Change of the focal length of the camera

유용길

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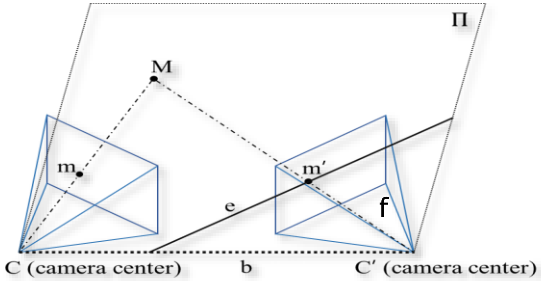
Background

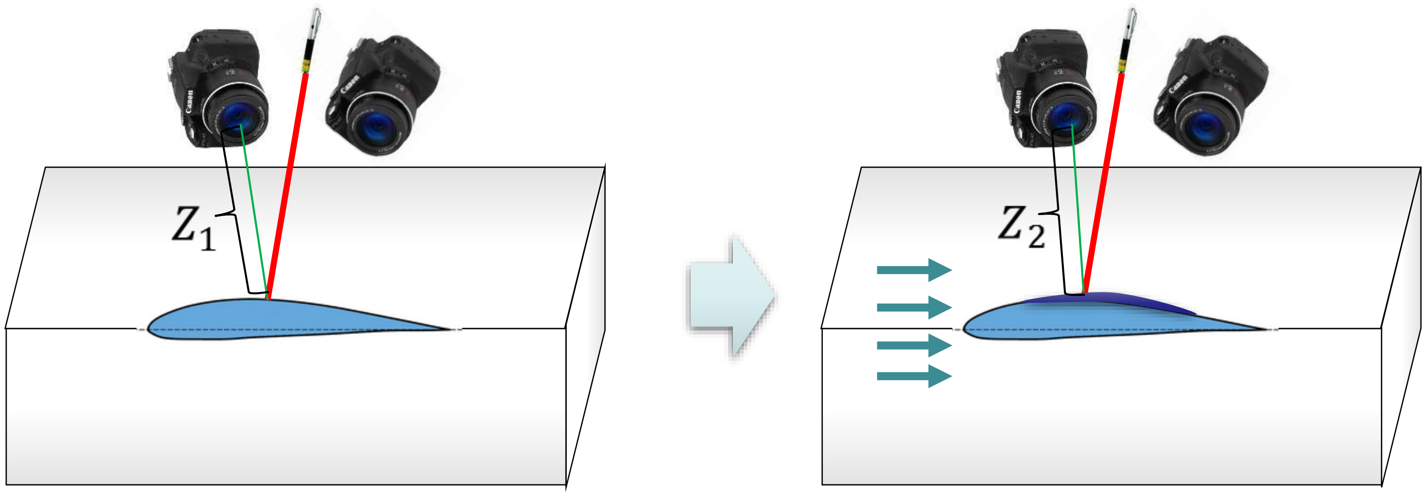
- **Cavitation 두께 계측**

  - ➢ **삼각 측량법(Stereo Triangulation)을 이용한 거리 정보 산출 방법**



M: 실제 정합점 위치
m,m′: 영상 평면에서의 정합점
f: 초점 거리
C,C′ 양 카메라의 영상중심

  - ➢ **Cavitation 두께 계측 방법**

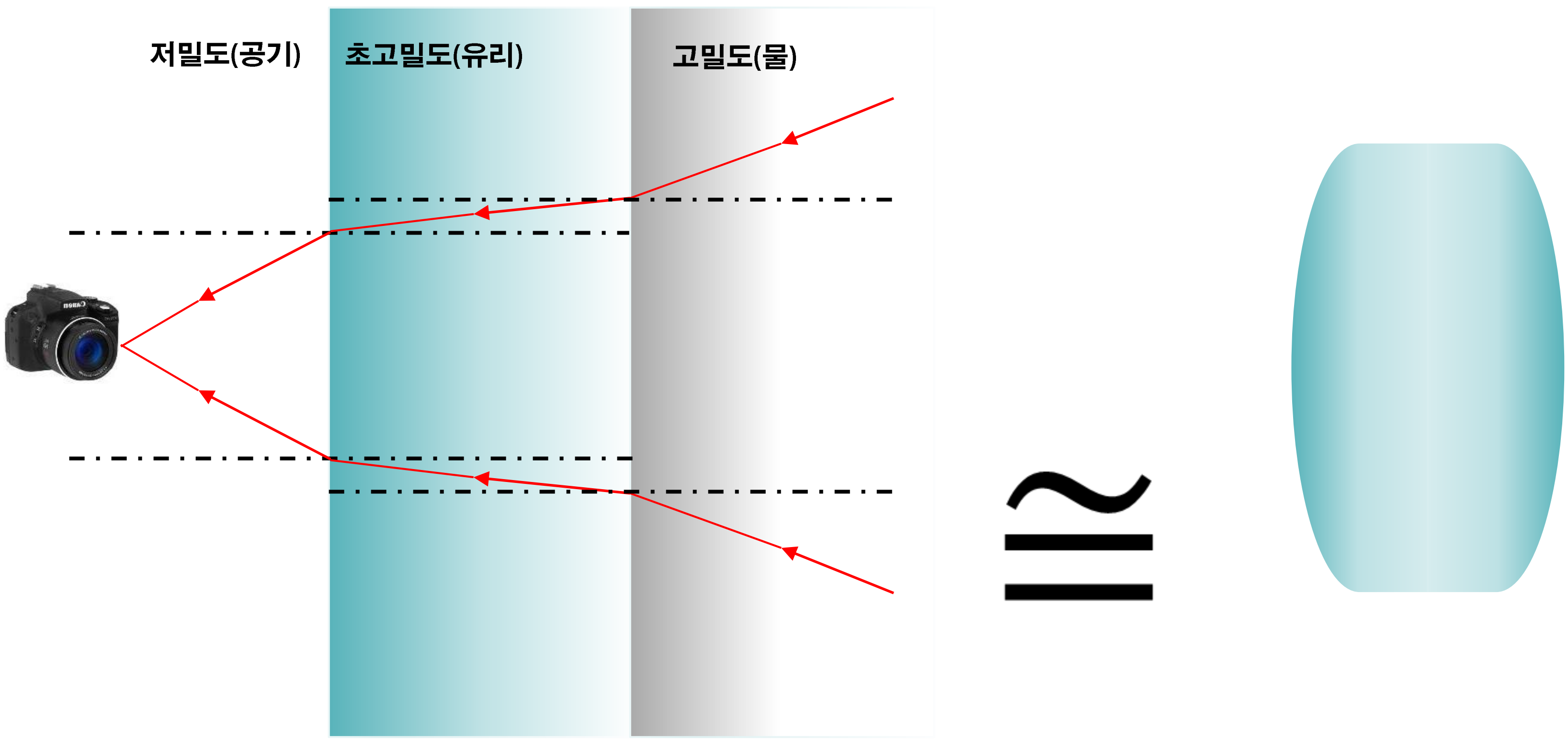


$$Tc = Z_1 - Z_2$$

$(Tc = Thickness\ of\ cavitation)$

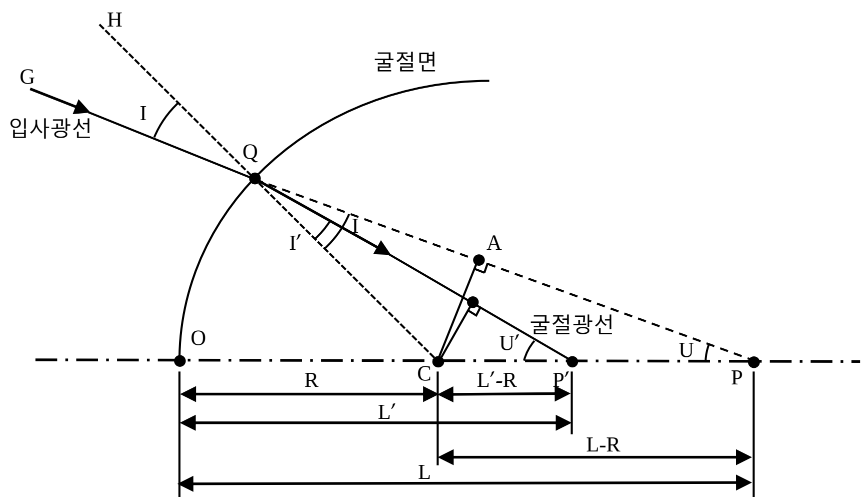
Background

- 다중 매질에서 렌즈의 광 특성과 새로운 모델



$(but, C = \infty)$

- **단일 면에서 광선의 굴절**



$$CA = (R - L)\sin U$$

$$\sin I = \frac{CA}{R}$$

