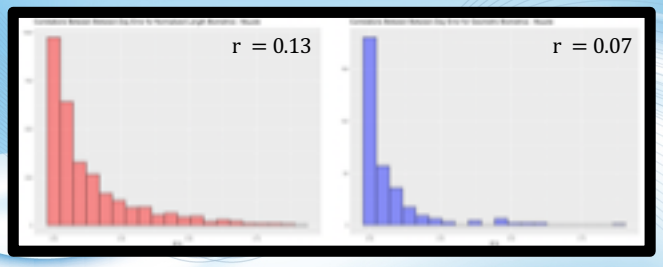
Eye Length Proportion:

$$EHP = \frac{\overline{AD} + 0}{\overline{AB}}$$

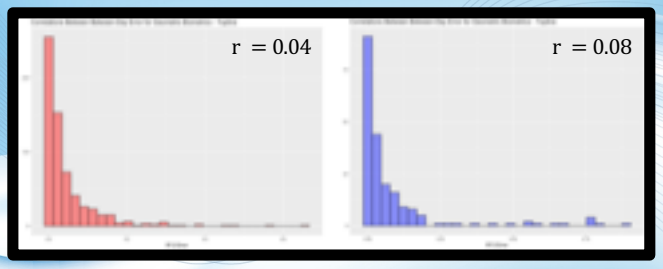
Resistance to Correlated Errors: Eye



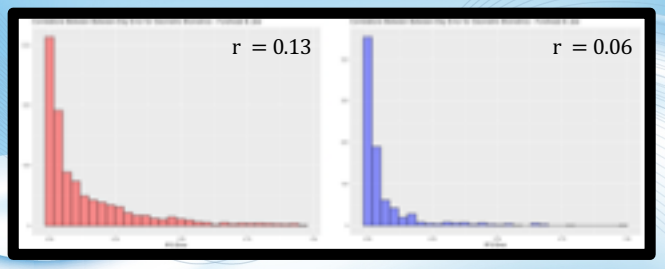
Resistance to Correlated Errors: Muzzle



Resistance to Correlated Errors: Topline



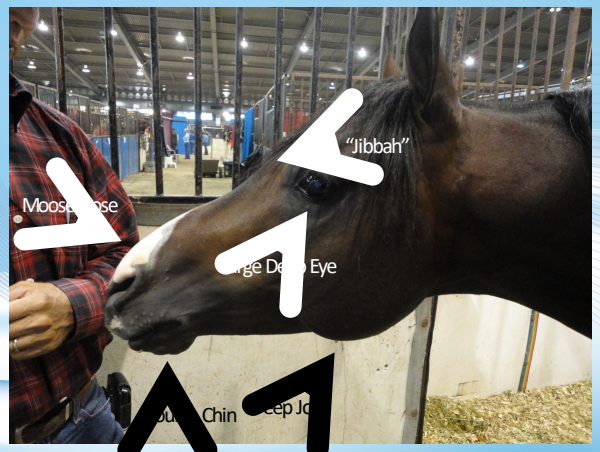
Resistance to Correlated Errors: Forehead



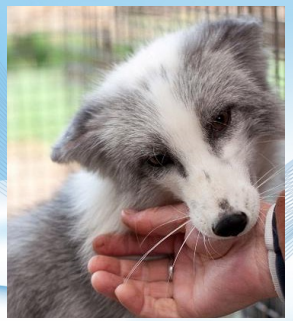
Conclusions

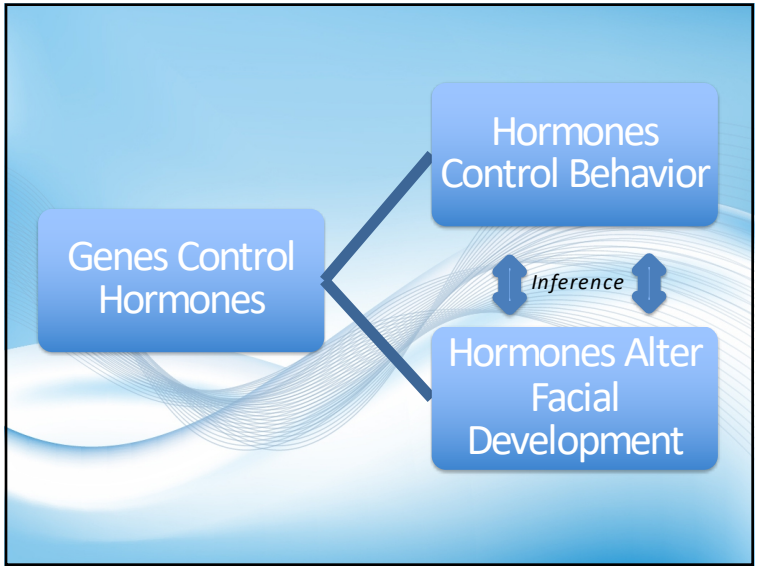
- Geometric biometrics are more resistance to variations in image quality, particularly the smaller traits
- Geometric biometrics have less correlated error than pairwise distance measures
- Geometric biometrics are more repeatable than pairwise distance measures for boney traits
- Geometric biometrics are way more interpretable

So why faces?



