

Color Matching for Plastics

Bill Cheetham

General Electric Global Research

Outline

Intro to General Electric Global Research

Color Matching Applications

- FormTool - lab color matching tool
- ColorXpress - web customer tool
- Global Grade Selector - sales and research tool

General Electric Overview

A diversified technology, manufacturing and services company with a commitment to achieving world leadership in each of its key businesses



Aircraft Engines
Capital Services
Consumer Products
Industrial Systems
Information Services
Medical Systems
Plastics
Power Systems
Specialty Materials
Transportation Systems
NBC

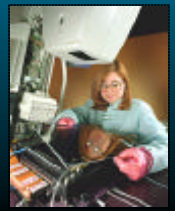


General Research Innovations



Innovations:

- Digital X-Ray
- High-Field MR
- Lexan
- Fan beam CT
- Man-Made Diamonds
- Many More...



General Research Locations

Niskayuna, NY – World Headquarters



Bangalore, India



Munich, Germany



Shanghai, China

Global Research Organization

Global Research Overview

GE Global Research Staff

- 2,100 people worldwide (750+ Ph.D.s)
- 12% of GE's total R&D spending
- 30% of GE's patents

Technical Disciplines

Chemistry	18%
Mechanical	17%
Physics	9%
Electrical	18%
Computer Science	17%
All Other	21%

Service Algorithms Lab (22 people)

Mission:

SAL performs research and development in Knowledge Engineering and Advanced Algorithm Techniques in order to provide game changing innovations to our customers. We are a diverse team of experts in the **collection, representation, visualization, analysis, and application of knowledge**. We provide next-generation technology to solve classification, fusion, reasoning with uncertainty, modeling, and computational complexity issues. This creates value for GE and our customers.

Key Customers:

- All of GE
- Lockheed Martin
- Externals:
 - DARPA
 - NIST
 - Air Force

Core Technologies:

- Soft Computing
- Information Fusion
- Information Visualization
- Case-Based Reasoning
- Knowledge Management
- Multi Objective Optimization
- Forecasting

Professional Activity (2002):

- 40 US patents filed
- 20 US patents granted
- 16 Papers published
- 3 Adjunct Professors

Automating knowledge-based tasks and creating new knowledge-based services.

7

Outline

Intro to General Electric Global Research

Applications – GE Plastics

- **FormTool - lab color matching tool**
- ColorXpress - web customer tool
- Global Grade Selector - sales and research tool

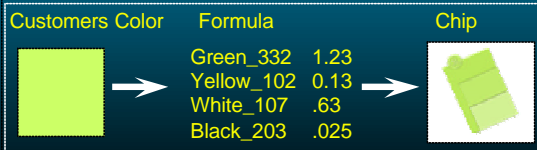
8

Introduction to Color Matching

GE is one of the worlds largest producers of plastics

Customers specify the color they want the plastic

GE needs to create a formula that matches the customers color
 - 10,000 color matches per year globally (\$500 per match)
 - colorants are the most expensive component of plastic



9

Introduction to Color Matching

There are 40 possible pigments that can be used. Choose 4 to 7 then specify the amount of each pigment.

Light passes through plastic, but reflects off paint.

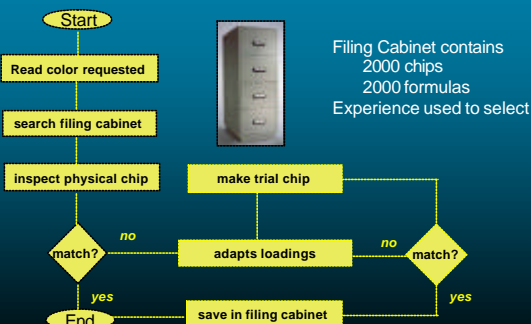
Physics can be used to predict colors created from a set of pigments, but not with good accuracy

The effect of small changes in colorant loadings can be predicted, but large changes are more difficult.

Easier to select a close match and adapt than create new.

10

Introduction to Color Matching



11

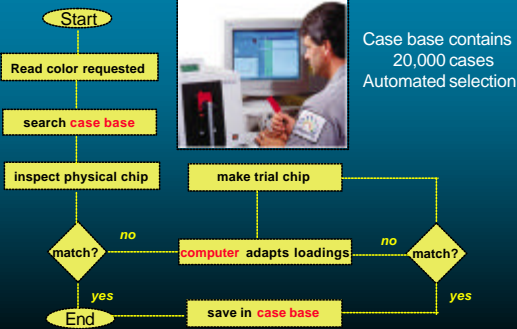
FormTool - started 1993

Digitize Knowledge (where is the knowledge?)

