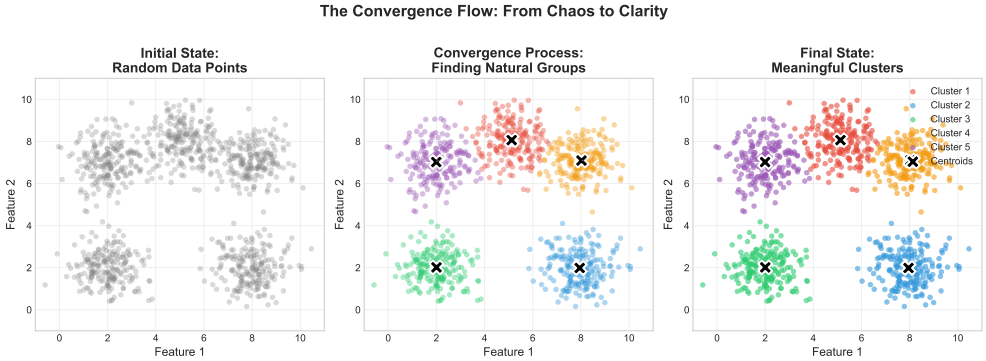
Machine Learning for Smarter Innovation

Week 1: Foundations & Clustering

Augmenting the Empathize Phase with ML

BSc Course in AI-Enhanced Innovation



The Convergence Flow: Order from Chaos

Watch 5000 data points self-organize into meaningful clusters

The Innovation Challenge

Why Traditional Design Needs AI Enhancement

Traditional Design Limits

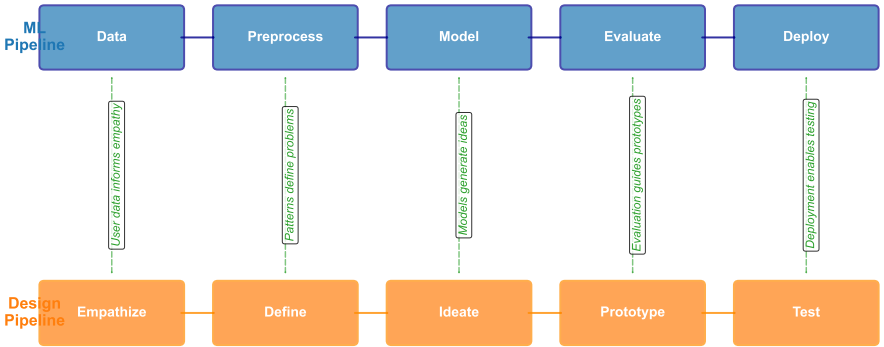
- **Scale**: Can interview 50 users, not 50,000
- **Speed**: Months for insights
- **Bias**: Designer's perspective dominates
- **Patterns**: Miss hidden connections
- **Iteration**: Slow feedback loops

AI-Enhanced Innovation

- **Scale**: Analyze millions of data points
- **Speed**: Real-time insights
- **Objectivity**: Data-driven discovery
- **Patterns**: Find non-obvious relationships
- **Iteration**: Continuous learning

The Promise: 100x more insights, 10x faster innovation

The Convergence: ML Meets Design Thinking



Each connection point creates innovation opportunities

The Dual Pipeline (Continued)

Understanding Both Worlds

ML Pipeline

Data → Preprocess → Model → Evaluate → Deploy

- Collect user behavior
- Clean and transform
- Train algorithms
- Validate accuracy
- Scale to production

Design Pipeline

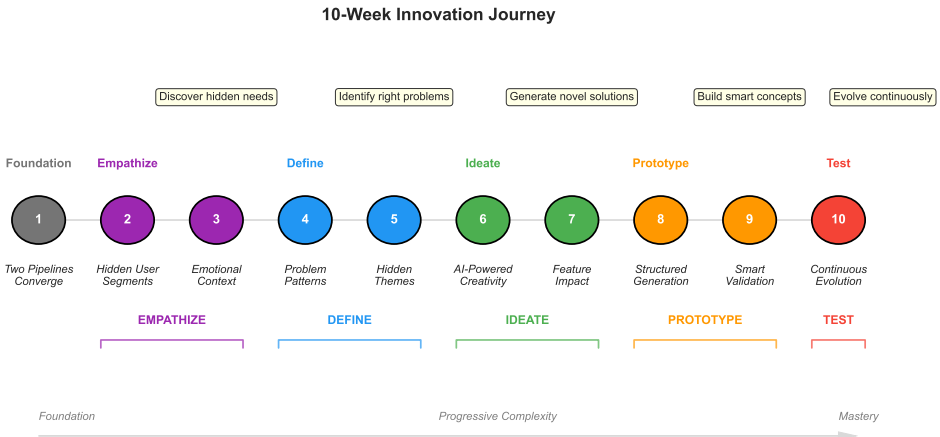
Empathize → Define → Ideate → Prototype → Test

