Hazel PHI: 10-modules

June 28, 2021

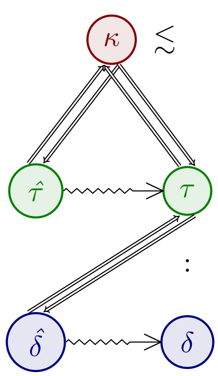
prerequisites

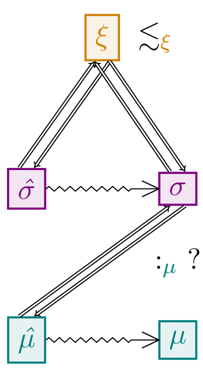
- Hazel PHI: 9-type-aliases-redux
  - github
  - current commit: 4410cd565ce717707e580e44f64868d3175fe2a6
- (optional) Hazel PHI: 1-labeled-tuples
  - github
  - current commit: 0a7d0b53ee7286d03ea3be13a7ac91a86f1c90b1

how to read

800000	kinds	D08000	signature kind
008000	types (constructors)	800080	signatures
000080	terms	008080	modules

notes





external typ/sig/mod syntax not written out yet (waiting for construction dust to settle); patterns not handled yet– will be left till end.

syntax

kind	κ	$::=$	$\texttt{Type}$	kind of types
		$\mid$	$\texttt{S}(\tau)$	singleton kind
		$\mid$	$\texttt{KHole}$	kind hole
		$\mid$	$\Pi_{t::\kappa_1}.\kappa_2$	dependent function kind

HTyp	τ	$::=$	t	type variable
		$\mid$	bse	base type
		$\mid$	$\tau_1 \oplus \tau_2$	type binop
		$\mid$	$[\tau]$	list type
		$\mid$	$\lambda t{::}\kappa.\tau$	type function
		$\mid$	$\tau_1\ \tau_2$	type application
		$\mid$	$\{lab_1 \hookrightarrow \tau_1, \ldots\ lab_n \hookrightarrow \tau_n\}$	labelled product type (record)
		$\mid$	$\mu.lab$	module type projection
		$\mid$	$(\!\|\!)$	empty type hole
		$\mid$	$(\!\|\tau\|\!)$	nonempty type hole
base type	bse	$::=$	$\texttt{Int}$	
		$\mid$	$\texttt{Float}$	
		$\mid$	$\texttt{Bool}$	
HTyp BinOp	$\oplus$	$::=$	$\times$	
		$\mid$	$+$	
		$\mid$	$\rightarrow$	
external expression	$\hat{\delta}$	$::=$	$\ldots$	
		$\mid$	x	
		$\mid$	$\texttt{signature}\ s = \hat{\sigma}\ \texttt{in}\ \hat{\delta}$	
		$\mid$	$\texttt{module}\ m = \hat{\mu}\ \texttt{in}\ \hat{\delta}$	
		$\mid$	$\texttt{module}\ m{:}_{\mu}s = \hat{\mu}\ \texttt{in}\ \hat{\delta}$	
		$\mid$	$\texttt{functor}\ \texttt{something} = \texttt{something}\ \texttt{in}\ \hat{\delta}$	
		$\mid$	$\hat{\mu}.lab$	module term projection
internal expression	δ	$::=$	$\ldots$	
		$\mid$	x	
		$\mid$	$\texttt{signature}\ s = \sigma\ \texttt{in}\ \delta$	
		$\mid$	$\texttt{module}\ m{:}_{\mu}s = \mu\ \texttt{in}\ \delta$	
		$\mid$	$\texttt{functor}\ \texttt{something} = \texttt{something}\ \texttt{in}\ \delta$	
		$\mid$	$\mu.lab$	module term projection
signature kind	ξ	$::=$	$\texttt{SSigKind}(\sigma)$	
		$\mid$	$\texttt{SigKHole}$	
signature	σ	$::=$	s	signature variable
		$\mid$	$\{sdecs\}$	structure signature
		$\mid$	$\Pi_{m:_{\mu}\sigma_1}.\sigma_2$	functor signature
		$\mid$	$(\!\|\!)$	empty signature hole
		$\mid$	$(\!\|s\|\!)$	nonempty signature hole
module	μ	$::=$	m	module variable
		$\mid$	$\{sbnds\}$	structure
		$\mid$	$\lambda m{:}_{\mu}\sigma.\mu$	functor
		$\mid$	$\mu_1\ \mu_2$	functor application
		$\mid$	$\mu.lab$	submodule projection
		$\mid$	$(\!\|\!)$	empty module hole
		$\mid$	$(\!\|\mu\|\!)$	nonempty module hole
signature declarations	$sdecs$	$::=$	$\cdot$	
		$\mid$	$sdec, sdecs$	
signature declaration	$sdec$	$::=$	$\texttt{type}\ lab$	
		$\mid$	$\texttt{type}\ lab = \tau$	
		$\mid$	$\texttt{val}\ lab{:}\tau$	
		$\mid$	$\texttt{module}\ lab{:}_{\mu}\sigma$	