- create **case** for each chip in filing cabinet
 - problem: numerical representation of color
 - solution: formula of color
- algorithm for **selecting** best case
- algorithm for **adapting** case selected
- process for **learning** new cases

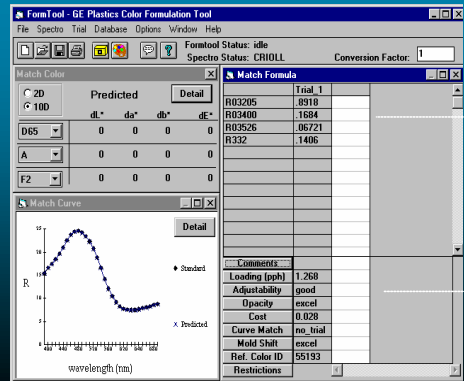
12

FormTool Process



13

FormTool – user interface 1995



Suggested
Trial
Formula

Evaluation
of Formula

14

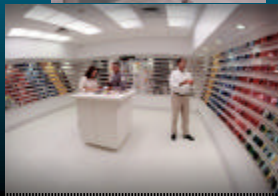
Innovation Center – started 1998

- All knowledge needed to select colors
- Chip room
 - Small lot manufacturing
 - Uses FormTool
 - Experienced color matchers

Create custom color in one day

- Closer ties with customers
- Customer Feedback
 - New products and features
 - Color is competitive advantage

- Examples
- iMac
 - Colored Cell Phones



15

FormTool - Benefits

- Productivity** – reduced time and materials
- average number of test chips created decreased from 4.2 to 2.7
 - average reduction of 4.5 hours per color match
 - savings of \$2.25 million per year in US
 - cost part of selection algorithm
 - average of \$2.4 million per year in US
- High Quality** – more accurate colors
- algorithms test manufacturability of color during match
 - meeting quality from Underwriters Laboratory
 - business rules embedded in tool (limit of organic pigments)
- Customer Satisfaction** - global consistency & speed
- standardization at all sites
 - time for match reduced from 4 - 8 weeks to 1 week
- Human Factors** – staff flexibility
- less experience needed to perform color match
 - staff can be added during peak demand (no backlog of orders)
- Growth** - new high priced services
- premium matches in 2 days cost \$2,000
 - innovation center for complete color selection for \$10,000

16

FormTool - Costs

- Creation**
- \$250K per year for 3 years
- Maintenance**
- \$50K - \$100K per year after creation finished
 - Part of one person's time from GE Plastics IT
 - Modifying tool for new color effects (marble, speckle)
 - New knowledge (Cases) added automatically
- Searching**
- Simple search: use spectrophotometer and 1 click
 - If no similar matches exist then alternative method used
- Applying**
- Existing matches automatically adapted with algorithm

17

Outline

- Intro to General Electric Global Research
- Applications – GE Plastics
- FormTool - lab color matching tool
 - ColorXpress - web customer tool
 - Global Grade Selector - sales and research tool

18

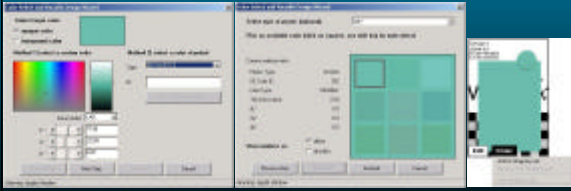
ColorXpress Select – started 1998

Provide color knowledge to customers so they can perform the match themselves.