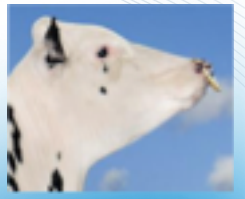
The Fox Farm Experiment





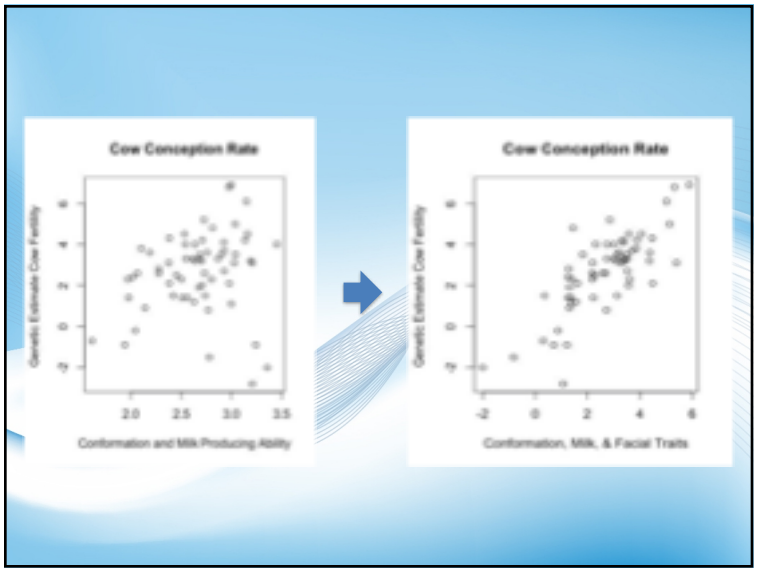
Data Mining Dairy Performance Traits

- Preliminary Data Set
  - Accelerated Genetics Bull Catalogue
  - 66 Holstein
  - 16 Preliminary Measures (Z1-Z16)
- Forward Selection Modeling
  - Soft beta test (~0.05) cutoff
  - Monotonically increasing adjusted r^2
  - Nested Model ANOVA Tests



Magnitude of Correlation

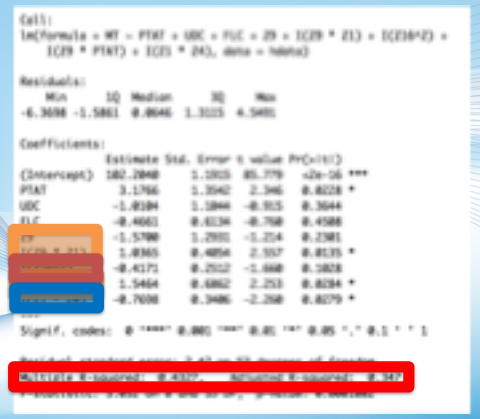
	Baseline Model		Biometric Model		p-value
	R_2	R_{a2}	R_2	R_{a2}	
PTAM	0.256	0.218	0.621	0.547	7.20e-06
PL	0.417	0.386	0.742	0.673	6.80e-06
CCR	0.042	0.009	0.608	0.511	9.56e-07
DCE	0.154	0.125	0.515	0.441	3.18e-05
Lameness	0.065	0.029	0.422	0.321	0.00077
Ketosis	0.079	0.025	0.511	0.413	4.59e-05
Mastitis	0.281	0.239	0.441	0.371	0.00669
Metritis	0.058	0.003	0.531	0.425	3.54e-05
Retained Placenta	0.013	-0.045	0.452	0.328	0.00029
Displaced Abomasum	0.022	-0.035	0.386	0.295	0.00017



Comparing Models

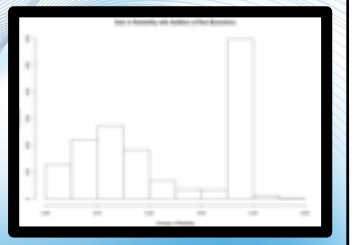
PTAM	PL	CCR	Lameness	Ketosis	Metritis	Retained P
(-)Z16	(+) Z7	(-)Z16	(-)Z5*FLC	(-)Z9	(-)PTAM*Z7	(-)Z7*PTA
(-)Z15	Z1*Z12*Z13	(+)Z16*PTAM	(-)Z11*Z9	(+)Z13	(+)Z7	(-)Z12*Z14
(+)Z7*PTA	(+)Z9	(+)Z12	FLC*Z11*Z9	(+)Z10*PTA	(-)Z9	(+)Z14
(-)Z12*Z13	(+)Z1*Z4	(-)Z3		Z1*Z2*Z3	(+)Z12*PTAM	(-)Z9
(+)Z8	(-)Z1*Z11				(-)Z9*Z10	(+)Z1
	(+)Z5*PTAT				(+)Z1*Z9	
	(+)Z15*Z3					
	(-)Z6					

Cross-Validating w/ Milking Temperament



Facial Biometrics As Indicator Traits in Genetic Evaluations

- Data
  - 681 First Calf Calving Ease (CE) Records
  - 622 Facial Biometric Records – 4 Eye Biometrics
  - 1552 Animals in 3-Generation Pedigree
- Results
  - H^2 CE = 0.13 $\pm$ 0.10
  - H^2 Eye Height = 0.28 $\pm$ 0.12
  - Genetic Correlation = 0.27



Future Work

- Factor analysis to adjust for variations in facial expression for soft tissue traits
- Geometric corrections for variations in out-of-plane angle
  - Canonical Correlation (CCA)
  - Angle Between Subspaces
  - Neural Net
- Confirm Regression Models to Genomic Health EBV's
- Social Network Analysis/Nonlinear Rank Order Modeling

Thanks!

- CSU Dairy Systems Crew – Pinedo Lab
- Our generous farm partners
- NSF GRF funding

Questions