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

Color Matching for Plastics

Bill Cheetham General Electric Global Research

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

ns: (-Ray



Innovations: • Digital X-Ray

- High-Field MR
 Lexan
 Fan beam CT
- Man-Made
- Diamonds
- Many More…







Service Algorithms Lab (22 people)

lission:

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
- - Multi Objective Optimization

Information Visualization

Core Technologies: • Soft Computing

Information Fusion

• 3 Adjunct Professors Case-Based Reasoning Knowledge Management

Professional Activity (2002): • 40 US patents filed

• 20 US patents granted

• 16 Papers published

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



Intro to General Electric Global Research

Applications – GE Plastics

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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 **Customers Color** Formula Chip Green 332 1.23 Yellow_102 0.13 White 107 .63 Black_203 .025

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.





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

FormTool Process Start Case base contains 20,000 cases Read color requested Automated selection search case base inspect physical chip make trial chip no atch adapts loadings natch? yes yes save in case base End

FormTool – user interface 1995 FormTool - GE Plastics Color Form . 🗆 X Formtool Status: idle Spectro Status: CRIOLL Conversion Factor: 🗵 🐧 Match Fo _ 🗆 X Detail ○ 2D ⊙ 10D Predicted .891 Suggested dE* .1684 .06721 R03400 R03526 D65 V 0 n п 0 Trial R332 1406 0 0 0 Formula A -0 -0 0 0 **R.** M - 🗆 🗵 Detail ing (pph) •••ability .268 Evaluation excel 0.028 of Formula Opacity Cost Curve Match no_trial w.w.w.w.w.w Mold Shift cel Ref. Color ID Restrictions 55193 wavelength (nm)

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



	FormTool - Benefits
	Productivity – reduced time and materials
	average number of test chips created decreased from 4.2 to 2.
L	average reduction of 4.5 hours per color match
L	savings of \$2.25 million per year in US
L	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

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

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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



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 peopletouchpoints (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)

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

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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

Strength1.23Flow0.13Heat Resist.63Stiffness.025UsageAuto panel









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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

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