$$
\begin{array}{rlcl}
 & & | & \texttt{functor}\ lab{:}_{\mu}\sigma \\
\text{structure bindings} & sbnds & ::= & \cdot \\
 & & | & sbnd, sbnds \\
\text{structure binding} & sbnd & ::= & \texttt{type}\ t = \tau \\
 & & | & \texttt{let}\ x{:}\tau = \delta \\
 & & | & \texttt{module}\ m = \mu \\
 & & | & \texttt{module}\ m{:}_{\mu}s = \mu \\
 & & | & \texttt{functor}\ m{:}_{\mu}s = \mu
\end{array}
$$

contexts

$$\Delta, ?; \Gamma, x{:}\tau; \Phi, t{::}\kappa; \Xi, m{:}_{\mu}\sigma; \Psi, s{::}_{\sigma}\xi$$

statics

scratch

$\boxed{\Delta;\Phi \vdash \kappa_1 \lesssim \kappa_2}$ κ_1 is a consistent subkind of κ_2

$$\texttt{KCSubsumption}\quad \frac{\textit{test}}{\textit{test}}$$

$\boxed{\Delta;\Phi;\Xi;\Psi \vdash \xi_1 \lesssim_\xi \xi_2}$ ξ_1 is a consistent sub signature kind of ξ_2

$$\texttt{nameMe}\quad \frac{\exists sdec_x \in sdecs_1 \;\textit{st}\; \Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(\{sdec_x\}) \lesssim_\xi \texttt{SSigKind}(\{sdec_2\}) \quad \Delta;\Phi,\mathsf{type}(sdec_2);\Xi,\mathsf{submodule}(sdec_2);\Psi \vdash \{sdecs_1\} \lesssim_\xi \{sdecs_2\}}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(\{sdec_{11}, sdec_{12}, sdecs_{13}\ \texttt{as}\ sdecs_1\}) \lesssim_\xi \texttt{SSigKind}(\{sdec_2, sdecs_2\})}$$

$$\texttt{singleType}\quad \frac{}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(\{\texttt{type}\ lab = \tau\}) \lesssim_\xi \texttt{SSigKind}(\{\texttt{type}\ lab\})}$$

$$\texttt{singleType2}\quad \frac{\Delta;\Phi;\Xi;\Psi \vdash \tau_1 \equiv \tau_2}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(\{\texttt{type}\ lab = \tau_1\}) \lesssim_\xi \texttt{SSigKind}(\{\texttt{type}\ lab = \tau_2\})}$$

$$\texttt{singleType3}\quad \frac{}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(\{\texttt{type}\ lab\}) \lesssim_\xi \texttt{SSigKind}(\{\texttt{type}\ lab\})}$$

$$\texttt{singleVa}\quad \frac{\Delta;\Phi;\Xi;\Psi \vdash \tau_1 \equiv \tau_2}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(\{\texttt{val}\ lab{:}\tau_1\}) \lesssim_\xi \texttt{SSigKind}(\{\texttt{val}\ lab{:}\tau_2\})}$$

$$\texttt{singleMod}\quad \frac{\Delta;\Phi;\Xi;\Psi \vdash \sigma_1 \Leftarrow \texttt{SSigKind}(\sigma_2)}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(\{\texttt{module}\ lab{:}_\mu\sigma_1\}) \lesssim_\xi \texttt{SSigKind}(\{\texttt{module}\ lab{:}_\mu\sigma_2\})}$$

$$\texttt{nil}\quad \frac{}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(\{sdecs\}) \lesssim_\xi \texttt{SSigKind}(\{\cdot\})}$$

$$\texttt{varprop}\quad \frac{s{::}_\sigma\xi \in \Psi}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(s) \lesssim_\xi \xi}$$

$$\texttt{nameMe}\quad \frac{\Delta;\Phi;\Xi;\Psi \vdash \sigma_1 \Leftarrow \texttt{SSigKind}(\sigma_2)}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SSigKind}(\sigma_1) \lesssim_\xi \texttt{SSigKind}(\sigma_2)}$$

$$\texttt{CSubSigKindHoleL}\quad \frac{}{\Delta;\Phi;\Xi;\Psi \vdash \texttt{SigKHole} \lesssim_\xi \xi}$$

$$\texttt{CSubSigKindHoleR}\quad \frac{}{\Delta;\Phi;\Xi;\Psi \vdash \xi \lesssim_\xi \texttt{SigKHole}}$$