Internet Color Matching and Ordering - <http://www.gecolorxpress.com/>

Customers use our pallet to select colors

Existing color samples delivered in 48 hours



Select Desired Color

Pick Closest Existing Color

Order Sample

19

ColorXpress Select - Benefits

Productivity

- customer self match eliminates custom color match
- reusing existing matches is better for manufacturing
- 50,000 on-line searches for colors (2002)

High Quality

- less paper and people touchpoints (possible errors)
- all test (e.g. flame resistance) have already been done

Customer Satisfaction

- simplified process for customers to submit color request
- 48 hour service vs. 1 week for custom color match
- examine customer searches to understand their needs

Human Factors

- less back office work, more with the customer

Growth

- new customers have found us on the web
- tool used in marketing campaign
- now charge \$40 per chip, may charge \$500 for color match
- GE now leads the plastic industry in on-line sales
- GE has larger dollar value of on-line sales than Amazon (2002)

20

ColorXpress Select - Cost

Creation

- \$400K in one year

Maintenance

- \$100K for updating web look and feel in 2000 and 2003
- \$50K per year after creation finished
 - Part of one person's time from GE Plastics IT
 - Keeping color chips in stock

Searching

- Performed by customer

Applying

- Performed by customer

21

Outline

Intro to General Electric Global Research

Applications – GE Plastics

- FormTool - lab color matching tool
- ColorXpress - web customer tool
- **Global Grade Selector - sales and research tool**

22

Global Grade Selector - problem

GE has hundreds of salespeople and researchers distributed globally

Large amount of knowledge sharing needed on products & experiments

3000 different grades globally

Knowledge: Strength, Flow, Heat Resistance, Stiffness, Usage, etc

2000 experiments done per year

Knowledge: Clusters of tests and trends in clusters

Customer Needs

Strength	1.23
Flow	0.13
Heat Resist	.63
Stiffness	.025
Usage	Auto panel

Existing or New Grade



23

GE Plastic Sites



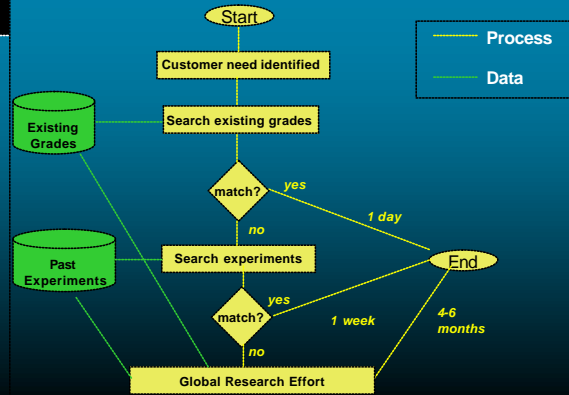
24

Old Process



25

Global Grade Selector – started 2001



26

Global Grade Selector - input

Item	Project	Size	Weight	Price Range	Units
Fiber Content		High	1.0	100	5
9500R MONOLIN		High	2.0	3000	100
HTS200-001'S 100		High	20	300	500 G
604 HASK/001'S 100		High	2.0	800	4000
604 Flow/100	Project	High	0.8	500	5000
604 HASK/100	Project	High	1	100	10000
Specialty Clarity		High	0.0000	24000	

27

Global Grade Selector - output

Search Results Summary

This page shows the 100 matches returned by the selected criteria. By default, results are ranked after following criteria:

- 1. Closest match to the user's criteria
- 2. Closest match to the user's criteria
- 3. Closest match to the user's criteria

Select	CTDA Item #	Material	Grade	Why Recommend	Price	Price Range	Weight Range	Units
1	3	9500	MONOLIN	Custom	1000000	1000	1000	1000
2	3	9500	MONOLIN	Custom	1000000	1000	1000	1000
3	3	9500	MONOLIN	Custom	1000000	1000	1000	1000

28

Global Grade Selector - Benefits

Productivity

- NPIs avoided – 10 – 50 person months of work
- example: Japan found US grades for customer
- example: experiments from US database satisfy new need
- experiments not reproduced at different sites

High Quality

- product selection changed from art to science
- standardized test globally
- products consistent globally

Customer Satisfaction

- most appropriate grade is suggested to customer
- average NPI time reduced from 6 months to 6 weeks

Human Factors

- knowledge not lost when staff moves
- experiments can be done in low cost countries

Growth

- new customers have found us on the web
- more new products can be introduced

29

Global Grade Selector - Cost

Creation

- \$1,000,000 per year for 2 years
- most of above is to organize / standardize knowledge

Maintenance

- none yet

Searching

- If grade search is unsuccessful the search experiments
- Some searches can not be done because knowledge is not in tool (e.g. chemical resistance)

Applying

- If experiments are close then new experiments are suggested by tool using 6 sigma design of experiment methodology

30