- Understand users
- Frame problems
- Generate solutions
- Build concepts
- Validate with users

Integration = Innovation at Scale

Your Innovation Journey

10 Weeks to AI-Powered Design Mastery



Stage	Weeks	Innovation Unlocked
Empathize	1-2	Discover hidden user needs at scale
Define	3-4	Identify the right problems to solve
Ideate	5-6	Generate novel solutions with AI
Prototype	7-8	Build smart, adaptive concepts
Test	9-10	Evolve through continuous learning

This Week: Clustering for Deep User Understanding

What We'll Learn:

- How clustering reveals user segments
- K-means algorithm fundamentals
- Finding the optimal number of clusters
- Quality metrics for validation
- Advanced clustering techniques

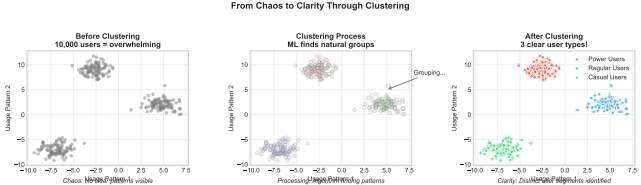
Design Applications:

- Create data-driven personas
- Map user journeys by segment
- Identify pain points systematically
- Prioritize design efforts
- Scale empathy to thousands

Goal: Transform data points into human insights

What is Clustering?

Finding Natural Groups in Data



Clustering Finds:

- Natural groupings
- Similar behaviors
- Hidden segments
- Pattern relationships

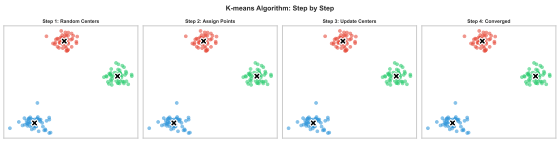
Key Insight:
Users who behave similarly likely have similar needs

K-Means: The Workhorse Algorithm

How It Organizes Your Users

The Process:

1. Choose K (number of clusters)
2. Place K random centroids
3. Assign points to nearest centroid
4. Move centroids to cluster mean
5. Repeat until stable

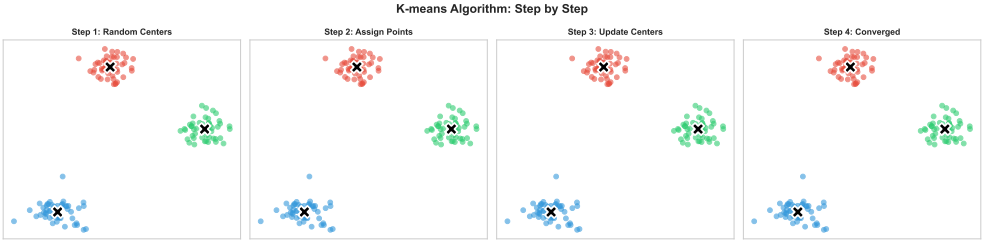


Strengths:

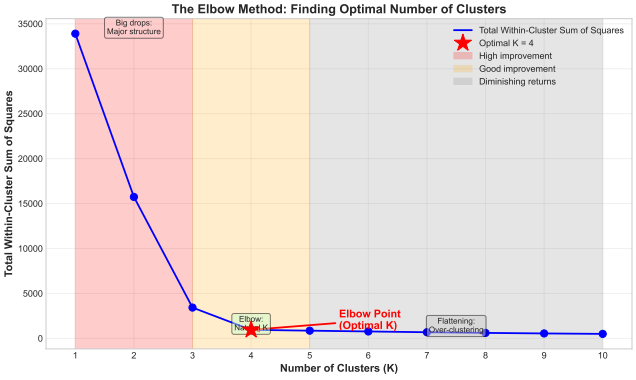
- Fast and scalable
- Easy to understand
- Works well for spherical clusters

K-Means in Action

Step-by-Step Convergence



Iteration 1 $\rightarrow$ Iteration 3 $\rightarrow$ Iteration 5 $\rightarrow$ **Converged**