$\boxed{\Delta;\Phi;\Xi;\Psi \vdash \sigma \Rightarrow \xi}$ σ synthesizes signature kind ξ

$$\texttt{SynSigKndVar}\quad \frac{s{::}_\sigma\xi \in \Psi}{\Delta;\Phi;\Xi;\Psi \vdash s \Rightarrow \texttt{SSigKind}(s)}$$

$$\texttt{SynSigKndVarFail}\quad \frac{s \notin \mathsf{dom}(\Psi)}{\Delta;\Phi;\Xi;\Psi \vdash s \Rightarrow \texttt{SigKHole}}$$

$$\frac{\{sdecs\}\textit{wellformed?}}{\vdash \{sdecs\} \Rightarrow \texttt{SSigKind}(\{sdecs\})}$$

$$\texttt{SynSigKndSigHole}\quad \frac{u{::}_\sigma\xi \in \Delta}{\Delta;\Phi;\Xi;\Psi \vdash (\!|\,|\!)^u \Rightarrow \xi}$$

$$\texttt{SynSigKndSigHole}\quad \frac{u{::}_\sigma\xi \in \Delta \qquad \Delta;\Phi;\Xi;\Psi \vdash s \Rightarrow \xi_1}{\Delta;\Phi;\Xi;\Psi \vdash (\!|s|\!)^u \Rightarrow \xi}$$

$\boxed{\Delta; \Phi; \Xi; \Psi \vdash \sigma \ \Leftarrow\ \xi}$ σ analyzes against signature kind ξ

$$\frac{\texttt{Sub} \quad \Delta; \Phi; \Xi; \Psi \vdash \sigma \ \Rightarrow\ \xi_1 \qquad \Delta; \Phi; \Xi; \Psi \vdash \xi_1 \lesssim_\xi \xi}{\Delta; \Phi; \Xi; \Psi \vdash \sigma \ \Leftarrow\ \xi}$$

elab

$\boxed{\Gamma; \Phi; \Xi \vdash \hat{\delta} \ \Rightarrow\ \tau \rightsquigarrow \delta \dashv \Delta}$ $\hat{\delta}$ synthesizes type τ and elaborates to δ with hole context Δ

...

$$\frac{\texttt{SynElabLetMod} \quad \Gamma; \Phi; \Xi \vdash \hat{\mu} \ \Rightarrow\ \sigma \rightsquigarrow \mu \dashv \Delta_1 \qquad \Gamma; \Phi; \Xi, m{:}_\mu\sigma \vdash \hat{\delta} \ \Rightarrow\ \tau \rightsquigarrow \delta \dashv \Delta_2}{\Gamma; \Phi; \Xi \vdash \texttt{module}\ m = \hat{\mu}\ \texttt{in}\ \hat{\delta} \ \Rightarrow\ \tau \rightsquigarrow \texttt{module}\ m = \mu\ \texttt{in}\ \delta \dashv \Delta_1 \cup \Delta_2}$$

$$\frac{\texttt{SynElabLetModAnn} \quad \Phi; \Xi \vdash \hat{\sigma} \ \Rightarrow\ \xi \rightsquigarrow \sigma \dashv \Delta_1 \qquad \Gamma; \Phi; \Xi \vdash \hat{\mu} \ \Leftarrow\ \sigma \rightsquigarrow \mu \dashv \Delta_2 \qquad \Gamma; \Phi; \Xi, m{:}_\mu\sigma \vdash \hat{\delta} \ \Rightarrow\ \tau \rightsquigarrow \delta \dashv \Delta_3}{\Gamma; \Phi; \Xi \vdash \texttt{module}\ m{:}_\mu\hat{\sigma} = \hat{\mu}\ \texttt{in}\ \hat{\delta} \ \Rightarrow\ \tau \rightsquigarrow \texttt{module}\ m{:}_\mu\sigma = \mu\ \texttt{in}\ \delta \dashv \Delta_1 \cup \Delta_2 \cup \Delta_3}$$

$$\frac{\texttt{SynElabModTermPrj} \quad \Gamma; \Phi; \Xi \vdash \hat{\mu} \ \Rightarrow\ \sigma \rightsquigarrow \mu \dashv \Delta \qquad \Phi; \Xi \vdash \sigma \ \Rightarrow\ \xi}{\Gamma; \Phi; \Xi \vdash \hat{\mu}.lab \ \Rightarrow\ \tau \rightsquigarrow \mu.lab \dashv \Delta}$$