$$\sin I' = \frac{n}{n'}\sin I$$

$$U' - I' = U - I$$

$$U' = U - I + I'$$

$$\sin I' = \frac{CA'}{R}$$

$$CA' = \frac{n}{n'}CA$$

$$L' = R - \frac{CA'}{\sin U'}$$

- **근축 영역 해석법**
  - **광축 근처 매우 좁은 영역의 광선 해석**

$$\sin\theta = \tan\theta$$

$$CA = (R - L)\sin U \rightarrow ca = -(\ell - R)u$$

$$u = -\frac{ca}{(\ell - R)}$$

$$\sin I = \frac{CA}{R} \rightarrow i = \frac{ca}{R}$$

$$\sin I' = \frac{n}{n'}\sin I \rightarrow i' = \frac{ni}{n'} = \frac{nca}{n'R}$$

$$U' = U - I + I' \rightarrow u' = u - i + i'$$

$$\sin I' = \frac{CA'}{R} \rightarrow i' = \frac{ca'}{R}$$

$$CA' = \frac{n}{n'}CA \rightarrow ca' = \frac{nca}{n'}$$

$$L' = R - \frac{CA'}{\sin U'} \rightarrow \ell' = R - \frac{ca'}{u'} = R - \frac{\frac{nca}{n'}}{u - i + i'} = R - \frac{\frac{nca}{n'}}{-\frac{ca}{(\ell - R)} - \frac{ca}{R} + \frac{nca}{n'R}} = R - \frac{\frac{n}{n'}}{-\frac{1}{(\ell - R)} - \frac{1}{R} + \frac{n}{n'R}}$$

$$= R - \frac{n}{-\frac{n'}{(\ell - R)} - \frac{n'}{R} + \frac{n}{R}} = R - \frac{n}{-\frac{n'}{(\ell - R)} + \frac{n - n'}{R}} = R - \frac{n}{\frac{-n'R + (n - n')\ell + n'R - nR}{(\ell - R)R}} = R - \frac{(\ell - R)nR}{(n - n')\ell - nR}$$

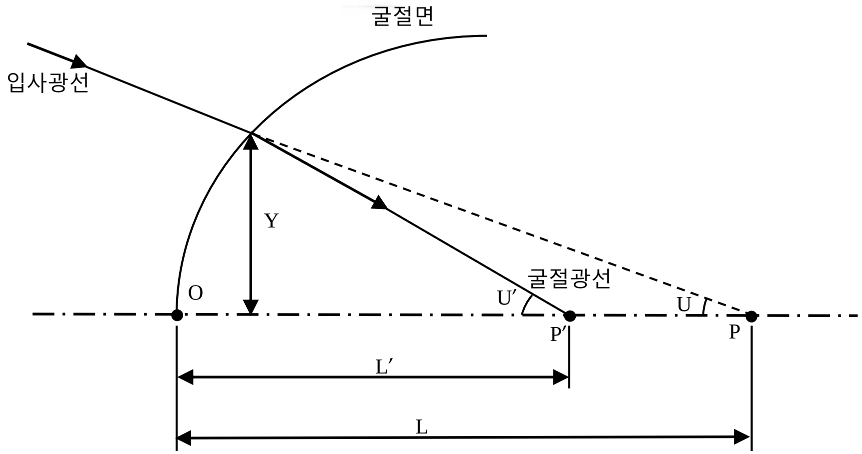
$$= \frac{nR\ell - n'R\ell - nR^2 - (nR\ell - nR^2)}{(n - n')\ell - nR} = \frac{n'R\ell}{(n' - n)\ell + nR}$$