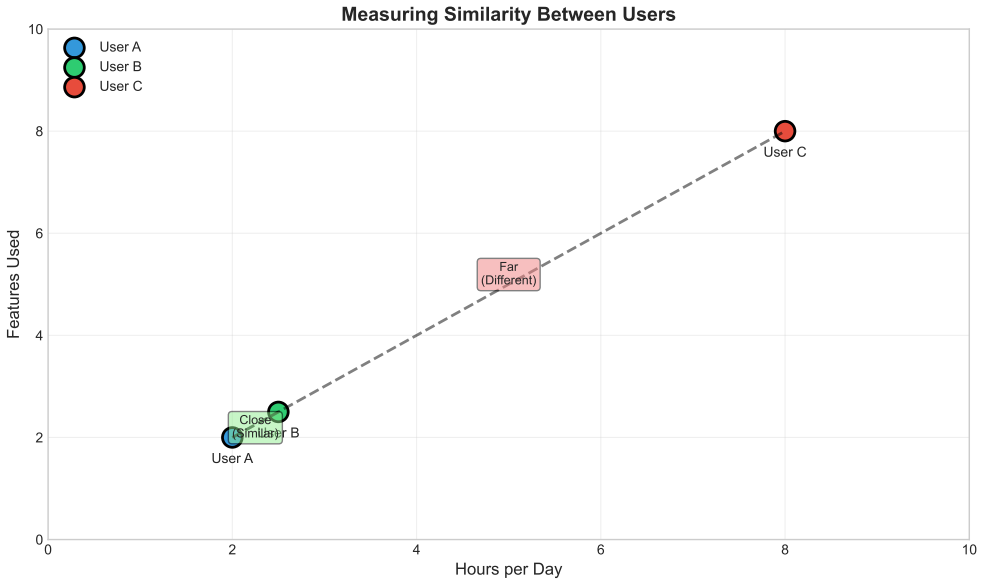
Finding the Elbow:

- Plot inertia vs K
- Look for the "elbow"
- Balance between:
  - Too few: Mixed groups
  - Too many: Overfitting

Optimal K = 5
Best trade-off between simplicity and accuracy

Distance Metrics

How We Measure Similarity



Cluster Quality Metrics

How Good Are Your Groups?

Silhouette Score:

- Ranges from -1 to +1
- Higher = better separation
- Our score: **0.73**

What it measures:

- Within-cluster cohesion
- Between-cluster separation
- Overall cluster validity

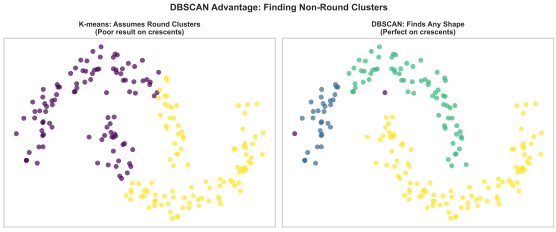
0.73 = Strong clusters!

DBSCAN Advantages:

- No need to specify K
- Finds arbitrary shapes
- Identifies outliers
- Handles noise well

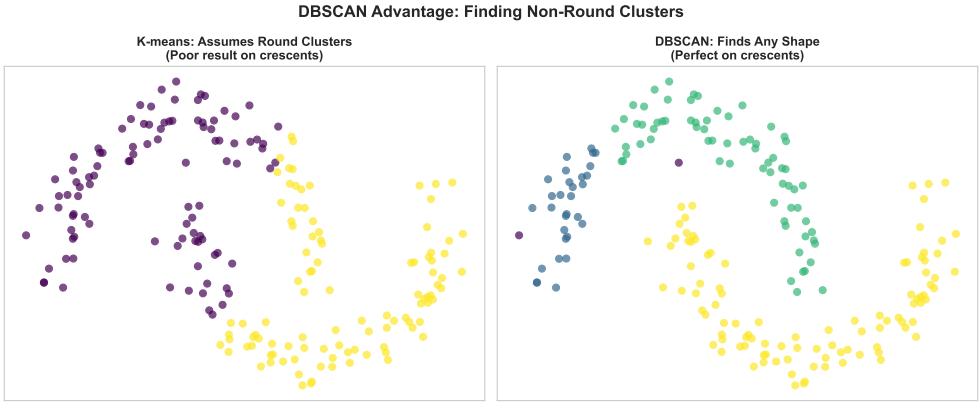
Perfect for:

- Non-spherical patterns
- Varying densities
- Outlier detection
- Exploratory analysis