$\boxed{\Phi; \Xi \vdash \hat{\tau} \ \Rightarrow\ \kappa \rightsquigarrow \tau \dashv \Delta}$ $\hat{\tau}$ synthesizes kind κ and elaborates to τ with hole context Δ

...

$$\frac{\texttt{SynElabModTypPrj} \quad \Phi; \Xi \vdash m \ \Rightarrow\ \sigma \rightsquigarrow m \dashv \Delta \qquad something\sigma\kappa}{\Phi; \Xi \vdash m.lab \ \Rightarrow\ \kappa \rightsquigarrow m.lab \dashv \Delta}$$

$\boxed{\Phi; \Xi \vdash \hat{\tau} \ \Leftarrow\ \kappa \rightsquigarrow \tau \dashv \Delta}$ $\hat{\tau}$ analyzes against kind κ and elaborates to τ with hole context Δ

$\boxed{\Gamma; \Phi; \Xi \vdash \hat{\mu} \ \Rightarrow\ \sigma \rightsquigarrow \mu \dashv \Delta}$ $\hat{\mu}$ synthesizes signature σ and elaborates to μ with hole context Δ

$$\frac{\texttt{SynElabModVar} \quad m{:}_\mu\sigma \in \Xi}{\Gamma; \Phi; \Xi \vdash m \ \Rightarrow\ \sigma \rightsquigarrow m \dashv \cdot}$$

$$\frac{\texttt{SynElabModVarFail} \quad m \notin \mathsf{dom}(\Xi)}{\Gamma; \Phi; \Xi \vdash m \ \Rightarrow\ (\!|\!) \rightsquigarrow (\!|m|\!)^u \dashv u{:}_\mu(\!|\!)}$$

$$\frac{\texttt{SynElabConsStruct} \quad \Gamma; \Phi; \Xi \vdash \widehat{sbnd} \ \Rightarrow\ sdec \rightsquigarrow sbnd \dashv \Delta_1 \qquad \Gamma, \mathsf{val}(sdec); \Phi, \mathsf{type}(sdec); \Xi, \mathsf{submodule}(sdec) \vdash \{\widehat{sbnds}\} \ \Rightarrow\ \{sdecs\} \rightsquigarrow \{sbnds\} \dashv \Delta_2}{\Gamma; \Phi; \Xi \vdash \{\widehat{sbnd}, \widehat{sbnds}\} \ \Rightarrow\ \{sdec, sdecs\} \rightsquigarrow \{sbnd, sbnds\} \dashv \Delta_1 \cup \Delta_2}$$

$$\frac{\texttt{SynElabNilStruct}}{\Gamma; \Phi; \Xi \vdash \{\cdot\} \ \Rightarrow\ \{\cdot\} \rightsquigarrow \{\cdot\} \dashv \cdot}$$

$$\frac{\texttt{SynElabEmptyModHole}}{\Gamma; \Phi; \Xi \vdash (\!|\!)^u \ \Rightarrow\ (\!|\!) \rightsquigarrow (\!|\!)^u \dashv u{:}_\mu(\!|\!)}$$

$$\frac{\texttt{SynElabNonemptyModHole}}{\Gamma; \Phi; \Xi \vdash (\!|m|\!)^u \ \Rightarrow\ (\!|\!) \rightsquigarrow (\!|m|\!)^u \dashv u{:}_\mu(\!|\!)}$$

functor stuff

$\boxed{\Gamma; \Phi; \Xi \vdash \hat{\mu} \ \Leftarrow\ \sigma \rightsquigarrow \mu \dashv \Delta}$ $\hat{\mu}$ analyzes against signature σ and elaborates to μ with hole context Δ

$$\frac{\texttt{AnaElabModSubsumption} \quad \Gamma; \Phi; \Xi \vdash \hat{\mu} \ \Rightarrow\ \sigma \rightsquigarrow \mu \dashv \Delta}{\Gamma; \Phi; \Xi \vdash \hat{\mu} \ \Leftarrow\ \sigma \rightsquigarrow \mu \dashv \Delta}$$

$\boxed{\Gamma;\Phi;\Xi \vdash \hat{sbnd} \;\Rightarrow\; sdec \rightsquigarrow sbnd \dashv \Delta}$ $\hat{sbnd}$ synthesizes declaration $sdec$ and elaborates to $sbnd$ with hole context Δ

