Isovists are polygons of visible areas from a point. They remove views that are blocked by objects, typically buildings. They can be used to understanding the existing impact of, or where to place urban design features that can change people’s behaviour (e.g. advertising boards, security cameras or trees). Here I present a custom function that creates a visibility polygon (isovist) using a uniform ray casting “physical” algorithm in R.

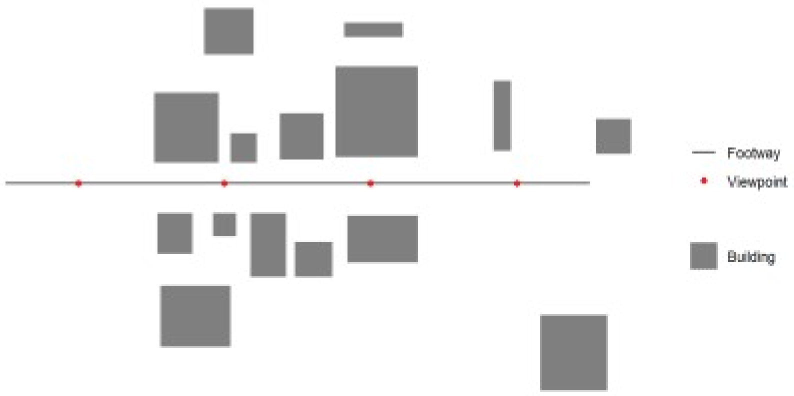
First we load the required packages (use `install.packages()` first if these are not already installed in R):

```
library(sf)
library(dplyr)
library(ggplot2)
```

Data generation

First we create and plot an example footway with viewpoints and set of buildings which block views. All data used should be in the same Coordinate Reference System (CRS). We generate one viewpoint every 50 m (note density here is a function of the st_crs() units, in this case meters)

```
library(sf)
footway <- st_sfc(st_linestring(rbind(c(-50,0),c(150,0))))
st_crs(footway) = 3035
viewpoints <- st_line_sample(footway, density = 1/50)
viewpoints <- st_cast(viewpoints,"POINT")

buildings <- rbind(c(1,7,1),c(1,31,1),c(23,31,1),c(23,7,1),c(1,7,1),
                   c(2,-24,2),c(2,-10,2),c(14,-10,2),c(14,-24,2),c(2,-
24,2),
                   c(21,-18,3),c(21,-10,3),c(29,-10,3),c(29,-
18,3),c(21,-18,3),
                   c(27,7,4),c(27,17,4),c(36,17,4),c(36,7,4),c(27,7,4),
                   c(18,44,5), c(18,60,5),c(35,60,5),c(35,44,
5),c(18,44,5),
                   c(49,-32,6),c(49,-20,6),c(62,-20,6),c(62,-
32,6),c(49,-32,6),
                   c(34,-32,7),c(34,-10,7),c(46,-10,7),c(46,-
32,7),c(34,-32,7),
                   c(63,9,8),c(63,40,8),c(91,40,8),c(91,9,8),c(63,9,8),
                   c(133,-71,9),c(133,-45,9),c(156,-45,9),c(156,-
71,9),c(133,-71,9),
                   c(152,10,10),c(152,22,10),c(
164,22,10),c(164,10,10),c(152,10,10),
                   c(44,8,11),c(44,24,11),c(59,
24,11),c(59,8,11),c(44,8,11),
                   c(3,-56,12),c(3,-35,12),c(27,-35,12),c(27,-
56,12),c(3,-56,12),
                   c(117,11,13),c(117,35,13),c(
123,35,13),c(123,11,13),c(117,11,13),
                   c(66,50,14),c(66,55,14),c(86,
55,14),c(86,50,14),c(66,50,14),
                   c(67,-27,15),c(67,-11,15),c(91,-11,15),c(91,-
27,15),c(67,-27,15))

buildings <- lapply( split( buildings[,1:2], buildings[,3] ), matrix,
ncol=2)
buildings   <- lapply(X = 1:length(buildings), FUN = function(x) {
  st_polygon(buildings[x])
})

buildings <- st_sfc(buildings)
st_crs(buildings) = 3035

# plot raw data
ggplot() +
  geom_sf(data = buildings,colour = "transparent",aes(fill =
'Building')) +
  geom_sf(data = footway, aes(color = 'Footway')) +
  geom_sf(data = viewpoints, aes(color = 'Viewpoint')) +
  scale_fill_manual(values = c("Building" = "grey50"),
                    guide = guide_legend(override.aes = list(linetype =
c("blank"),
                                        nshape = c(NA)))) +

  scale_color_manual(values = c("Footway" = "black",
                                "Viewpoint" = "red",
                                "Visible area" = "red"),
                     labels = c("Footway", "Viewpoint","Visible
area"))+
  guides(color = guide_legend(
    order = 1,
    override.aes = list(
      color = c("black","red"),
      fill  = c("transparent","transparent"),
      linetype = c("solid","blank"),
      shape = c(NA,16))))+
  theme_minimal()+
  coord_sf(datum = NA)+
  theme(legend.title=element_blank())
```



Isovist function

Function inputs

Buildings should be cast to `"POLYGON"` if they are not already

```
buildings <- st_cast(buildings,"POLYGON")
```