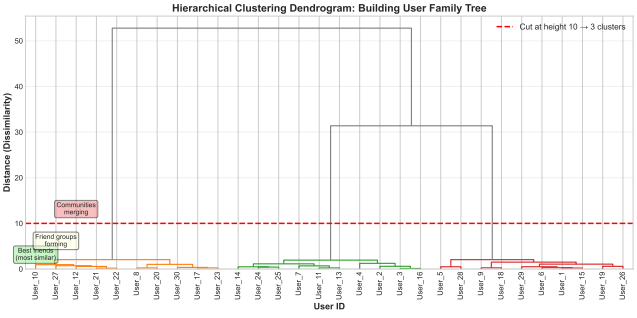


DBSCAN: Complex Patterns

When K-Means Isn't Enough



K-Means: Forces spherical shapes — DBSCAN: Finds natural boundaries



Dendrogram Benefits:

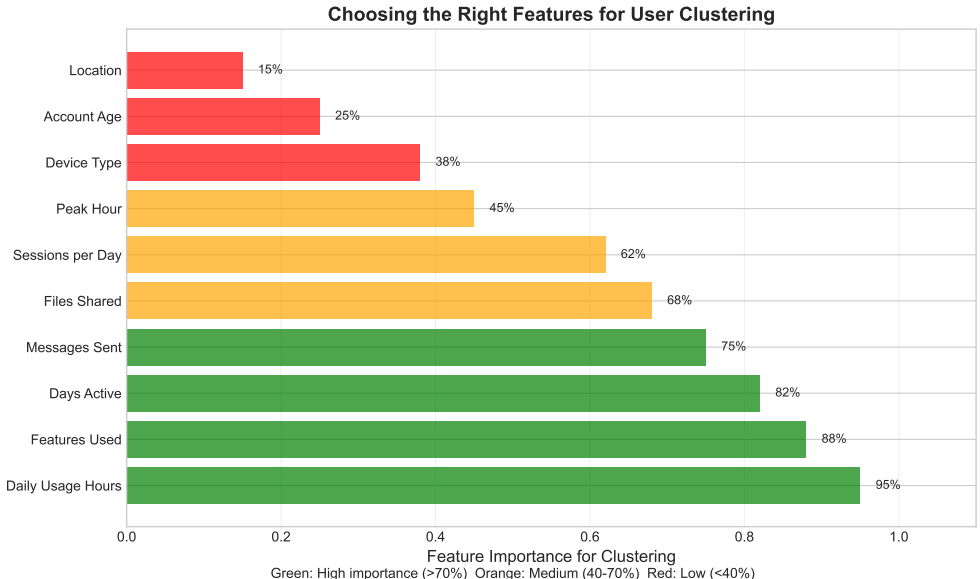
- Shows cluster hierarchy
- Multiple granularities
- Natural relationships
- No preset K needed

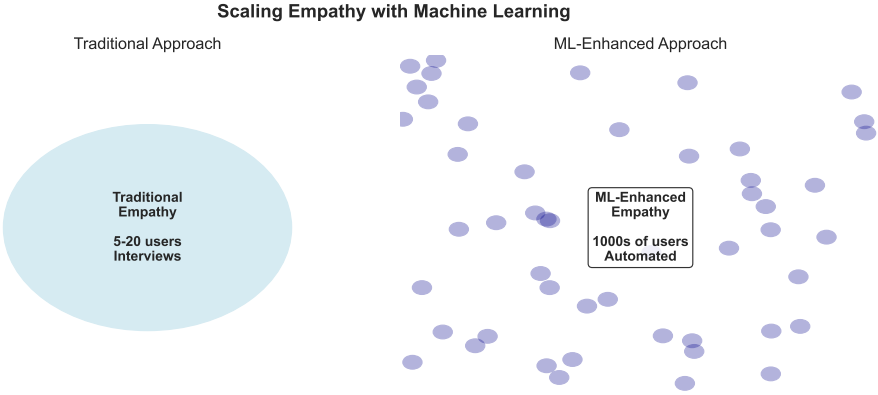
Cut the tree at any level:

- High cut = Few clusters
- Low cut = Many clusters
- Choose based on needs

What Drives the Clusters?