$$\frac{1}{\ell'} = \frac{(n' - n)\ell + nR}{n'R\ell}$$

$$\frac{n'}{\ell'} = \frac{(n' - n)\ell + nR}{R\ell} = \frac{(n' - n)}{R} + \frac{n}{\ell}$$

ynu Ray Tracing

- **단일면 근축 영역 추적법**



$$\sin\theta = \tan\theta = \theta$$

$$u = -\frac{y}{\ell}$$

$$\ell = -\frac{y}{u}$$

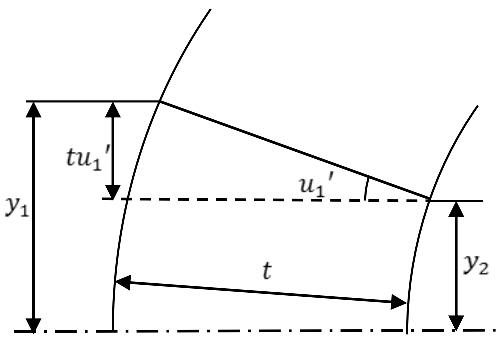
$$u' = -\frac{y}{\ell'}$$

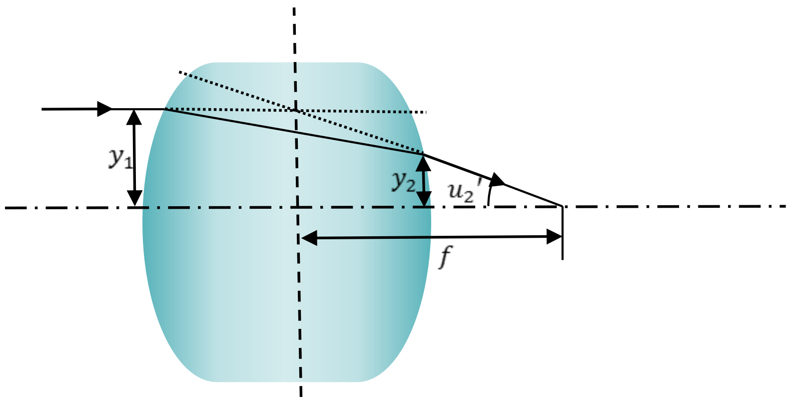
$$\ell' = -\frac{y}{u'}$$

$$-\frac{n'u'}{y} = \frac{(n'-n)}{R} - \frac{nu}{y}$$

$$n'u' = nu - y\frac{(n'-n)}{R} = nu - y(n'-n)C$$

- **다중면 근축 영역 추적법**





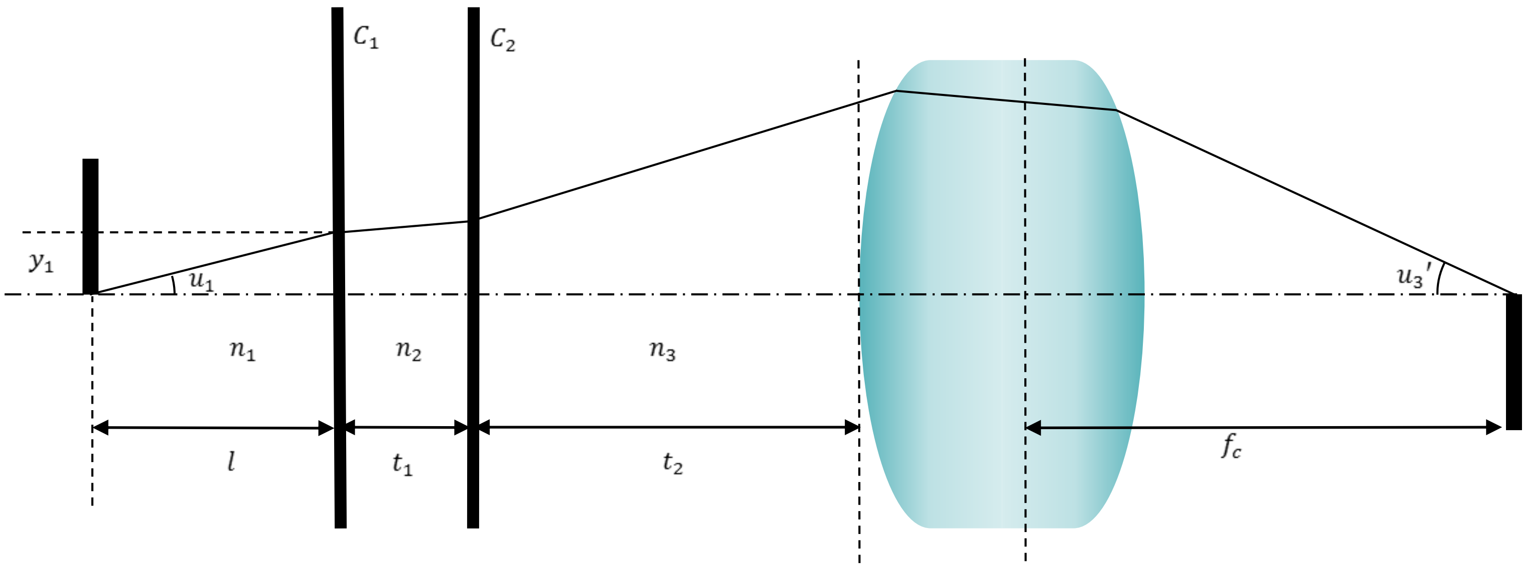
$$y_2 = y_1 + tu_1' = y_1 + t\frac{n_1'u_1'}{n_1'}$$

$$n_1'u_1' = n_2u_2$$

$$f = \frac{-y_1}{u_2'} = \frac{-y_1}{u_k'}$$

Find Hardware Focal-Length

- 다중 매질에서 하드웨어 초점 거리 변화