SynElabTypeSbnd
$$\frac{\Phi;\Xi \vdash \hat{\tau} \;\Rightarrow\; \kappa \rightsquigarrow \tau \dashv \Delta}{\Gamma;\Phi;\Xi \vdash \mathtt{type}\ t = \hat{\tau} \;\Rightarrow\; \mathtt{type}\ t = \tau \rightsquigarrow \mathtt{type}\ t = \tau \dashv \Delta}$$

SynElabValSbnd
$$\frac{\Phi;\Xi \vdash \hat{\tau} \;\Rightarrow\; \kappa \rightsquigarrow \tau \dashv \Delta_1 \qquad \Gamma;\Phi;\Xi \vdash \hat{\delta} \;\Leftarrow\; \tau \rightsquigarrow \delta \dashv \Delta_2}{\Gamma;\Phi;\Xi \vdash \mathtt{let}\ x{:}\hat{\tau} = \hat{\delta} \;\Rightarrow\; \mathtt{val}\ x{:}\tau \rightsquigarrow \mathtt{let}\ x{:}\tau = \delta \dashv \Delta_1 \cup \Delta_2}$$

SynElabModSbnd
$$\frac{\Gamma;\Phi;\Xi \vdash \hat{\mu} \;\Rightarrow\; \sigma \rightsquigarrow \mu \dashv \Delta}{\Gamma;\Phi;\Xi \vdash \mathtt{module}\ m = \hat{\mu} \;\Rightarrow\; \mathtt{module}\ m{:}_{\mu}\sigma \rightsquigarrow \mathtt{module}\ m{:}_{\mu}\sigma = \mu \dashv \Delta}$$

SynElabModAnnSbnd
$$\frac{\Phi;\Xi \vdash \hat{\sigma} \;\Rightarrow\; \xi \rightsquigarrow \sigma_1 \dashv \Delta_1 \qquad \Gamma;\Phi;\Xi \vdash \hat{\mu} \;\Rightarrow\; \sigma_2 \rightsquigarrow \mu \dashv \Delta_2 \qquad \Phi;\Xi;\Psi \vdash \sigma_2 \;\Leftarrow\; \xi}{\Gamma;\Phi;\Xi \vdash \mathtt{module}\ m{:}_{\mu}\hat{\sigma} = \hat{\mu} \;\Rightarrow\; \mathtt{module}\ m{:}_{\mu}\sigma_1 \rightsquigarrow \mathtt{module}\ m{:}_{\mu}\sigma_1 = \mu \dashv \Delta_1 \cup \Delta_2}$$

$\boxed{\Gamma;\Phi;\Xi \vdash \hat{sbnd} \;\Leftarrow\; sdec \rightsquigarrow sbnd \dashv \Delta}$ $\hat{sbnd}$ analyzes against declaration $sdec$ and elaborates to $sbnd$ with hole context Δ

$\boxed{\vdash \hat{sdec} \;\Rightarrow\; sdecknd \rightsquigarrow sdec \dashv \Delta}$

$\boxed{\Phi;\Xi;\Psi \vdash \hat{\sigma} \;\Rightarrow\; \xi \rightsquigarrow \sigma \dashv \Delta}$ $\hat{\sigma}$ synthesizes signature kind ξ and elaborates to σ with hole context Δ

SynSigEmptyHole
$$\frac{}{\Phi;\Xi;\Psi \vdash (\!|\!)^u \;\Rightarrow\; \mathtt{SigKHole} \rightsquigarrow (\!|\!)^u \dashv u{::}_{\sigma}\mathtt{SigKHole}}$$

SynSigNonEmptyHole

$\boxed{\Phi;\Xi \vdash \hat{\sigma} \;\Leftarrow\; \xi \rightsquigarrow \sigma \dashv \Delta}$ $\hat{\sigma}$ analyzes against signature kind ξ and elaborates to σ with hole context Δ

misc

$$\mathsf{val}(sdec) = \begin{cases} lab{:}\tau & sdec \equiv \mathtt{val}\ lab{:}\tau \\ \cdot & \text{otherwise} \end{cases}$$

$$\mathsf{type}(sdec) = \begin{cases} lab{::}\mathtt{Type} & sdec \equiv \mathtt{type}\ lab \\ lab{::}\kappa & sdec \equiv \mathtt{type}\ lab = \tau \\ & \text{where} \vdash \tau \;\Rightarrow\; \kappa \\ \cdot & \text{otherwise} \end{cases}$$

$$\mathsf{submodule}(sdec) = \begin{cases} lab{:}_{\mu}\sigma & sdec \equiv \mathtt{module}\ lab{:}_{\mu}\sigma \\ \cdot & \text{otherwise} \end{cases}$$