Creating the function

A few parameters can be set before running the function. `rayno` is the number of observer view angles from the viewpoint. More rays are more precise, but decrease processing speed.`raydist` is the maximum view distance. The function takes`sfc_POLYGON type` and `sfc_POINT` objects as inputs for buildings abd the viewpoint respectively. If points have a variable view distance the function can be modified by creating a vector of view distance of length(viewpoints) here and then selecting `raydist[x]` in st_buffer below. Each ray is intersected with building data within its `raycast` distance, creating one or more ray line segments. The ray line segment closest to the viewpoint is then extracted, and the furthest away vertex of this line segement is taken as a boundary vertex for the isovist. The boundary vertices are joined in a clockwise direction to create an isovist.

```
st_isovist <- function(
  buildings,
  viewpoint,

  # Defaults
  rayno = 20,
  raydist = 100) {

  # Warning messages
  if(!class(buildings)[1]=="sfc_POLYGON")     stop('Buildings must be
sfc_POLYGON')
  if(!class(viewpoint)[1]=="sfc_POINT") stop('Viewpoint must be sf
object')

  rayends     <- st_buffer(viewpoint,dist = raydist,nQuadSegs = (rayno-
1)/4)
  rayvertices <- st_cast(rayends,"POINT")

  # Buildings in raydist
  buildintersections <- st_intersects(buildings,rayends,sparse = FALSE)

  # If no buildings block max view, return view
  if (!TRUE %in% buildintersections){
    isovist <- rayends
  }

  # Calculate isovist if buildings block view from viewpoint
  if (TRUE %in% buildintersections){

    rays <- lapply(X = 1:length(rayvertices), FUN = function(x) {
      pair      <- st_combine(c(rayvertices[x],viewpoint))
      line      <- st_cast(pair, "LINESTRING")
      return(line)
    })

    rays <- do.call(c,rays)
    rays <- st_sf(geometry = rays,
                  id = 1:length(rays))

    buildsinmaxview <- buildings[buildintersections]
    buildsinmaxview <- st_union(buildsinmaxview)
    raysioutsidebuilding <- st_difference(rays,buildsinmaxview)

    # Getting each ray segement closest to viewpoint
    multilines  <- dplyr::filter(raysioutsidebuilding, st_is(geometry,
c("MULTILINESTRING")))
    singlelines <- dplyr::filter(raysioutsidebuilding, st_is(geometry,
c("LINESTRING")))
    multilines  <- st_cast(multilines,"MULTIPOINT")
    multilines  <- st_cast(multilines,"POINT")
    singlelines <- st_cast(singlelines,"POINT")

    # Getting furthest vertex of ray segement closest to view point
    singlelines <- singlelines %>%
      group_by(id) %>%
      dplyr::slice_tail(n = 2) %>%
      dplyr::slice_head(n = 1) %>%
      summarise(do_union = FALSE,.groups = 'drop') %>%
      st_cast("POINT")

    multilines  <- multilines %>%
      group_by(id) %>%
      dplyr::slice_tail(n = 2) %>%
      dplyr::slice_head(n = 1) %>%
      summarise(do_union = FALSE,.groups = 'drop') %>%
      st_cast("POINT")
    # Combining vertices, ordering clockwise by ray angle and casting
to polygon
    alllines <- rbind(singlelines,multilines)
    alllines <- alllines[order(alllines$id),]
    isovist  <- st_cast(st_combine(alllines),"POLYGON")
  }
  isovist
}
```

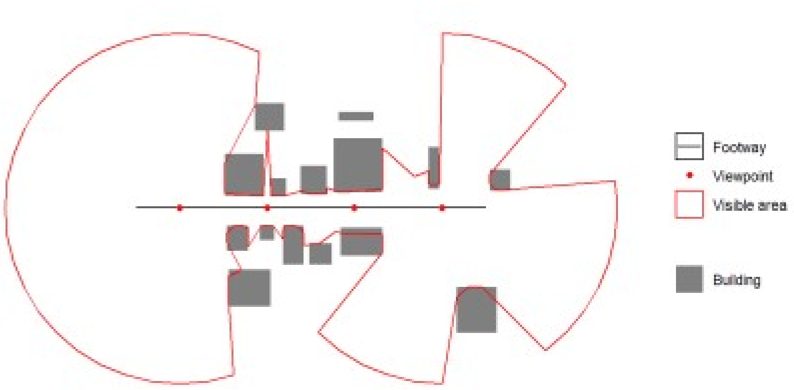
Running the function in a loop

It is possible to wrap the function in a loop to get multiple isovists for a multirow `sfc_POINT` object. There is no need to heed the `repeating attributes for all sub-geometries` warning as we want that to happen in this case.

```
isovists   <- lapply(X = 1:length(viewpoints), FUN = function(x) {
  viewpoint   <- viewpoints[x]
  st_isovist(buildings = buildings,
             viewpoint = viewpoint,
             rayno = 41,
             raydist = 100)
})
```

All isovists are unioned to create a visible area polygon, which can see plotted over the original path, viewpoint and building data below.

```
isovists <- do.call(c,isovists)
visareapoly <- st_union(isovists)

ggplot() +
  geom_sf(data = buildings,colour = "transparent",aes(fill =
'Building')) +
  geom_sf(data = footway, aes(color = 'Footway')) +
  geom_sf(data = viewpoints, aes(color = 'Viewpoint')) +
  geom_sf(data = visareapoly,fill="transparent",aes(color = 'Visible
area')) +
  scale_fill_manual(values = c("Building" = "grey50"),
                    guide = guide_legend(override.aes = list(linetype =
c("blank"),
                                         shape = c(NA)))) +
  scale_color_manual(values = c("Footway" = "black",
                                "Viewpoint" = "red",
                                "Visible area" = "red"),
                     labels = c("Footway", "Viewpoint","Visible
area"))+
  guides( color = guide_legend(
    order = 1,
    override.aes = list(
      color = c("black","red","red"),
      fill  = c("transparent","transparent","white"),
      linetype = c("solid","blank", "solid"),
      shape = c(NA,16,NA))))+
  theme_minimal()+
  coord_sf(datum = NA)+
  theme(legend.title=element_blank())
```


Footway
Viewpoint
Visible area
Building