Feature Importance Analysis

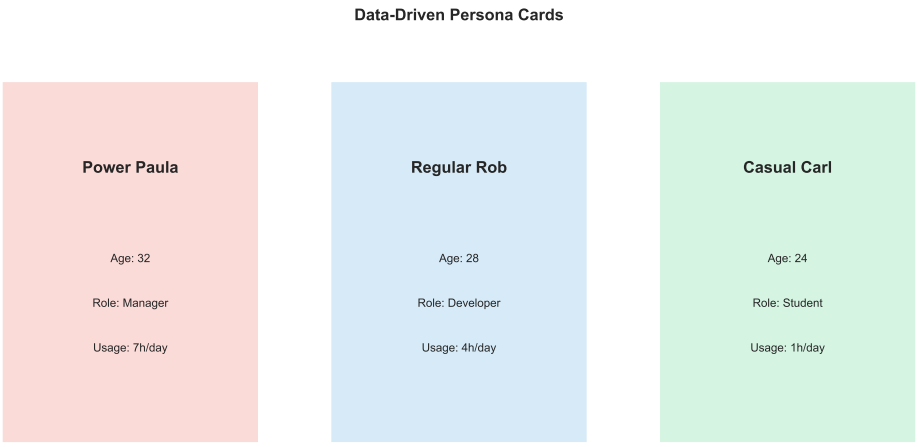




Each cluster represents real human needs

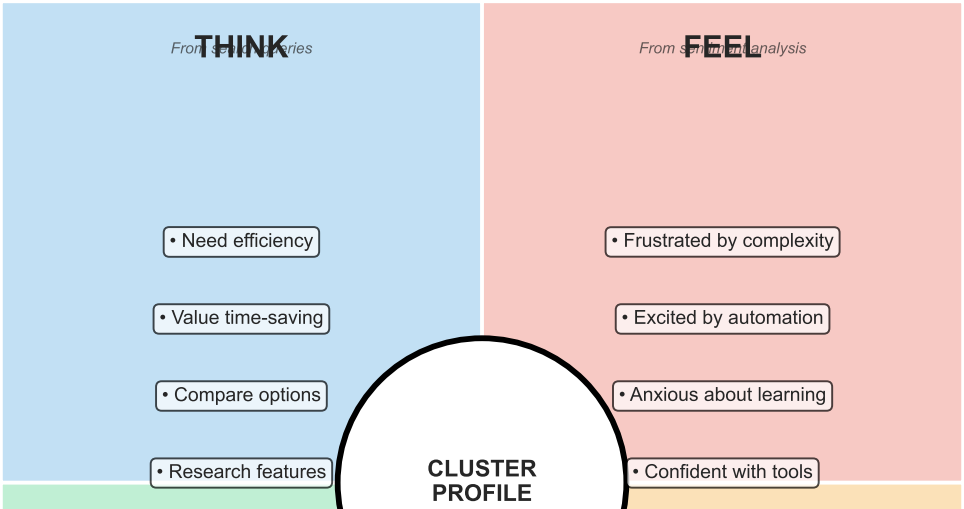
AI-Generated User Personas

Data-Driven Character Development



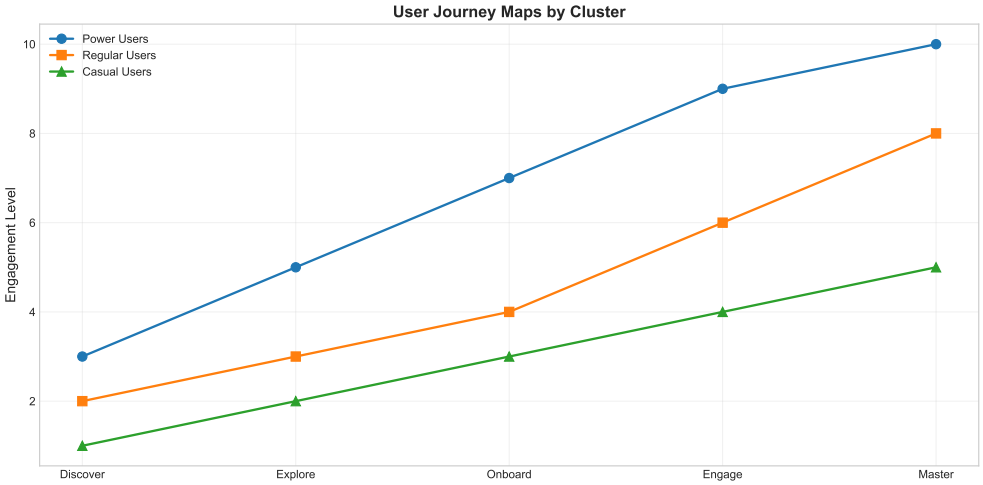
Power Users — Casual Browsers — Price-Conscious — Feature Seekers — New Users