$$C_1 = C_2 = flat = 0$$

$$u_1 = -\frac{y_1}{l}$$

$$n_1' u_1' = -y_1(n_1' - n_1)C_1 + n_1 u_1 = -y_1(n_2 - n_1)C_1 + n_1 u_1 = n_1 u_1$$

$$y_2 = y_1 + \frac{t_1(n_1' u_1')}{n_1} = y_1 + t_1 u_1$$

$$n_2 u_2 = n_1' u_1'$$

$$n_2' u_2' = -y_2(n_2' - n_2)C_2 + n_2 u_2 = -y_2(n_3 - n_2)C_2 + n_2 u_2 = n_1 u_1$$

Find Hardware Focal-Length

- 다중 매질에서 하드웨어 초점 거리 변화

$$y_3 = y_2 + \frac{t_2(n_2' u_2')}{n_2} = y_2 + \frac{t_2 n_1 u_1}{n_2} = y_1 - \frac{y_1 t_1}{l} - \frac{t_2 n_1 y_1}{n_2 l} = y_1(1 - \frac{t_1}{l} - \frac{t_2 n_1}{n_2 l})$$

$$u_3' = -\frac{y_3}{f_c} = -\frac{y_1(1 - \frac{t_1}{l} - \frac{t_2 n_1}{n_2 l})}{f_c}$$

$$f = -\frac{y_1}{u_3'} = -\frac{f_c y_1}{-y_1(1 - \frac{t_1}{l} - \frac{t_2 n_1}{n_2 l})} = -\frac{f_c}{-(1 - \frac{t_1}{l} - \frac{t_2 n_1}{n_2 l})}$$

