Hazel PHI: 10-modules

June 29, 2021

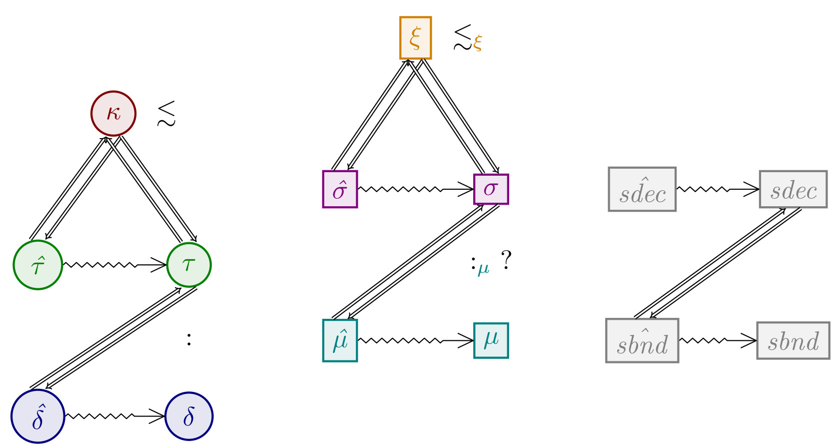
prerequisites

- 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	::=	`Type`	kind of types
		|	`S`(τ)	singleton kind
		|	`KHole`	kind hole
		|	$\Pi_{t::\kappa_1}.\kappa_2$	dependent function kind

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

$|$ $\texttt{functor}\ m{:}_{\mu} s = \mu$

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

KCSubsumption
$$\frac{test}{test}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\frac{\{sdecs\} well formed?}{\vdash \{sdecs\} \Rightarrow \texttt{SSigKind}(\{sdecs\})}$$

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

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

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

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

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

...

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

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

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

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

...

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

$\boxed{\Phi;\Xi \vdash \hat{\tau} \;\Leftarrow\; \kappa \rightsquigarrow \tau \dashv \Delta}$ $\hat{\tau}$ 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

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

$$\frac{\begin{array}{c}\Gamma;\Phi;\Xi \vdash \hat{sbnd} \;\Rightarrow\; sdec \rightsquigarrow sbnd \dashv \Delta_1 \\ \Gamma, \mathsf{val}(sdec);\Phi, \mathsf{type}(sdec);\Xi, \mathsf{submodule}(sdec) \vdash \{\hat{sbnds}\} \;\Rightarrow\; \{sdecs\} \rightsquigarrow \{sbnds\} \dashv \Delta_2\end{array}}{\Gamma;\Phi;\Xi \vdash \{\hat{sbnd}, \hat{sbnds}\} \;\Rightarrow\; \{sdec, sdecs\} \rightsquigarrow \{sbnd, sbnds\} \dashv \Delta_1 \cup \Delta_2}\ \texttt{SynElabConsStruct}$$

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

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

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

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

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

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

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

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

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

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

$\boxed{\Gamma;\Phi;\Xi;\Psi \vdash \hat{sdec} \rightsquigarrow sdec \dashv \Delta}$ $\hat{sdec}$ elaborates to $sdec$ with hole context Δ

opq
$$\frac{}{\Gamma;\Phi;\Xi;\Psi \vdash \texttt{type}\ lab \rightsquigarrow \texttt{type}\ lab \dashv \cdot}$$

trn
$$\frac{\Gamma;\Phi;\Xi;\Psi \vdash \hat{\tau} \Rightarrow \kappa \rightsquigarrow \tau \dashv \Delta}{\Gamma;\Phi;\Xi;\Psi \vdash \texttt{type}\ lab = \hat{\tau} \rightsquigarrow \texttt{type}\ lab = \tau \dashv \Delta}$$

val
$$\frac{\Gamma;\Phi;\Xi;\Psi \vdash \hat{\tau} \Rightarrow \kappa \rightsquigarrow \tau \dashv \Delta}{\Gamma;\Phi;\Xi;\Psi \vdash \texttt{val}\ lab{:}\hat{\tau} \rightsquigarrow \texttt{val}\ lab{:}\tau \dashv \Delta}$$

mod
$$\frac{\Gamma;\Phi;\Xi;\Psi \vdash \hat{\sigma} \Rightarrow \xi \rightsquigarrow \sigma \dashv \Delta}{\Gamma;\Phi;\Xi;\Psi \vdash \texttt{module}\ lab{:}_{\mu}\hat{\sigma} \rightsquigarrow \texttt{module}\ lab{:}_{\mu}\sigma \dashv \Delta}$$

`we're going to need HOFunctors so we don't need to preclude users from typing a functor into a module and vice versa`

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

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

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

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

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

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