Empathy Map: Data-Driven User Understanding



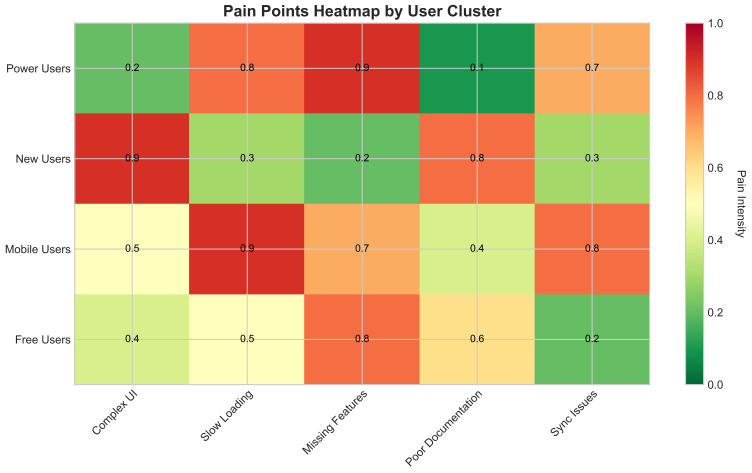
Different Journeys for Different Clusters

Personalized Path Understanding



Pain Points by Cluster

Where Each Segment Struggles



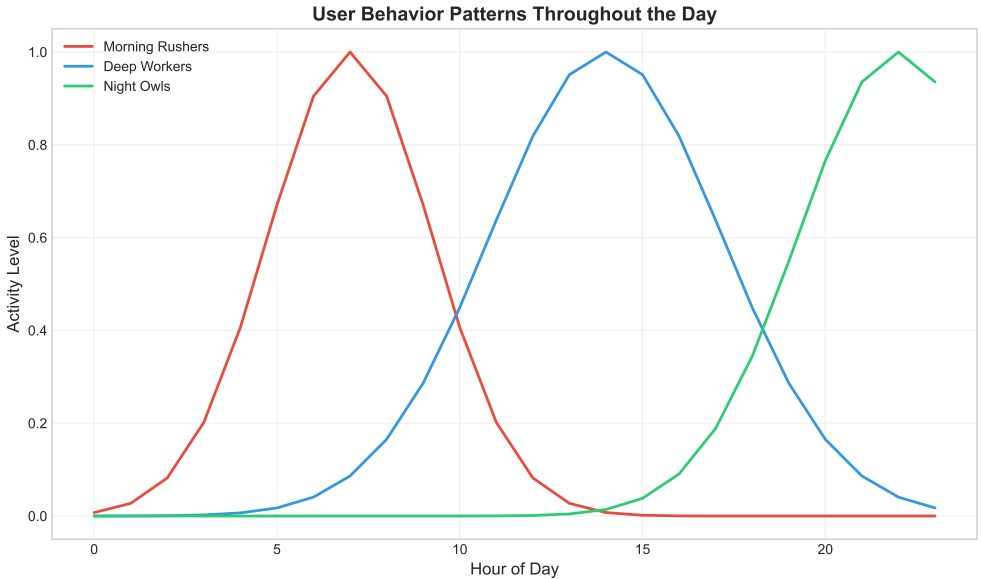
Key Findings:

- New users: Onboarding
- Power users: Speed
- Casual: Complexity
- Price-conscious: Value

Design implication:
One solution won't fit all!

