GADTs Meet Their Match:

Pattern-Matching Warnings That Account for GADTs, Guards, and Laziness

SEBASTIAN GRAF, Karlsruhe Institute of Technology, Germany
SIMON PEYTON JONES, Microsoft Research, UK

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Authors' addresses: Sebastian Graf, Karlsruhe Institute of Technology, Karlsruhe, Germany, sebastian.graf@kit.edu; Simon Peyton Jones, Microsoft Research, Cambridge, UK, simonpj@microsoft.com.

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Pattern Syntax

$$
\begin{array}{rlll}
K \in & \mathsf{Con} & & \\
x, y, a, b \in & \mathsf{Var} & & \\
\tau, \sigma \in & \mathsf{Type} & & \\
e \in & \mathsf{Expr} & ::= & x : \tau \\
& & \mid & K\ \overline{a}\ \overline{\gamma}\ \overline{e : \tau} \\
& & \mid & \ldots \\
\gamma \in & \mathsf{TyCt} & ::= & \tau_1 \sim \tau_2 \mid \ldots \\
g \in & \mathsf{Grd} & ::= & \mathsf{let}\ x : \tau = e; \\
& & \mid & K\ \overline{a}\ \overline{\gamma}\ \overline{y : \tau} \leftarrow x; \\
& & \mid & !x;
\end{array}
$$

Oracle Syntax

$$
\begin{array}{rlll}
\Gamma & ::= & \varnothing \mid \Gamma, x : \tau \mid \Gamma, a & \text{Context} \\
\Delta & ::= & \times \mid \checkmark \mid \delta, \Delta \mid \Delta_1 \vee \Delta_2 & \text{Delta} \\
\delta & ::= & \gamma \mid x_1 \approx x_2 \mid K\ \overline{a}\ \overline{x : \tau} \leftarrow y \mid x \not\approx K \mid x \approx \bot \mid x \not\approx \bot \mid \mathsf{let}\ x = e & \text{Constraints}
\end{array}
$$

Pattern-match Result

$$r ::= \langle \Theta_u, \Theta_d, \Theta_c \rangle$$

$$\langle \Theta_u, \Theta_d, \Theta_c \rangle \cup_U \Theta = \langle \Theta_u \vee \Theta, \Theta_d, \Theta_c \rangle$$
$$\langle \Theta_u, \Theta_d, \Theta_c \rangle \cup_D \Theta = \langle \Theta_u, \Theta_d \vee \Theta, \Theta_c \rangle$$

Constraint tree translation

$$\boxed{\mathtt{ctt}\ \overline{\mathsf{Grd}} = r}$$

$$
\begin{array}{lcl}
\mathtt{ctt}\ \epsilon & = & \langle \times, \times, \checkmark \rangle \\
\mathtt{ctt}\ (\mathsf{let}\ x : \tau = e; \overline{g}) & = & \mathsf{let}\ x = e, \mathtt{ctt}\ \overline{g} \\
\mathtt{ctt}\ (!x; \overline{g}) & = & (x \not\approx \bot, \mathtt{ctt}\ \overline{g}) \cup_D x \approx \bot \\
\mathtt{ctt}\ (K\ \overline{a}\ \overline{\gamma}\ \overline{x : \tau} \leftarrow y; \overline{g}) & = & (\overline{\gamma}, K\ \overline{a}\ \overline{x : \tau} \leftarrow y, \mathtt{ctt}\ \overline{g}) \cup_D x \approx \bot \cup_U x \not\approx K
\end{array}
$$