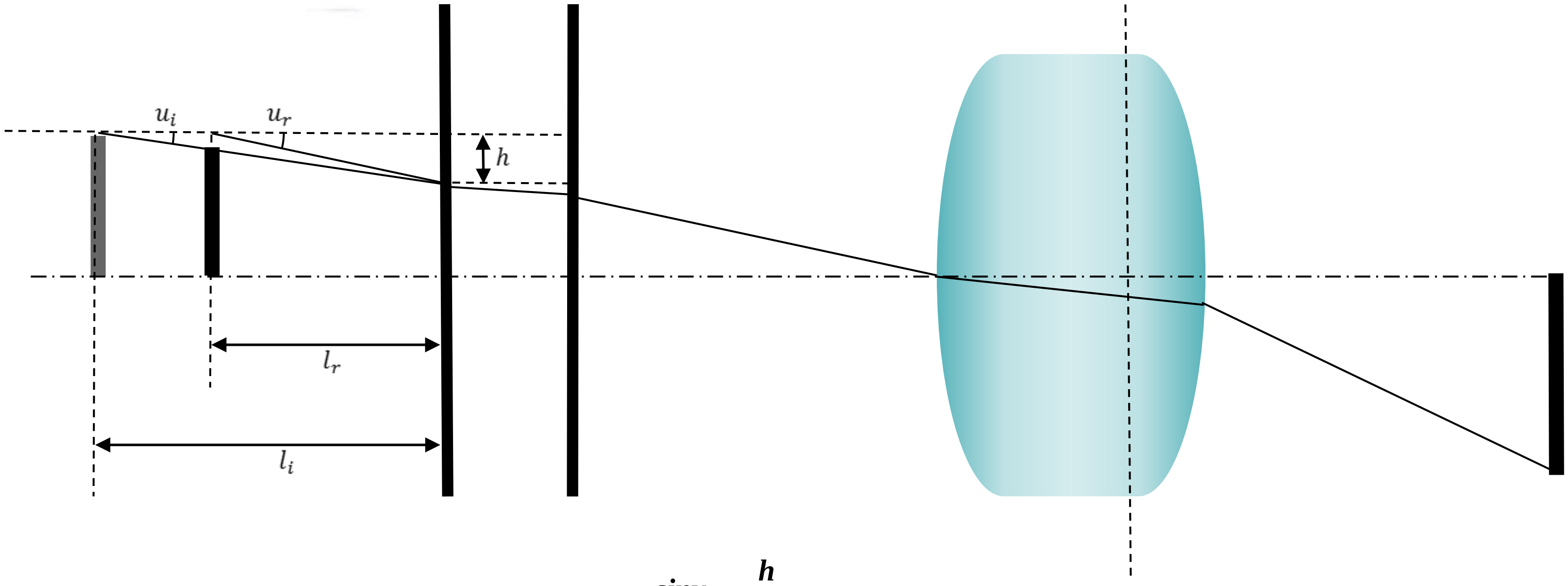
$$\lim_{l \to \infty} f = f_c$$

- 중간 매질의 종류와 관계 없이 하드웨어 초점 거리는 일정하다.

Image System Laboratory

Find Software Focal-Length

- **다중 매질에서 소프트웨어 초점 거리 변화**



$$\sin u_i = \frac{h}{l_i}$$

$$\sin u_r = \frac{h}{l_r}$$

$$\sin u_i l_i = \sin u_r l_r$$

$$n_i \sin u_i = n_r \sin u_r$$

$$l_i = \frac{n_i}{n_r} l_r = 1.33 l_r$$

$$f_i = 1.33 f_r$$

Conclusion

- **각 상태 별 내부 행렬 비교**

  - ➢ **오른쪽 카메라 내부 행렬**

배수시

$$\begin{bmatrix} 1.318e+3 & 0 & 5.323e+2 \\ 0 & 1.316e+3 & 3.847e+2 \\ 0 & 0 & 1 \end{bmatrix}$$

저수시

$$\begin{bmatrix} 1.793e+3 & 0 & 5.198e+2 \\ 0 & 1.792e+3 & 3.835e+2 \\ 0 & 0 & 1 \end{bmatrix}$$

  - ➢ **왼쪽 카메라 내부 행렬**

배수시

$$\begin{bmatrix} 1.318e+3 & 0 & 5.333e+2 \\ 0 & 1.317e+3 & 3.870e+2 \\ 0 & 0 & 1 \end{bmatrix}$$

저수시

$$\begin{bmatrix} 1.773e+3 & 0 & 5.406e+2 \\ 0 & 1.758e+3 & 3.858e+2 \\ 0 & 0 & 1 \end{bmatrix}$$

►unit = pixel

  - ➢ **양 카메라의 초점거리가 약 1.33배 차이가 나는 것을 확인.**

Q&A