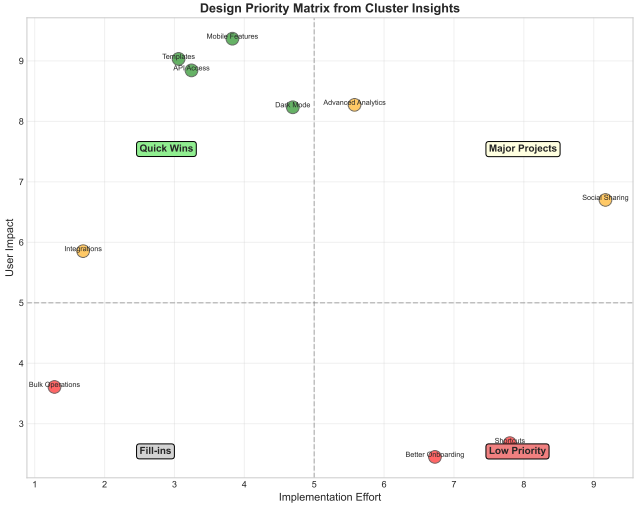
Behavioral Patterns Revealed

What Clusters Tell Us About Usage



Design Priority Matrix

Where to Focus Your Efforts

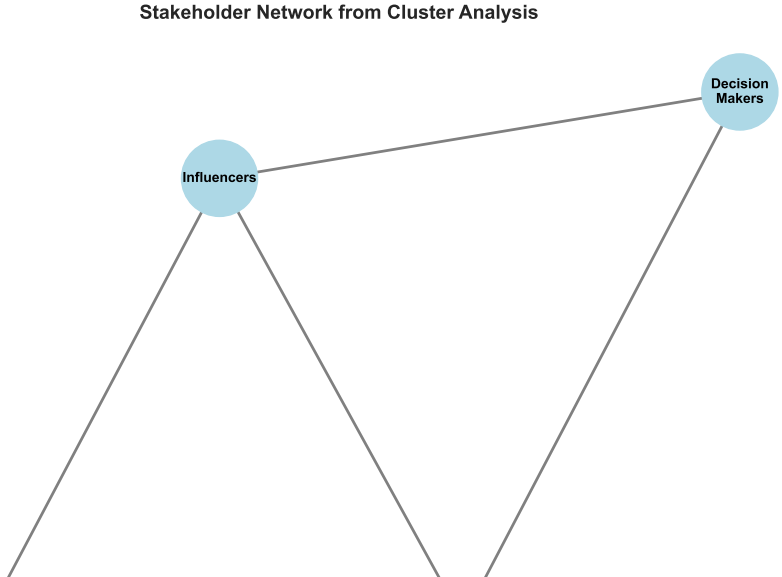


Priority Quadrants:

- **High Impact + High Effort**
  Strategic initiatives
- **High Impact + Low Effort**
  Quick wins
- **Low Impact + Low Effort**
  Fill-ins
- **Low Impact + High Effort**
  Avoid

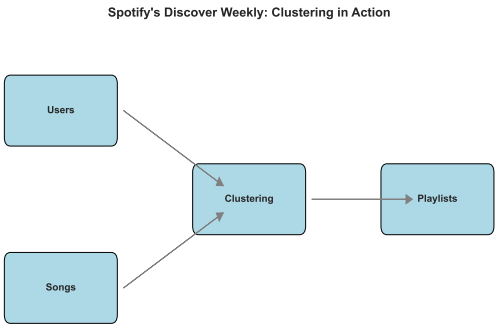
Understanding Stakeholder Connections

Network Analysis of User Relationships



Case Study: Spotify's Clustering Success

Real-World Application



Spotify Uses Clustering For:

- Music taste profiles
- Discover Weekly playlists
- User segmentation
- Recommendation engine

Results:

- Personalized experience
- Increased engagement
- Better retention
- Discovery of new artists

Key Takeaways

What We've Learned

Technical Skills

- K-means clustering algorithm
- Choosing optimal K with elbow method
- Silhouette scores for validation
- DBSCAN for complex shapes
- Hierarchical clustering

Design Applications

- Data-driven personas
- Segment-specific journeys
- Pain point identification
- Priority matrices
- Scaled empathy

Clustering transforms data into actionable user insights

Exercise: Segment Your Users

Scenario: You have data from 1000 app users including:

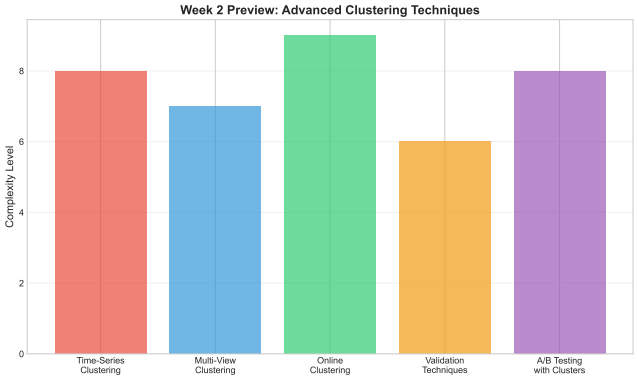
- Usage frequency
- Feature preferences
- Time spent
- Purchase history

Tasks:

1. Choose appropriate features for clustering
2. Determine optimal number of clusters
3. Interpret what each cluster represents
4. Create one persona per cluster
5. Identify key pain points for each segment

Next Week: Advanced Clustering

Going Deeper into User Understanding



Week 2 Topics:

- Density-based clustering
- Gaussian mixture models
- Clustering validation
- Feature engineering
- Real-time clustering

Design Focus:

- Dynamic personas
- Evolving segments
- Predictive empathy
- Micro-segmentation

Resources & Further Reading

Deepen Your Understanding

Technical Resources

Papers:

- MacQueen, J. (1967). K-means
- Ester et al. (1996). DBSCAN
- Rousseeuw (1987). Silhouettes

Tools:

- scikit-learn clustering
- Orange data mining
- KNIME analytics

Design Resources

Books:

- "Design Thinking" - Tim Brown
- "Sprint" - Jake Knapp
- "Lean UX" - Jeff Gothelf

Applications:

- Miro (journey mapping)
- Figma (persona creation)
- Optimal Workshop

Questions? Let's discuss!