Pattern-match checking

$$\boxed{\mathtt{pmc}\ \overline{\Delta}\ \overline{\mathsf{Grd}}\ = r}$$

$$
\begin{array}{lcl}
\mathtt{pmc}\ \Gamma\ \epsilon & = & \langle \times, \times, \checkmark \rangle \\
\mathtt{pmc}\ \Gamma\ \Delta\ (\mathsf{let}\ x : \tau = e; \overline{g}) & = & \mathtt{pmc}\ (\Gamma, x : \tau)\ (\Delta, \mathsf{let}\ x = e)\ \overline{g} \\
\mathtt{pmc}\ \Gamma\ \Delta\ (!x; \overline{g}) & = & \mathtt{pmc}\ \Gamma\ (\Delta, x \not\approx \bot)\ \overline{g} \\
& & \quad \cup_D\ (\Delta, x \approx \bot) \\
\mathtt{pmc}\ \Gamma\ \Delta\ (K\ \overline{a}\ \overline{\gamma}\ \overline{x : \tau} \leftarrow y; \overline{g}) & = & \mathtt{pmc}\ (\Gamma, \overline{a}, \overline{x : \tau})\ (\Delta, \overline{\gamma}, K\ \overline{a}\ \overline{x : \tau} \leftarrow y)\ \overline{g} \\
& & \quad \cup_D\ \Delta\ \oplus\ x \approx \bot \\
& & \quad \cup_U\ \Delta\ \oplus\ x \not\approx K
\end{array}
$$

TODO LIST

Test if Oracle state Delta is unsatisfiable

$$\frac{\boxed{\nvdash_{\text{SAT}} \Gamma \vdash \Delta}}{\nvdash_{\text{SAT}} \Gamma \vdash fvs\Gamma \triangleright \Delta}$$
$$\nvdash_{\text{SAT}} \Gamma \vdash \Delta$$

Test a list of SAT roots for inhabitants

$$\frac{\boxed{\nvdash_{\text{SAT}} \Gamma \vdash \overline{x} \triangleright \Delta}}{\nvdash_{\text{SAT}} \Gamma \vdash x_i \triangleright \Delta}$$
$$\nvdash_{\text{SAT}} \Gamma \vdash \overline{x} \triangleright \Delta$$

Test a single SAT root for inhabitants

$$\frac{\boxed{\nvdash_{\text{SAT}} \Gamma \vdash x \triangleright \Delta}}{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta x \approx \bot \quad \{\overline{K}\} \text{ COMPLETE set} \quad \overline{\forall \overline{y : \tau}.\ \nvdash_{\text{SAT}} \Gamma, \overline{y : \tau} \vdash \oplus \Delta x \approx K\ \overline{y}}}$$
$$\nvdash_{\text{SAT}} \Gamma \vdash x \triangleright \Delta$$

Add a single equality to Δ

$$\boxed{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta\delta}$$

Term stuff: Bottom, negative info, positive info + generativity, positive info + univalence

$$\frac{x \not\approx sth \in \Delta}{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta x \approx \bot} \qquad \frac{x \approx K\ \overline{y} \in \Delta}{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta x \approx \bot}$$

$$\frac{x \not\approx K \in \Delta}{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta x \approx K\ \overline{y}} \qquad \frac{x \approx K_i\ \overline{y} \in \Delta \quad i \neq j \quad K_i \text{ and } K_j \text{ generative}}{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta x \approx K_j\ \overline{z}}$$

$$\frac{x \approx K\ \overline{\tau}\ \overline{y} \in \Delta \quad \nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta\tau_i \sim \sigma_i}{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta x \approx K\ \overline{\sigma}\ \overline{z}} \qquad \frac{x \approx K\ \overline{\tau}\ \overline{y} \in \Delta \quad \nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta y_i \approx z_i}{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta x \approx K\ \overline{\sigma}\ \overline{z}}$$

Type stuff: Hand over to unspecified type oracle

$$\frac{\tau_1 \text{ and } \tau_2 \text{ incompatible to Givens in } \Delta \text{ according to type oracle}}{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta\tau_1 \sim \tau_2}$$

Mixed: Instantiate K and see if that leads to a contradiction TODO: Proper instantiation

$$\frac{\overline{\nvdash_{\text{SAT}} \Gamma \vdash y \triangleright \Delta \cup y \not\approx \bot}}{\nvdash_{\text{SAT}} \Gamma \vdash \oplus \Delta x \approx K\ \overline{y}}$$

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