Objective Function (Inertia):

$$J = \sum_{i=1}^{n} \sum_{j=1}^{k} w_{ij} ||x_i - \mu_j||^2$$

Where:

- n = number of data points
- k = number of clusters
- $w_{ij} = 1$ if x_i belongs to cluster j, 0 otherwise
- μ_j = centroid of cluster j

Update Rules:

1. Assignment: $c^{(i)} = \arg\min_j ||x^{(i)} - \mu_j||^2$
2. Update: $\mu_j = \frac{1}{|S_j|} \sum_{i \in S_j} x^{(i)}$

Appendix: Distance Metrics

Mathematical Definitions

Euclidean Distance:

$$d(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}$$

Manhattan Distance:

$$d(x, y) = \sum_{i=1}^{n} |x_i - y_i|$$

Minkowski Distance:

$$d(x, y) = \left(\sum_{i=1}^{n} |x_i - y_i|^p \right)^{1/p}$$

Cosine Similarity:

$$\cos(\theta) = \frac{x \cdot y}{||x|| \cdot ||y||}$$

Jaccard Distance:

$$J(A, B) = 1 - \frac{|A \cap B|}{|A \cup B|}$$

Mahalanobis Distance:

$$d(x, y) = \sqrt{(x - y)^T S^{-1} (x - y)}$$

Silhouette Score for point i:

$$s(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}}$$

Where:

- $a(i)$ = average distance to points in same cluster
- $b(i)$ = average distance to points in nearest neighbor cluster

Interpretation:

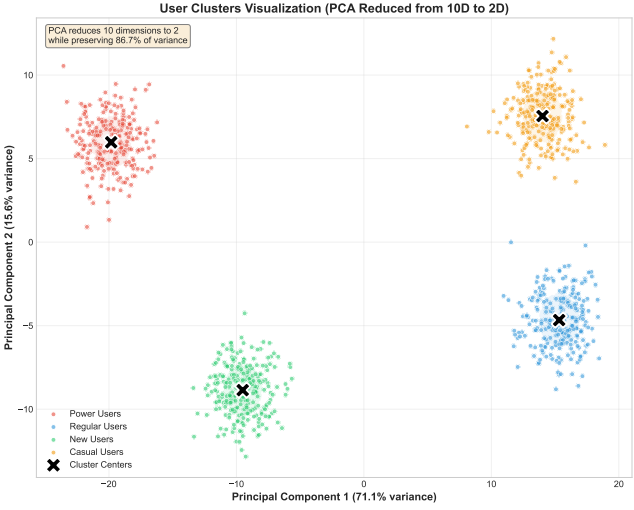
- $s(i) \approx 1$: Well clustered
- $s(i) \approx 0$: On border between clusters
- $s(i) \approx -1$: Misclassified

Overall Score:

$$S = \frac{1}{n} \sum_{i=1}^{n} s(i)$$

Appendix: PCA for Cluster Visualization

Dimensionality Reduction



PCA Process:

1. Standardize data
2. Compute covariance matrix
3. Find eigenvectors/values
4. Select top 2 components
5. Transform data

Variance Explained:

- PC1: 45.2%
- PC2: 28.7%
- Total: 73.9%

Key Parameters:

- ϵ (eps): Maximum distance between points
- MinPts: Minimum points to form dense region

Point Classification:

- **Core point**: Has $\geq$ MinPts within ϵ
- **Border point**: Within ϵ of core point
- **Noise point**: Neither core nor border

Algorithm Steps:

1. Find all core points
2. Form clusters from core points within ϵ
3. Assign border points to clusters
4. Mark remaining as noise

Appendix: Implementation Guidelines

Practical Considerations

Data Preparation

- Standardize features
- Handle missing values
- Remove outliers (if needed)
- Feature selection/engineering
- Consider scaling methods

Validation Methods

- Silhouette score
- Davies-Bouldin index
- Calinski-Harabasz score
- Visual inspection
- Domain expert review

Algorithm Selection

- K-means: Spherical, similar size
- DBSCAN: Arbitrary shapes
- Hierarchical: Nested structure
- GMM: Overlapping clusters

Common Pitfalls

- Not scaling features
- Wrong distance metric
- Ignoring outliers
- Over-clustering
- Forcing clusters